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FINDING A REASONABLE AQUIFER YIELD: DECISION SUPPORT METHODS FOR GROUNDWATER POLICY DEVELOPMENT IN TEXAS

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FINDING A REASONABLE AQUIFER YIELD: DECISION SUPPORT METHODS FOR GROUNDWATER POLICY DEVELOPMENT IN TEXAS

by

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Dedication

In the memory of my adventurous parents, who inspired me with their dissertation trials and triumphs, and allowed me to experience their fascinating research efforts from Normal, Illinois, to the Library of Congress, to Paris, France.

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I would like to acknowledge and sincerely thank the many people who saw me through this journey. Many important people participated in educating me including my friendly and supportive 2004 and 2005 cohorts, graduate students, many University of Texas professors and University of Texas staff, Texas Water Development Board co-workers, and of utmost importance, my committee chair, David Eaton, who believed enough in my research goals to encourage and support this endeavor.

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Special recognition goes to my many loyal friends and dear family who inspired and supported me in my educational and research efforts over these many years, even in my absence from their lives. This effort would not have been successful without the initial support of my father, and final support of my fiancé, Michael Wied.

Abstract

FINDING A REASONABLE AQUIFER YIELD: DECISION SUPPORT METHODS FOR GROUNDWATER POLICY DEVELOPMENT IN TEXAS

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The University of Texas at Austin, 2013

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Managing groundwater can be difficult because there is no common perspective among stakeholders about what they wish for their desired future conditions (DFCs) for Texas' aquifers. Conflicts over how to manage aquifers, whether to mine or sustain groundwater levels are complicated by diverse state and local approaches. This dissertation proposes a decision support method to derive acceptable future aquifer conditions through engaging stakeholders by combining five processes: landowner surveys, stakeholder and decision maker focus groups, contingent valuation, system element identification and scenario-testing. Surveys of water users identified conflicts among water users and decision makers' preferences. For example, how much is groundwater worth in Texas? Responses to two survey questions revealed a willingness to buy groundwater for an average of $2,872 per acre-foot. Most landowners most did not want to sell groundwater at any cost. Those willing to sell revealed an average of $4,069 per acre-foot, resulting in a 1.4 ratio of willingness-to-accept-payment compared to willingness-to-pay. A survey of landowners and decision makers indicated that 41 percent of landowners indicated that no new users be issued permits to support stable Trinity Aquifer groundwater levels. Meanwhile,

the decision makers chose a DFC of a 30 foot drawdown in the Trinity Aquifer over 50 years. Stakeholder surveys identified the ‘best groundwater decision makers’ as being the stakeholders or well owners, yet 75 percent of the decision makers preferred the groundwater conservation district board presidents. This suggests that stakeholders would prefer to be the decision makers rather than being asked for their preferences. One decision-maker focus group identified 12 elements representing their understanding of the DFC process. These elements form a system information diagram or preference map. Such a map can help identify alternative pathways for solving problems in the decision process. These complexities remain challenging as Texas moves toward more local regulatory control, more competing interests, and less certainty about Texas’ future groundwater supply.

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Executive Summary

Texas Groundwater Policy

This dissertation discusses and assesses methods that can identify uncertainties and conflicts over the choices of desired future conditions of Texas' aquifers. Its premise is that managing groundwater is difficult because it involves a life-maintaining resource of value from which owners can make money by preserving or using the water. Questions emerge, such as how much is groundwater worth in Texas? Who should regulate groundwater and who, if anyone, should profit from selling it? How can people reasonably address the environmental consequences of groundwater extraction yet not discourage growth? Managing groundwater can be incompatible with private property rights, intergenerational rights, commodity marketing, or state supervision of surface water resource use. Myths about groundwater infuse the stories, beliefs and decisions people make about groundwater. Groundwater extraction decisions reflect the future financial values and security risks. People who make these decisions have diverse interests in environmental preservation, aquifer depletion, property rights, or water marketing. In Texas the people making decisions about groundwater differ from the people that own the groundwater, because in Texas groundwater is a private property right and it is not treated as a public good or a common pool resource held in a public trust with usufructory rights.

Groundwater Management Areas

Groundwater management areas (GMAs), the sixteen statewide decision making boundaries targeting aquifers, are composed of groundwater conservation districts (GCDs) which are usually single county or multi-county. Currently, final decisions about groundwater availability involve a vote from one person from each GCD. This one-vote-per-GCD contrasts with regional surface and groundwater planning effort involving hundreds of stakeholders representing diverse interests. This dissertation describes research which provides stakeholder narratives generated through surveys and focus groups, of groundwater decision maker's beliefs statewide and the GMA 9 Hill Country stakeholder's beliefs and revealed preferences. It also calculated stakeholders value of their groundwater resources developed through Contingent Valuation (CV) survey methods. Using information generated from surveys and focus groups, this research tests methods to engage stakeholders and decision makers to reveal preferences, values, and concepts about groundwater decisions and to incorporate this information into the decision making process.

Desired Future Conditions Process

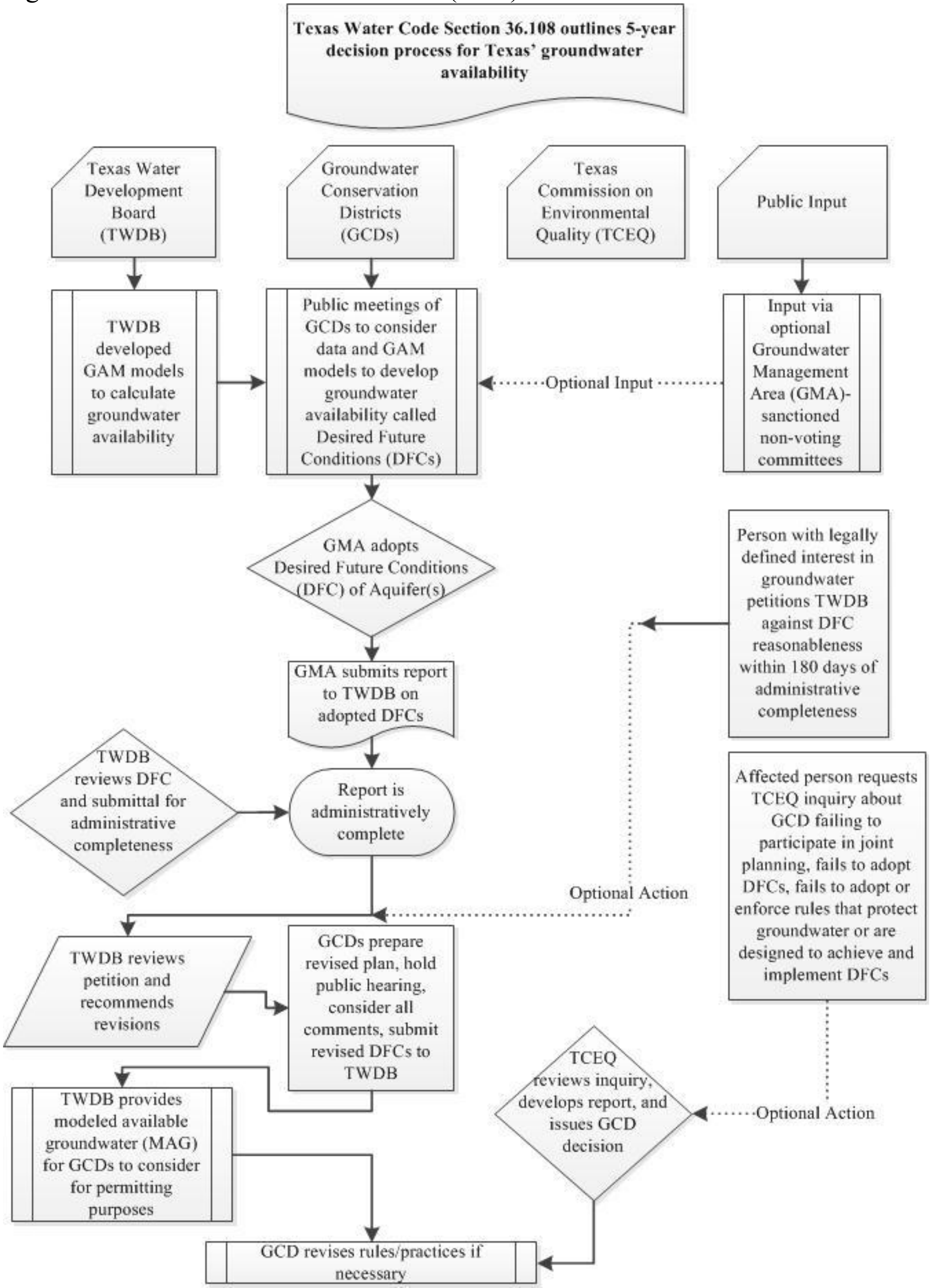
The desired future conditions (DFC) process, introduced by the Texas Legislature in 2005 and updated in 2011, began to address the problem of GCDs making independent analyses and permitting decisions about groundwater without considering neighboring practices within the same aquifer. Prior to 2005, many GCDs had no permitting or data-collection efforts in place. Some GCDs collaborated with neighboring GCDs but did not have common groundwater withdrawal rules or expectations in place. Texas GCDs on the edges of the state trans-border aquifers (with four bordering states and Mexico) may have made assumptions about other states' differing regulatory practices and individual landowner rights and uses without considering the effect of additional groundwater extractions by those external entities. Texas uses Absolute Dominion or the so-called "Rule of Capture" Doctrine to approach groundwater regulation. New Mexico, Oklahoma, Arkansas, Louisiana, and Mexico each use different groundwater capture doctrines and have different regulatory processes. Within Texas, this new groundwater decision making process mandates cooperative efforts within Texas for GCDs to apply available groundwater data and models to articulate desired future conditions addressing stakeholders' current and 50-year groundwater use. However, stakeholders and decision makers from outside of Texas may continue to use incompatible approaches, which might affect groundwater availability and quality without explicitly known consequences. Texas Supreme Court's February 2012 decision in *Edwards Aquifer Authority and State of Texas v. Burrell Day and Joel McDaniel*, supporting property rights in groundwater, should compel and motivate all stakeholders to become fully engaged in the desired future conditions process even if currently there is not an organized way to do so.

Groundwater availability models (hereafter called GAMs) based on open-source United States Geological Survey MODFLOW code and developed by the Texas Water Development Board (TWDB) account for some of these boundary issues in a few areas. Groundwater extraction decisions being made outside of Texas will affect how a shared aquifer looks in 50 years. What do Texans want their aquifers to look like in 50 years and how can they achieve those goals with all these problems? This research suggests that Texans can manage their aquifers better through a process that seeks out and supports stakeholder preferences, reveals individual financial implications, accounting for both environmental uncertainty and groundwater science to inform the outcome of future groundwater extractions.

This story begins with trying to understand people's beliefs and preferences about Texas' groundwater by developing methodologies to uncover and report them. Those beliefs and preferences provide the basis for estimating the financial value of groundwater using several methods. The value of groundwater is one key to extraction decisions. People decide when groundwater found beneath their property is more valuable for them to leave in the ground for the future, withdraw for domestic and livestock purposes, irrigate crops, or sell. Along with uncovering people's values about groundwater in the Texas Hill Country and decision makers statewide, this dissertation presents the principles of groundwater management, legal approaches, other state and country approaches to controlling groundwater extraction, as well as Texas' current water planning processes. By understanding these management principles and the water users' reactions to groundwater planning efforts, this dissertation provides a framework to understand the parameters defining the problems of determining groundwater availability in Texas. The evolution of the groundwater conservation districts from 1949 which set the tone for establishment of groundwater management areas in 2002, legislation in 2005, and associated responsible state agencies contribute to this groundwater story.

Texas took a roundabout approach to establish and reinforce collaborative regional control of groundwater extraction in areas where there have been districts for the past sixty years. Although planning for Texas surface water and groundwater resources occurred at the state level from 1961 through 2006, Senate Bill 1 in 1997 first established a regional consensus planning process. By 2011, this process resulted in the approximately 376 voting decision makers acting for a minimum of 12 interest groups, including newly-appointed GMA representatives. These members collaborate to identify water needs and develop water management strategies for 50-year plans. In 2005, House Bill 1763 established a separate regional planning process for groundwater alone (see Figure 1), also divided into 16 areas of the state with roughly comparable boundaries to the regional water planning areas.

Figure 1: The Desired Future Condition (DFC) Administrative Process



Source: Rima Petrossian, 2012

In contrast, in 2005 statute authorized only 88 decision makers (the then-current number of GCDs) to establish the desired future conditions of aquifers and future groundwater availability in each GCD and areas without a GCD. Each GCD had one decision maker, with the GMA required by law to have a 2/3 of 2/3 majority for voting purposes rather than consensus. In 2011, the Texas 82nd Legislature simultaneously took a step toward slowly expanding GMA decision making yet away from state control by recognizing vested private property rights in the Texas Water Code (TWC). This tilt to groundwater as a private property may be a signpost of one of three future roads. One future is a fast 'superhighway' to fully-established functioning water markets and higher land values with an open market driving groundwater pricing. A second route would be for Texans to reject that free and uncontrolled approach to future groundwater resource security, retract regional authority and strengthen local oversight. A third option would be eventual state governance over what would be no longer a private resource. At its core this story seeks to present and recommend qualitative and quantitative methods that can improve the process for determining the DFCs of Texas' aquifers, help stakeholders select a "reasonable yield" of groundwater for the future that most can accept, while recognizing the unresolved problems to be answered through the Texas Legislature or the courts.

Chapter 1

Chapter 1 presents the context for groundwater management in Texas. In this chapter, historical events, people and their pathways provide the backdrop extending from the first artesian wells drilled in 1858 and the Texas 7th Legislature's financial support developing groundwater to provide freely to her citizens, through a legal case about groundwater rights in 1904, to the progression of the TWC Chapter 36 from 1949 through 2011 as affected by key actors, such as High Plains geologist William Broadhurst and businessman and petroleum geologist T. Boone Pickens. The story continues to the current GMA-based groundwater decision making approach for the DFCs. Chapter 1 contrasts past decision making efforts with the new DFC policy approach and resulting problems, the GMA decision making process, and this dissertation's research approach to uncover people's beliefs and preferences about groundwater.

Chapter 2

Chapter 2 describes past planning efforts and historical timelines and historical events leading to current management approaches. Eight relevant legal cases testing the interpretation of the groundwater governance are also described. Past statewide and regional water planning efforts combined surface water and groundwater together from 1961 through 2005 are summarized. These approaches can be contrasted to the GMA joint planning process that began in 2005 which authorized one vote per district in deciding the groundwater availability.

Chapter 3

Chapter 3 describes water governance theories and regulation in fourteen countries and all U.S. states, with more detailed description of policy history in fourteen select U.S. states. The important commonality in all states is that even under differing regulatory approaches each landowner in every state has the right to withdraw groundwater, where it is available, for a least indoor domestic uses. The amounts considered "exempt" from permitting vary, depending upon natural hydrological regimes and local policy approaches, from a low of about 402 gallons per day in Utah to unlimited withdrawals in non-district areas in Texas and other states where the so-called rule-of-capture prevails. Each state has its own rules for regulating groundwater, usually requiring administrative efforts to report how much groundwater is being reserved for use. With such data states can determine which extractions are meeting state withdrawal guideline or federal guidelines for contamination. The federal role in groundwater regulation is public safety through providing drinking water standards of maximum contaminant levels, but that is not a standard for the individual landowner. Texas remains unique with its acceptance of 'rule of capture' without sustainability, preference for a small user, or water quality issues as policy goals. In Texas GCDs are free to develop production rules based on historical use, a "first in time, first in right" withdrawal, a rate of withdrawal, tract size, or proportionate reduction. This new GMA process represents a previously identified groundwater management doctrine called the Groundwater Management Doctrine or New Managerialism, capturing the transition between so-called 'rule-of-capture' and local approaches to managing aquifers while recognizing the interconnectedness of groundwater users affecting their neighbors' resources.

Chapter 4

Chapter 4 reports on research instruments and methods including the psychology of choosing, Grounded Theory, Contingent Valuation method, and Interactive Qualitative Analysis. Results from 831 stakeholder and 89 decision maker surveys and fifteen focus groups indicate that stakeholders and decision makers seem to believe that the wrong group is making decisions about the future of groundwater extraction. Stakeholders in GMA 9 indicated that the aquifers should remain as they are today or even increasing the groundwater elevations or stored volume in the aquifer to improve to pre-development levels. These preferences contrast with decision makers' choice of 30 feet of drawdown for the Trinity Aquifer, aquifer-wide over the next 50 years, called a DFC.

Chapter 5

Chapter 5 presents the case of GMA 9, used as an example for researching new methods to devise DFCs. Regional planning areas formerly responsible for identifying groundwater availability Region J, Region K, and Region L, are contrasted with state-generated groundwater modeling efforts, called GAM runs, including the basic science that led to the GMA 9's DFC choice. Climate components addressed through the GAM groundwater availability models are described, such as the aquifer recharge values simulating over 350 years of past rainfall for the Trinity Aquifer.

Chapter 6

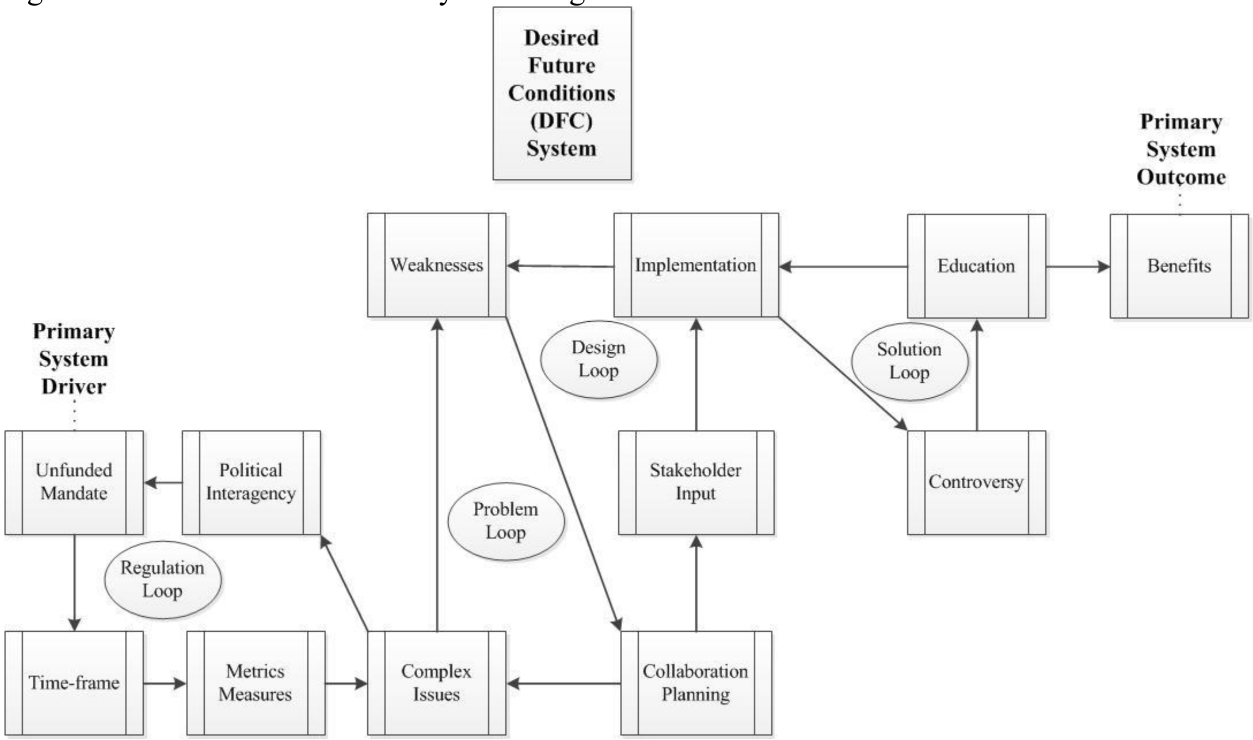
Chapter 6 reports on stakeholders contingent valuation values, which revealed a willingness to pay for groundwater for an average of $2,855 per acre-foot. Most landowners most did not want to sell groundwater at any cost. Those willing to accept payment sought an average of $4,069 per acre-foot. GMA 9 stakeholder characteristics and statewide decision makers survey responses are summarized using examples such as identifying the best entity to decide on groundwater availability. Stakeholders identified the best groundwater decision makers as being the stakeholders or well owners. In contrast 75 percent of the decision makers preferred the district board presidents as decision makers. This suggests that stakeholders would prefer to be the decision makers rather than being asked for their preferences. About 41 percent of landowners preferred that no new users be issued permits to support stabilized Trinity Aquifer groundwater levels. Meanwhile, the decision makers chose a DFC of a 30 foot drawdown in the Trinity Aquifer over 50 years. A smaller group (14 focus groups with 64 survey responses) revealed knowledgeable and concerned stakeholders articulating commonly-identified issues of uncontrolled development, groundwater waste, water quality and availability problems. Groundwater stakeholders did not agree with the decision makers that TWC Section 36.108 guidelines were specific enough to result in reasonable DFCs. This chapter uses decision makers' survey comments to retell the story behind their responses. Their concerns range from seeking better methods to quantify groundwater availability to including more decision makers to weigh in on groundwater availability, with or without the knowledge of groundwater resources, and with or without the support of the electorate through GCD board member voting. This chapter also reports commonly-voiced issues through public meetings: flawed groundwater modeling effort; a flawed decision process; and a conflict between the underlying goals of tax-based versus fee-based groundwater districts.

Chi-squared test results of goodness of fit for focus group survey responses to the same questions revealed that stakeholders and decision makers differ significantly when answering seven DFC-related questions. Responses reflect whether the respondent is a stakeholder or decision maker. When asked to rank seven tools importance in deciding a reasonable DFC, stakeholders and decision makers agreed about the top four and the bottom three choices, but not the order except for the most important tool: Historical Groundwater Data/Current Aquifer Conditions.

Chapter 7

Chapter 7 converts stakeholders' concerns in their own words into 11 categories or elements. Stakeholder-identified elements when compared to the decision maker's development of 12 categories differ with regard to the desired future conditions. For example, decision makers focus on the mechanics and legislative requirements of the decision. Stakeholders focused on groundwater and its uses. A systems diagram or "Mindmap" (see Figure 2) visually illustrates the GMA 9 decision maker's perceived DFC system driver, called 'unfunded mandate,' and outcome, called 'benefits' of the DFC process, shows disparities in how these two groups envision the process for deciding future groundwater availability for their aquifers. This chapter tests the system developed from the stakeholders and decision makers with possible scenarios. For example, if issues drives the way the group collaborates and helps the decision makers plan the design phase of the decision process, the group ought to understand those processes before they seek to educate the public. Conversely, can stakeholder input to implementation approaches lead the group in a recursive feedback loop to redesign a better way to implement the DFC process rather than moving forward to controversy and then seeking to educate the public?

Figure 2: Decision Makers DFC System Diagram



Source: Rima Petrossian, 2012

Chapter 8 concludes this dissertation by provides planning recommendations based on the research as well as conclusions about stakeholder participation, the planning efforts, and related financial consequences. This chapter recommends developing a process for calculating financial impacts, defining reasonable yield, and improving legislative guidance.

This dissertation's contributions begin with its summary and comparison of each of the states groundwater management approach in the United States and fourteen countries. It identifies a Groundwater Management doctrine relevant to the DFC process in Texas. It reports on the 7th Texas Legislature's groundwater management philosophy in 1858 as groundwater being a common pool resource. It records and reports stakeholder and decision maker survey and focus group multiple choice responses and narratives describing people's understanding and preferences about groundwater. It develops methods to quantify stakeholder financial values of groundwater determined through CV research efforts. It develops a systems diagram or

“Mindmap” describing decision makers’ conception of the DFC process useful for scenario testing. For example, decision makers can use this system to identify how to apply policy changes or exert efforts to improve their DFC decision making or management approaches.

This dissertation’s contributions represent an effort to understand past groundwater management approaches to create new methods for improving the DFC process, which either could be distributed to the GMAs or enacted through updates to Texas’ groundwater law, TWC Section 36.108. These methods seek to reveal people’s preferences about groundwater to help decision makers develop reasonable DFCs for future groundwater and for landowners to express their preferences. Engaged and informed stakeholders can make this process less controversial, reducing discord among the groundwater decision makers and the groundwater owners.

Chapter 1: Texas' Groundwater Management Story

INTRODUCTION

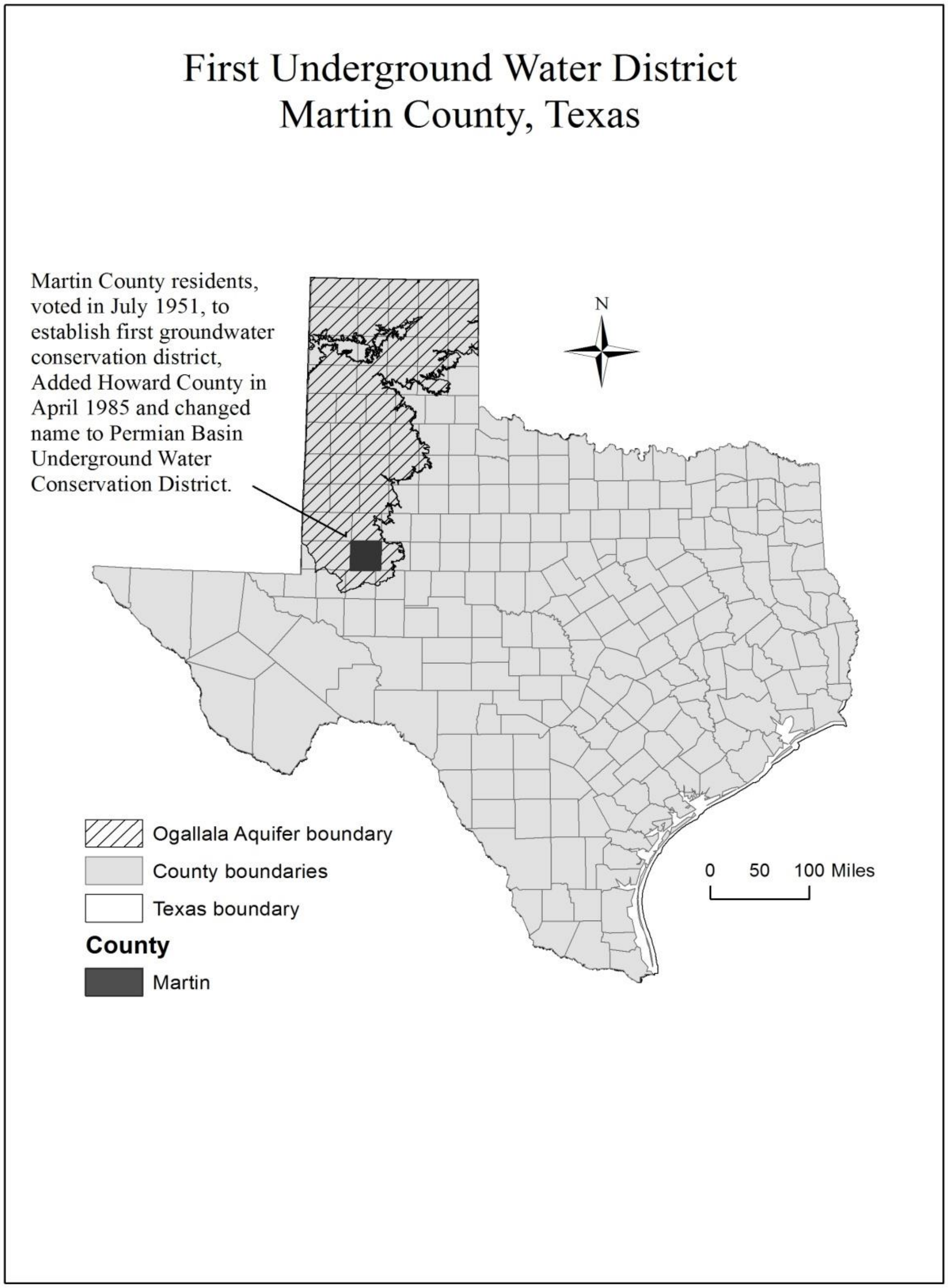
For 150 years Texans have known how to install a well and use wind power and later electric pumps to extract groundwater at rates that now vary from a few gallons to several thousand gallons a minute. Groundwater wells allow landowners to withdraw groundwater and modify natural surroundings to overcome scarcity, climate, and geological constraints to have water for drinking, irrigating, watering livestock, building industrial facilities, or selling. Individual well owners have primarily made these groundwater use decisions. For example, Texas adopted common law in 1840,[1] in 1858 the 7th Texas Legislature authorized and paid for drilling groundwater wells allowing free public access to those wells,[2] and later Texas adopted the so-called 'rule-of-capture' in 1904 in the *East* case: if a user pumps groundwater for beneficial use, no adjacent groundwater user has grounds to object.[3] While some analysts interpret the 1917 Conservation Amendment to address all water resources,[3] until 1949 there was no administrative mention of groundwater specifically.[4] Attempted regulation of artesian wells before 1949 failed due to lack of measures for administrative enforcement.[4] Legislative sessions in 1937, 1939, and 1941 both introduced and rejected legislation addressing groundwater administration.[4] Between 1941 and 1949, Texas experienced a decade with both the wettest individual year on record in 1941 and a drought in 1946-47.[5] Due to this drought and political fears of state control,[6] the 51st Texas Legislature authorized voters to create groundwater conservation districts (GCDs) for the "…conservation, preservation, protection, and recharging and the prevention of waste of the underground water of the underground water reservoir...".[7] The costs to drill a well, including the power and the pumps, represented personal risks and choices people made independently with little private or public intervention until 1949.[8] With the new legislation, new administrative costs, through new taxes or fees, added to groundwater users' costs to withdraw groundwater. Local concerns about groundwater administration began with the rules the 51st Texas Legislature established with the Texas Groundwater District Act, Article 7880-3c, Texas Civil Statutes, in 1949.[4] These rules and regulations about pumping, spacing, and permitting rules were meant to compliment but not interfere with the prevailing groundwater doctrine, the so-called 'rule of capture'.[9] Groundwater withdrawals, although generally guided through state-authorized planning and local groundwater administration, remains a contentious and complex subject despite growing detailed administrative guidance for GCDs.[10]

GROUNDWATER CONSERVATION DISTRICT FORMATION

In 1936, the State Board of Water Engineers gauged and recorded 710 wells in Martin County, most sourced in the Ogallala Aquifer and some dating to 1890.[11] In 1951, local voters recognized emerging groundwater elevation declines in the county and pioneered a locally supported GCD (see Figure 1.1), located in a large agricultural economy similar to where the original supporters for the 1949 legislation resided.[12]

The largest GCDs formed over the Ogallala Aquifer, where scientists and farmers recognized the problems of drawdown as early as 1951, related to rainfall, pumpage, and geologic conditions.[13] The largest GCD (High Plains Underground Water Conservation District No. 1 or HPUWCD #1) started in September 1951, remains the largest such district[14] and a source of argument against state control.[15] Local activism and promises of local control of groundwater resources had its own champions and believers, but the initial set of support and complaints about state intervention originated in the High Plains.[16]

Figure 1.1: First Underground Water Conservation District in Texas, July 1951.



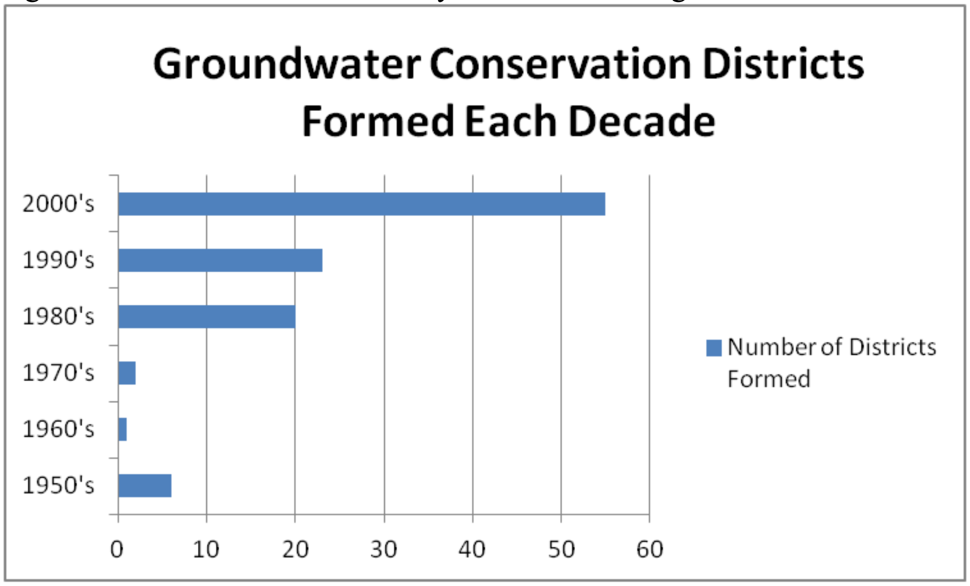
Source: Rima Petrossian, 2010.

Geologist William H. Broadhurst of the U.S. Geological Survey, a key High Plains GCD advocate due to his concern about dropping water elevations and potential state intervention, prepared reports documenting water levels in the Ogallala Aquifer in the late 1940's.[6] The

HPUWD #1 hired Broadhurst to become staff hydrologist in 1951 because of his expertise, interest, and concern about the Ogallala Aquifer.[16] At the time, voters supported groundwater district development mostly in west Texas, due to the increasing extraction rates and increasing concerns about potential state control due to the declining aquifer levels.[16] With his deep roots in the Texas panhandle and geologic understanding, Broadhurst later indicated that he sparked local leaders to influence legislators to support local control via district formation.[16] This support evolved as landowners feared eventual state control stemming from stricter local control due to groundwater depletion.[16]

Five GCDs emerged during the drought of the 1950's, garnering enough local support to address most of the northern and central part of the Ogallala Aquifer.[17; 18] The 1960's through the 1970's were quiet for GCD formation.[18] GCD formation activity has increased recently (see Figure 1.2), as there were 21 GCDs formed in the 1980's and 15 GCDs formed in the 1990's in central, western, and west-central Texas. GCD creation peaked during the 2000's at 54 GCDs formed in the 2000's, mostly in central, south-central, and southeastern Texas.[19] Holladay has speculated that the proliferation of GCDs after 1997 resulted from changes in the process for forming a GCD, ostensibly making it easier than before.[20]

Figure 1.2: GCD Formation in 60 years: 1951 Through 2009

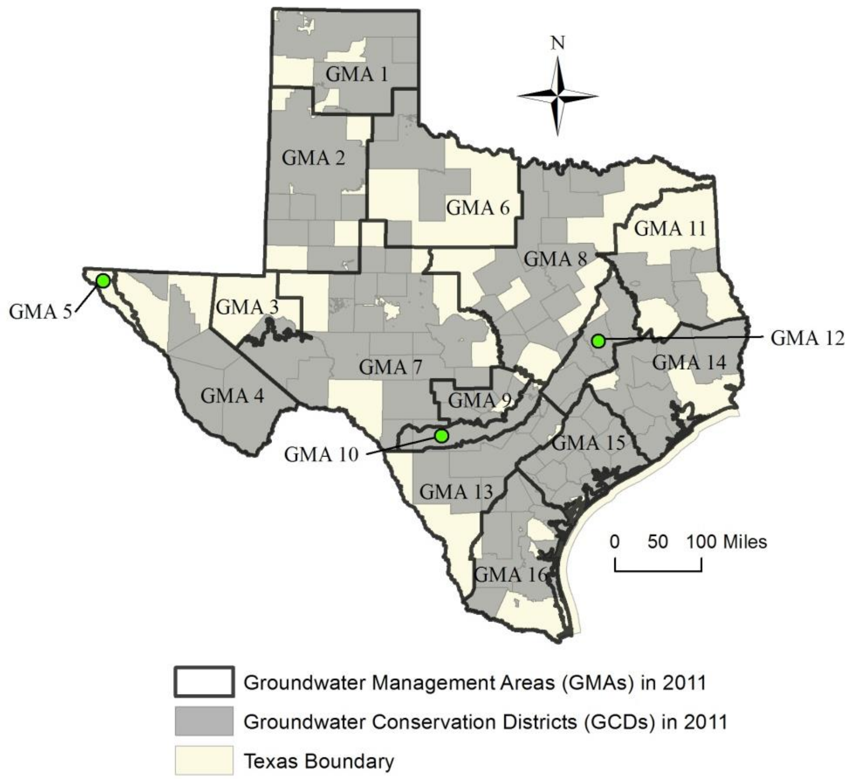


Source: Rima Petrossian, 2012

Note: Not all districts formed still exist. Districts joined with other counties count as one formed in the original decade.

GCD formation expanded into the 21st century as more GCDs (see Figure 1.3) formed in rest of the High Plains and around the state.[21] In 2011, the 82nd Texas Legislature proposed two single-county GCDs.[22] As of 2011, voters had confirmed 96 GCDs and three awaited confirmation or dissolution.[23] These 96 GCDs covered about 67 percent of the state.[24] Fear of state control existed in 2012 just as strongly as in the 1940's, with the majority of aquifers under local control; the state's largest district continues to cite an unnamed but ominous agency in Austin potentially controlling all withdrawals as one of the reasons to support local control such as GCDs.[25]

Figure 1.3: Texas GCDs and GMAs in 2011.



Source: Rima Petrossian, April 23, 2012

Sixty years after the Texas Groundwater District Act of 1949, voters had established GCDs in a majority of Texas' areas producing groundwater[26] and GCDs had doubled in number from 1997 through 2005.[18] These diverse institutions incongruently managed groundwater over the rather irregular larger aquifer boundaries,[23] creating complications for any state effort to predict groundwater availability. Through Senate Bill 1 the 75th Texas Legislature addressed groundwater[27] as a strategic and significant water supply source that provides almost one-third of the supply in the state[28] even though individual landowners control most of the resource. The 79th Texas Legislature changed this independent approach by requiring the people making the decisions about quantifying groundwater, the GCD board presidents, to cooperate in a groundwater management area (GMA) to decide how much would be needed over the ensuing

50 years.[29] Table 1.1 lists elements of Texas' updated approach to groundwater management beginning in 1997 with the 75th Legislature's changes.

Table 1.1: Legislative Changes to Groundwater Management: 1997 through 2005

In their 1997 biennial report to the 75th Legislature TCEQ planted the seed by recommending a change to the Texas Water Code (TWC) to require existing GMAs to have joint planning meetings, to establish a way for new GMAs to petition TCEQ to form[30]
In 1997, the 75th Texas Legislature passed Senate Bill 1, explicitly preferring GCDs to manage groundwater[27]
In 1997, Senate Bill 1 authorized Texas Water Development Board (TWDB) to provide a management plan administrative review every five years [27]; previously 30 of the 40 GCDs had irregularly submitted management plans to the Texas Commission on Environmental Quality (TCEQ) for review[30]
In 2001, in TWC Section 35.004, the 77th Legislature required the TWDB to divide the state into areas suitable for groundwater management without identifying specific planning requirements for those areas[31]
In the 2002 State Water Plan, TWDB recommendations to the Legislature included establishing regionally-based compatible aquifer management goals, in a management areas, called "desired future condition for the aquifer" which identified GCDs and Regional Water Planning Groups (RWPGs) and collaborating to achieve these goals and strategies[32]
In 2005, GMAs became the source of groundwater availability estimates for the state's 50-year planning process rather than RWPGs[29]

Source: Rima Petrossian, 2012

GROUNDWATER ADMINISTRATION COMPLEXITIES

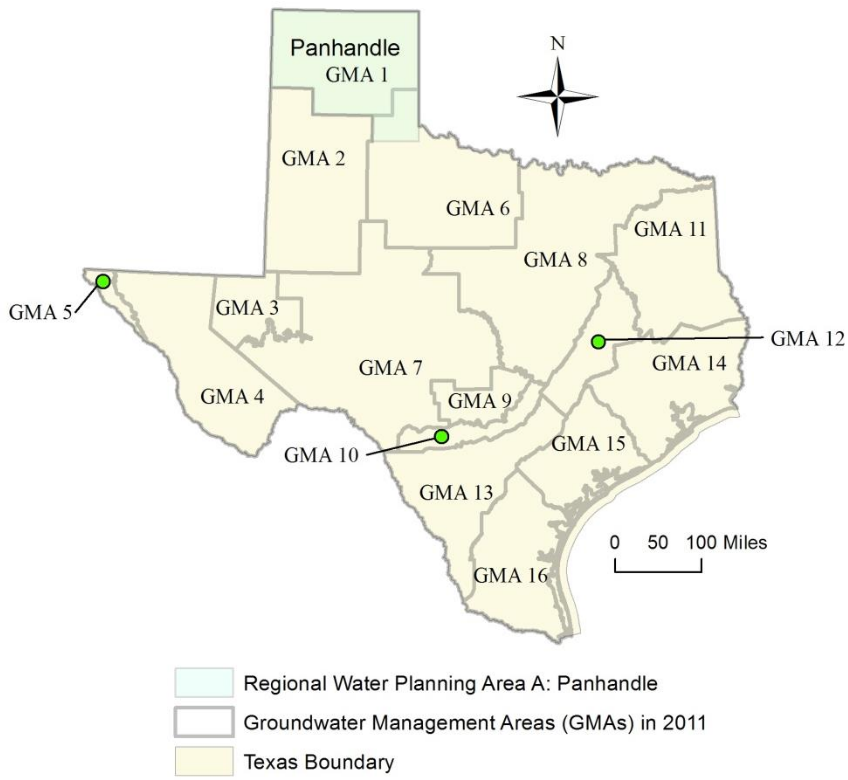
This complexity arguably stems from a 1904 Texas court case supporting private property rights in groundwater, which said a landowner is not responsible for neighboring water level declines due to pumping groundwater.[3] Subsequent management of the right to use groundwater through a state-authorized GCD in 1949 created an inherently contradictory approach.[8] Newer guidance from the 79th Texas Legislature in 2005 authorized GCDs to develop plans to control exempt groundwater withdrawals, usually over 25,000 gallons per day (gpd), in areas with GCDs.[33] Previously, each GCD sought to control groundwater extraction in an organized but uniquely local way governed by a GCD's general powers.[7]

The 1949 legislative guidance for aquifer definitions and groundwater practices continue to guide GCD duties in 2012.[7] One difference is that a landowner's groundwater withdrawal exemption limits from GCD control declined from 100,000 gpd to a recommended 25,000 gpd.[7; 34] Oversight of regulatory decisions controlling resource extraction and use is primarily exercised in many GCDs through voters controlling representation on the GCDs board of directors[35; 36] although a number of GCDs have appointed boards. These localized powers could create limited authority to control of groundwater but people's private property rights are simultaneously recognized creating a fundamental tension,[37] because nothing in the code is supposed to be, "…granting the authority to deprive or divest a landowner, including a landowner's lessees, heirs, and assigns, of the groundwater ownership and rights…" This tension adds to the complexity of quantifying groundwater availability in Texas and identifying sources for the future. Landowners retain a property right to groundwater incident to ownership of their land.[8]

Groundwater Management Challenges

This decision-making process allows for one or several landowners controlling large amounts of groundwater to influence a large area and many people. For example, in 2012 landowner Mr. T. Boone Pickens and his water development company Mesa Water sold groundwater rights both owned and contracted from other landowners in the Ogallala Aquifer to the Canadian River Municipal Water Authority (CRMWA).[38] They sold a total of 177,717 surface acres for $86,566,171, for $500.00 or $400.00 per acre depending upon location.[38] This sale was thought to be the largest groundwater transaction in Texas and in the world.[38] It included groundwater from Roberts, Lipscomb, and Hemphill counties, counties in the northeastern part of GMA 1 and the Panhandle RWPG area (see Figure 1.4).

Figure 1.4: 2012 Groundwater Management Areas, GMA 1, and Panhandle RWPG Boundaries



Source: Rima Petrossian, April 23, 2012

The CRMWA purchase secured a water supply to an area where both the RWPG and the GCDs in GMA 1 and 2 s intend to deplete their groundwater by 20, 50, or 60 percent volume, or by an average annual drawdown rate in some GCDs over the next 50 years [39]. Since the mid-1960's, when the Corps of Engineers (COE) built Lake Meredith in Hutchison, Moore and Potter Counties, CRMWA built an aqueduct system in the High Plains to serve a huge area with over a half million people in 11 cities, several GCDs, two regional water planning areas (RWPAs), and two GMAs.[40] Panhandle residents in the CRMWA service area had previously relied on both additional Ogallala Aquifer wells and surface water from Lake Meredith, which experienced a record lifetime low in April 2012.[41] CRMWA pipelines stretch hundreds of miles from Pampa, through Borger, down to Lamesa in Dawson County, with an offshoot line through Lubbock into Brownfield in Terry County and Levelland in Hockley County.[40]

How did the Pickens and Mesa Water transaction happen? Why did landowners in Roberts, Lipscomb, and Hemphill Counties decide to sell vast amounts of water from an ancient aquifer under their private property? When much of the U.S. is trying to achieve sustainable water resources, why did these Texans decide to mine and deplete a common pool resource?

Continuing conflicts over water use motivated these changes. In the Panhandle RWPG A and the area called GMA 1 (see Figure 1.4) several GCD general managers participated in both planning efforts. The 2005 legislation changed the onus of quantifying groundwater availability from the RWPG to the GMA.[33] As a matter of practice TWDB and other state agencies performed those calculations prior to 1997,[42] illustrating the continued shift from state-level planning to regional to local groundwater planning. Originally GCDs had to ensure they were accounting for enough groundwater being available for regional planning efforts.[27] As of 2005, the process reversed where GMAs through the GCDs, adopted aquifer condition goals which control groundwater in the regional planning process.[33]

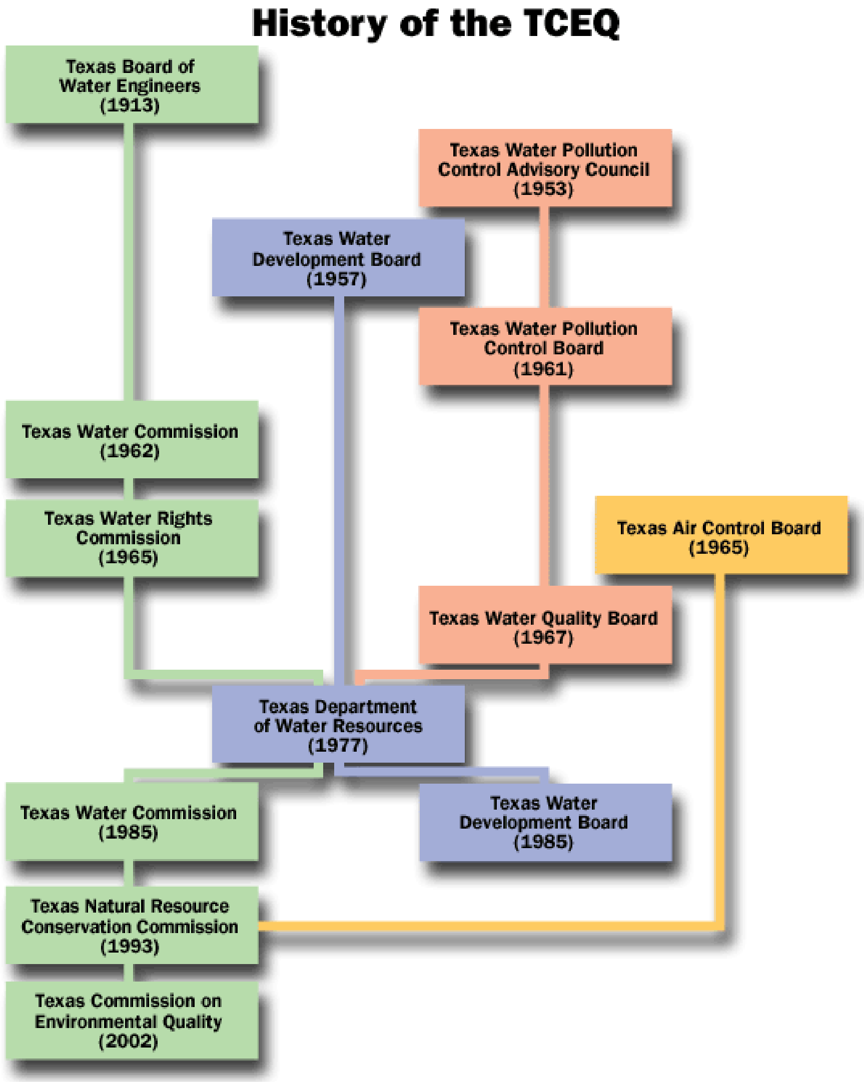
In 2011, the 82nd Texas Legislature returned to update and improve the process by making the decision more transparent and attempting to balance competing interests and specified considerations.[34] This approach might be complicated further and ultimately ineffectual due to a 2012 Supreme Court decision in *Edwards Aquifer Authority v. Day* strengthening landowner's rights over GCDs permitting efforts limiting groundwater withdrawals and landowner's perceptions.[43]

Past Groundwater Availability Quantification Efforts

Each of the GCDs acted independently of each other and the state when issuing permits or exempting wells from withdrawing groundwater, even in shared aquifers.[21; 29] Although GCDs could control permitting groundwater uses and calculate groundwater availability for local aquifers, in 1979 the water planning agency Texas Department of Water Resources (TDWR) published estimates of groundwater availability for all aquifers to help with statewide water planning efforts (see Figure 1.5).[44] From 1977 through 1985, as the TDWR, the state managed water quality, water rights, and water planning under one institution.[44] In 1985, the TDWR was split into two agencies, the TWDB and the Texas Water Commission (TWC).[44] The TWC subsequently became part of the Texas Natural Resource Conservation Commission in 1993 and the Texas Commission on Environmental Quality (TCEQ) in 2002.[44] Within these state organizations there are several groundwater regulatory layers that developed over the past 60 years.

The TDWR premised its development estimates by referring to pumping on a "sustained basis," while recognizing excessive drawdown in areas like El Paso, Dimmitt, Zavala, Angelina, and Nacogdoches counties, the High Plains, as well as the Gulf Coast Aquifer saltwater intrusion.[45] Estimates of groundwater availability usually assumed withdrawals equating to the annual aquifer recharge.[45] State water plans subsequently reported on "total recoverable reserves"[46] for all groundwater but reported groundwater supply and demand by river basin without detailing methods for quantifying future "reserves".[46]

Figure 1.5: Texas Water Resources Predecessor Agencies



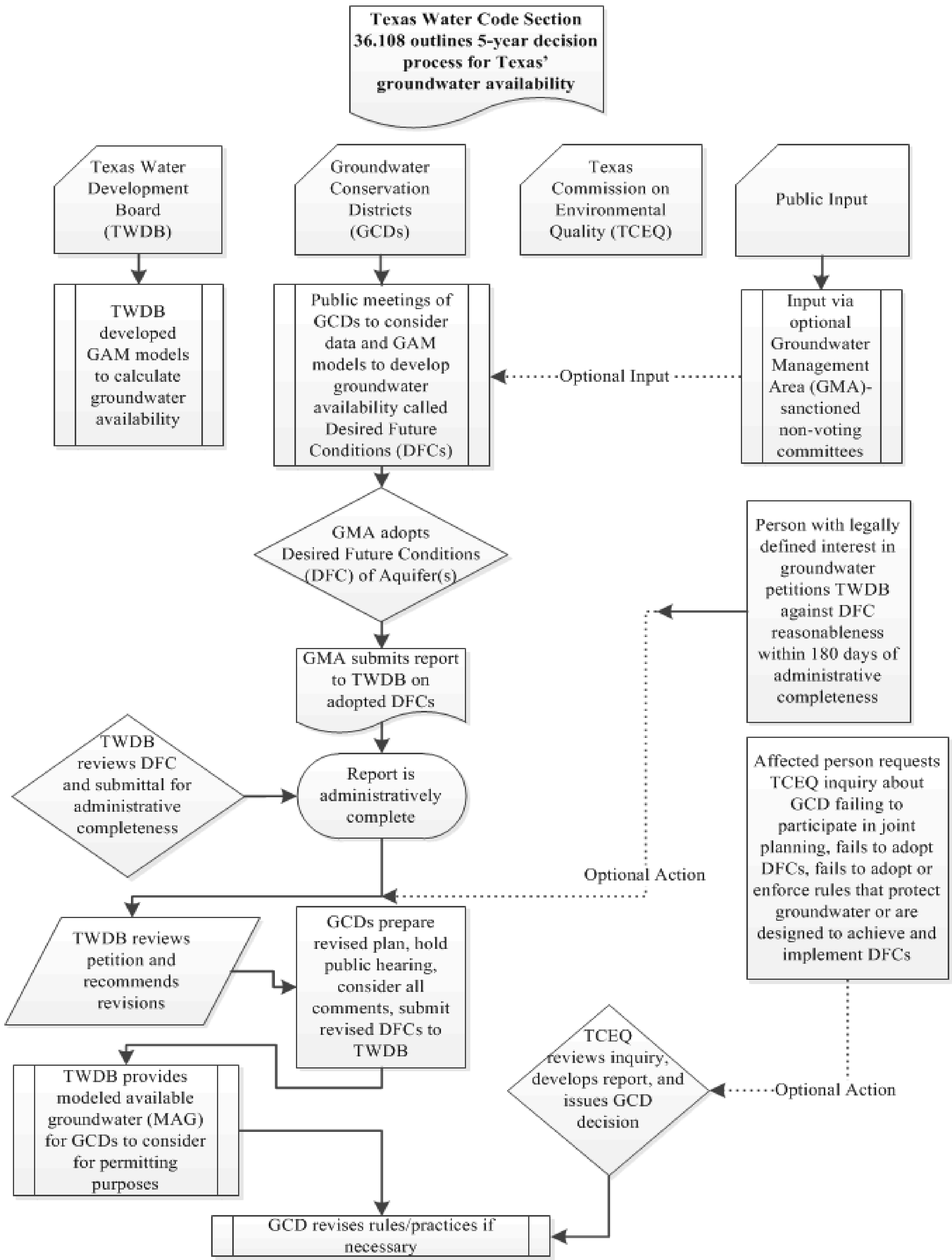
Source: Texas Commission on Environmental Quality, 2009

TWDB or previous agency reports (called "Numbered Reports")[25] quantified how much was groundwater was withdrawn in a specified area or aquifer. Some reports described how the aquifer might change due to withdrawal practices.[40] If any effort was made toward quantifying how much might be recoverable or available in the future, past use served as the proxy for future management practices.[40]

The Shift to Joint Planning

In 2002 the TWDB State Water Plan urged the Texas Legislature to identify a new goal for GCDs to establish and address that of "quantifying the desired future condition (DFC) of the aquifer."[32] In 2005 the 79th Legislature shifted the state's approach to allow the GMAs to quantify future groundwater availability rather than RWPG decisions for state water planning.[29] This approach involved state agency input, GCDs meeting together as a GMA and jointly deciding about future groundwater availability. This new process allowed public attendance at an annual meeting and authorized two petition processes (see Figure 1.6). These newly TWDB-identified GMAs had only one discrete directive: determine how much groundwater was available in Texas to quantify the amount of groundwater available for use in Texas.[29]

Figure 1.6: Desired Future Conditions Administrative Process



Source: Rima Petrossian, December 2012

GROUNDWATER AVAILABILITY EXPRESSED THROUGH DESIRED FUTURE CONDITIONS

Groundwater, water beneath the ground,[47] can be considered an aquifer when enough water is extracted and used in significant quantities.[48] In any DFC decision, the amount of groundwater 'available' for use from an aquifer is the amount that can be extracted for beneficial use depending upon groundwater flow and decision makers' choices.[29] Some believe that the decision makers must know how much water exists in the entire aquifer in order to decide how much is available. While the volume of water underground is not required explicitly as an input to the decision process, it exists implicitly in a groundwater model, even if it may be a value associated with significant uncertainty. TWDB scientists develop modeled available groundwater (MAG), an annual pumping volume term, through either through running groundwater models or by using complex hydraulic equations using hypothetical pumping scenarios.[29] These models or calculations result in future pumping amounts and include household or small uses exempt from local GCD control.[29] By statute, up to 25,000 gpd per individual household well are exempt from regulation,[34] except in several districts that have either increased or decreased this amount; exempt uses are included undifferentiated in the model as part of the MAG. However, this process does not address how exempt use and private property rights are different and how those exemptions and rights will be affected by a newly developed permitting system based on newly articulated DFCs.

After September 1, 2005, fifteen GMAs started meeting (one GMA has no GCDs) as well as some officials from the areas outside of GCDs without official representation.[49] The 79th Texas Legislature mandated that these decision makers, GCD presidents or their representative, deliberate in public about the future state of the aquifer or volume of groundwater available for use [33]. TWC Section 36.108 requires GCDs to follow a set of administrative requirements in only one required public meeting a year [33]. The set of presidents of each GCD or their representatives are the decision making board (one person-one vote).[33] This means that members of the public can watch in deliberations but only GCD leaders can participate to adopt DFCs.[33] After the 2011 legislation, GMAs could organize non-voting advisory subcommittees to advise decision makers.[34] If a stakeholder disagrees with either the GMA-chosen DFC or if the GCD responsible does not approach its management responsibilities satisfactorily, a stakeholder has up to 180 days to take action.[34] An affected person in a GMA who does not like the way the GCD is participating in the process or how they are attempting to manage the aquifer with regard to their stated policy can protest the decision by petitioning the state agency responsible for administrative oversight of GCDs, the TCEQ.[34] A person with a "legally defined interest in groundwater" who does not like the chosen DFC in a GMA can protest the decision by petitioning the state agency responsible for developing and planning for water, the TWDB.[34]

GROUNDWATER MANAGEMENT AREA 1 AND A PETITION

The T. Boone Pickens story involved one of the first petitions against the reasonableness of the available groundwater, the aquifer's DFC (see Table 1.2) for one of the largest and most-exploited aquifers in the world, the Ogallala Aquifer.[50] In GMA 1, four GCDs worked together beginning in 2006 to establish aquifer conditions they wanted to reach in the Texas Panhandle over a 50-year planning cycle.[51] Mr. Pickens challenged these new planning processes first in his approach to the RWPG for developing a groundwater export strategy[52] and then through a petition and subsequent lawsuit against the TWDB about the GMA 1 DFCs.[53]

Table 1.2: GMA 1 Desired Future Conditions Adopted July 7, 2009

Location	Water Availability Goal
North Plains GCD: parts of Dallam, Hartley, and Moore, and all of Sherman; Outside a district: Dallam, Hartley, and Moore.	40 percent volume in storage remaining in 50 years
High Plains Underground Water Conservation District (UWCD): parts of Armstrong, Potter, and Randall; North Plains GCD: Hansford, parts of Hutchison, Lipscomb, Ochiltree; Panhandle GCD: parts of Armstrong, all of Carson, Donley, and Gray, parts of Hutchinson, parts of Potter, all of Roberts and Wheeler; Outside a district: parts of Hutchinson, all of Oldham, and parts of Randall.	50 percent volume in storage remaining in 50 years
Hemphill County UWCD: Hemphill County	80 percent volume in storage remaining in 50 years

Source: www.twdb.state.tx.us/groundwater/docs/DFC/GMA1_DFC_Adopted_2009-0707.pdf

Over the course of about a decade, Mr. Pickens developed a large water marketing effort in the Ogallala Aquifer where he owned and leased property within the Texas Panhandle.[54] Groundwater decision makers, regional water planners, and stakeholders had not supported Mr. Pickens' plan[52] as being viable or desirable for long-term water supply.[45] At issue was whether water users in urban areas—some who consume water at relatively high per capita rates—should be allowed to deplete fresh groundwater resources of the High Plains, rare and fossil water resources, without any potential of recharging the aquifer.[55] This story encapsulates many of the complex issues involving extraction of groundwater in Texas. Bowman[56] called this one type of water marketing *groundwater ranching*, and believed it was unique in Texas to the Panhandle area. To set the story into perspective, it is important to understand that Texas' boundaries enclose unusually disparate temperature and rainfall conditions. Texas is so large that its landscape varies west to northwest, central to southeast from subtropical arid to continental steppe, subtropical steppe to sub-tropical humid.[57] Rainfall annual averages range in far west to far southeast Texas from 8 inches to 56 inches.[57] In far north Texas an aerial image (see Figure 1.7) of the Texas Panhandle shows the bright green of crops growing, reddish-tan soils, and pale yellow residue from harvested crops in irrigation circles arranged geometrically like Texas-sized domino tiles and dice, small silvery blue circles reflecting close to 19,300 playa lakes[58] and slim rivers snaking across the land. This composed image belies the growing conflict among people who are playing a Texas-sized high stakes game by seeking to extract and move ancient subterranean groundwater from the Ogallala Aquifer, hidden beneath the irrigated yet parched Texas High Plains.

The people in the conflict over Ogallala Aquifer groundwater include farmers, ranchers, local officials authorized to make decisions about Texas' future water supplies, as well as Mr. Pickens, a billionaire seeking profit from supplying water and wind energy to bigger cities. Mr. Pickens personifies the persuasiveness of a single stakeholder in the regional water planning process and GMA to control groundwater resources now and into the future.

Since 2000, Mr. Pickens, the energetic 85 year-old billionaire energy developer (dubbed the "Oracle of Oil")[59] has combined his Texas Panhandle interests in wind energy with water supply development to propose an export of thousands of acre-feet of groundwater over a 20-year period from Roberts and surrounding counties to major Texas cities like Dallas, El Paso, or San Antonio.[60] He had sought to include this privately funded water resource as a water management strategy in the legislatively authorized and funded regional and state water plans.[52] To manifest this outcome, Mr. Pickens created a groundwater consortium, initially buying over 100,000 acre-feet of groundwater rights in Roberts, Grey, and Hemphill counties.[54]

Figure 1.7: Carson County in the Texas Panhandle

Source: Google Maps, March 29, 2012

In a 2000 proposal, Mesa Water Inc. (Mesa Water) reported that its goal was to buy enough water rights to supply larger cities like El Paso, San Antonio, Lubbock, Midland, and Dallas-Fort Worth for 60 years.[52] Despite this lengthy and detailed proposal[52] in 2001 the regional water plan failed to approve his private venture as a water management strategy.[61] Later, Mr. Pickens established his own state-authorized fresh water supply district in Roberts County after he previously had applied for and received pumping permits from the Panhandle GCD in 2002 and 2004.[54] The Panhandle GCD general manager, C.E. Williams who was responsible for issuing extraction permits to Mesa Water, was coincidently the chair of the Panhandle RWPG tasked with planning for Texas' future water supplies and a member of the GMA 1 group tasked with developing desired future conditions of the aquifers.[62]

In a parallel path beginning in January 2006, Mesa Water representatives also began attending GMA 1 meetings.[63] Later, in 2010, two petitioners Mesa Water and G & J Ranch in

Canadian, Texas, protested against GMA 1's adopted DFCs (see Table 1.3), based on arguments such as the unequal protection of spring flow between Hemphill County and the North Plains districts.[64]

Table 1.3: Petition Summary of Groundwater Management Area 1 DFCs

Petitioners: Aquifer(s) and Issues
Mesa Water, G & J Ranch: Ogallala Aquifer (see DFCs listed in Table 1.5) • Conditions not based on science but political boundaries; • all areas should receive equal treatment, including for spring flow rather than just protecting spring flow in Hemphill County; • private property takings, no eminent domain power in Hemphill County; • 80 percent of volume to remain in Hemphill County is unrelated to physical aquifer constraints; • conditions not physically possible; • socio-economic impacts not quantified.

Source: Jones, Marvin W. and Andrew Little, *The Ownership of Groundwater in Texas: A Contrived Battle for State Control of Groundwater.* Baylor Law Review, 2010. **61**(2): p. 578-609.

The petitioners also claimed that the GMA 1's DFCs resulted in a private property taking of their groundwater and a "diminution in the present fair market value of the Plaintiff's Hemphill County groundwater rights,"[64] while the Hemphill County UWCD was seeking to sustain ecosystem services through spring flow.[65] The TWDB, which reviews the petitions and makes a non-binding decision about the reasonableness of the desired future condition, disagreed with the petitioners and indicated some of their arguments were beyond the state's authority.[66] Mesa Water's subsequent lawsuit against the TWDB in Travis County Court[67] was dropped in February 2012, after Mesa Water successfully sold their water rights to the Canadian River Municipal Water Authority and filed a motion to dismiss the appeal because the controversy was no longer an issue.[68] Practically synchronous with this lawsuit, stakeholder private property rights were being addressed in the Texas Supreme Court case *Edwards Aquifer Authority and*

State of Texas v. Burrell Day and Joel McDaniel (the *Day* case) decided February 24, 2012.[43] This case appeared to allow all stakeholders, even those without exceptional resources, to seek compensation if they argued that GCD permitting processes unfairly limited their private property rights in groundwater.[69]

GROUNDWATER CONFLICTS IN TEXAS

The Ogallala Aquifer in Texas is but one of many Texas aquifers enmeshed in conflicts among diverse groundwater stakeholders. These more distant water users in urban water markets, which are much more populous than the rural areas where the water is withdrawn, compete with local landowners who seek to capture and use "their" groundwater. Implications include the right of future generations in the rural areas to live and work using the local aquifers, as did their parents or grandparents or even for newly established residents.

Private Property Rights in Groundwater

In the past, the crux of the issue was whether landowners must capture groundwater before they "own" it. The Court in the *Day* case indicated that landowners did not have to capture groundwater to own it[43] and that landowners do indeed own the water under their property. The Court observed that state recognition of landowner rights was more fully articulated in 2011 with the Legislature's amendment of Texas Water Code (TWC) Section 36.002.[69] This section says that the state does not claim to own groundwater and appears to recognize ownership of groundwater in place.[33] Specifically, TWC Section 36.002 provides that "the ownership and rights of the owners of the land and their lessees and assigns in groundwater are hereby recognized, and nothing in this code shall be construed as depriving or divesting the owners or their lessees and assigns of the ownership or rights, except as those rights may be limited or altered by rules promulgated by the district."[33] In reference to TWC Section 36.002, the court stated that, "Subsection (c) and (e) appear to be in some tension."[69] This unresolved tension, between the original 1995 legislation in TWC Section 36.002, stating that nothing in the code deprives or divests a landowner of their groundwater rights and ownership, and in TWC Section 36.0205 stating the legislative authorization of districts to set fees if they meet certain requirements[33] illustrates a complex balance between people's private property rights and use of groundwater in Texas.

Water Marketing, Environmental Protection, and Controversy

In central Texas some water users, such as the Wimberley Valley Watershed Association (WVWA), wanted assurance that future Trinity Aquifer levels and local spring flow will be sustained without overexploitation.[70] They petitioned against the reasonableness of the adopted DFCs in GMA 9.[70] Other parts of the state experience controversial groundwater decisions, where Clayton Williams in Pecos County and the Colorado River Municipal Water District (CRMWD), each proposed separate large-scale groundwater development and marketing despite the potential for increased resource depletion.[71] In 2011, Clayton Williams was not able to gain a new production permit from the Middle Pecos GCD to transport up to 42,332,062 gpd (47,418 acre-feet per year) for municipal and industrial uses.[72] In another nearby large production and transportation example, CRMWD was able to obtain funding from the TWDB to drill several wells in a relatively small but prolific local aquifer in Ward and Winkler counties to export water to cities like Midland-Odessa and provide groundwater when the Colorado River experiences extreme or exceptional droughts, such as occurred in 2011. There were no rules or permitting issues because there were no groundwater districts in those two counties.[18] A narrowly focused part of TWC Section 36.121 limited rulemaking powers of districts formed after 1991 and in counties with populations less than 14,000.[33] If Ward[73] and Winkler[74] counties formed new districts, they would fall into that category. Unless the code was changed, even within a district they could not prevent groundwater transport inside or outside of the district's boundaries if the water is to be used solely to supply an urban population greater than 100,000 and less than 121,000.[33]

Discussion

These Texas water-marketing examples illustrate what has become an ongoing groundwater narrative with counterpoints: groundwater stasis versus development; state sovereignty versus property rights, or even basic human rights. Water export plans have contributed to tension among private landowners, publicly supplied groundwater or profit-making corporations selling a life-sustaining necessity, often viewed as a 'God-given right.' The Mesa Water/Pickens water export transaction is an example of what have been called "outdated laws" controlling groundwater markets.[75] Texas' conflicts over quantifying, securing, financing, regulating, and ensuring groundwater have come to involve the courts, the Texas Legislature, water districts, state agencies, and the key players, the landowners.

POLICY PROBLEM

Within one year of the adoption of the DFCs, in 2009 and 2011, stakeholders in seven GMAs[76] identified fundamental problems, referring to two recurring arguments: data/models and rights. When petitioning against the reasonableness of adopted DFCs the petitioners either asserted that: a) the wrong data, models, or assumptions were considered or used leading to the wrong amounts of groundwater being available and/or b) private property rights and peoples preferences were not considered, leading to some current or future personal economic or environmental loss.[64; 77-83] Petitioners either sought to increase or decrease the adopted DFCs.

They claimed that the decision makers did not consider their preferences and/or that their private property investment or constitutional rights were violated through this decision process.[64; 77-83]

Will private property rights control groundwater extraction and export? No one can predict how the courts will respond to new cases about the so-called 'rule of capture' and managed available groundwater. As of 2012 in the *Day* case, Texas' Supreme Court has decided that in the Edwards Aquifer, private property rights trumped one GCDs historic-use permitting process.[43]

How much groundwater is available for future use? The way people choose to measure or to predict how much groundwater could be available in the future and how private property rights in groundwater are interpreted affects the answer to this question. In these petitions and some GMA public meetings, both the stakeholders and the decision makers criticized the GCDs or state-collected historical pumping estimates, state-funded groundwater flow models (complicated flow equations within the models used for quantifying an amount of available groundwater), and the lack of recent or extensive data. It is reasonable to expect that any DFCs developed without public participation could suffer similar fates of petition to the TCEQ/TWDB or legal suits arguing a taking or failure to follow the state procedures.

The DFC process currently does not have a plan to evaluate the effect of the chosen DFCs or the effectiveness of a GCDs' governance over groundwater and permitting implementation. Ostrom argued that communities that cooperate in the control and use of a common resource self-manage that resource more effectively without state regulation or privatization by including all in decisions, limiting outside users, and self-regulating use.[84] Arguably a GCD as community-based governance could benefit from critical analysis as a component of the DFC process, called Institutional Analysis and Development (IAD).[84]

Research Goals

This research seeks to illuminate the Texas struggle about groundwater through the lens of: (a) current versus historical groundwater policy practices; (b) landowners versus local control; (c) local water extraction versus export; and (d) current financial considerations versus future generations. This dissertation accepts the possibility that the original guidelines articulated in TWC Section 36.108[33] may be challenged as a reasonable DFC decision. It accepts the possibility that the updated 2011 code[34] does not include some guidance that could be critical components for a reasonable DFC. As a result, until the code is revised, groundwater decisions are likely to remain divisive. By using a decision support system (DSS), comprised of social, scientific, and financial aspects of groundwater extraction, a GMA can invest in a comprehensive and defensible process to decide on reasonable DFC of an aquifer.

The premise of this dissertation is that Texans can manage their aquifers through existing institutions and processes. A DSS could help improve this process by including five components:

- descriptions and definitions of the critical data and decision components;
- financial consequences in dollars of DFCs through a contingent valuation;
- advice from stakeholder meetings, focus groups, surveys, and filmed narratives;
- easy-to-use groundwater models for non-expert use using variable climate; and,
- DFC system scenario building.

The 2005 legislative guidelines established eight administrative requirements to anchor the new legislation for GCDs deciding groundwater availability within GMAs[33] (see Table 1.4). These guidelines provide guidance to the GCDs about the decision timeframe, minimum required meeting efforts, voting, and how the GCDs and RWPGs must use the groundwater volumes derived from the DFC process. The GCDs were not directed to develop reasonable conditions.

DFCs had to be physically possible and aquifer conditions could be open to a challenge of reasonableness through a two separate petition processes.[33]

Table 1.4: Original Guidelines for Adopting DFCs

GCDs must adopt DFCs of aquifers by September 1, 2010, and at least every subsequent five years
Only the GCD Board presiding officer or their assigns may vote as a GMA group
The GMA group must meet at least once a year in a public meeting properly noticed by all GCDs
A GMAs decision makers must consider groundwater availability models and other data or information, including the uses or conditions of an aquifer to establish desired future conditions
The GMA statement of future conditions must be supported by at least 2/3rd votes of those present with at least 2/3rd existing member districts attending
Regional water planning groups must use the managed available groundwater (MAG) values in their planning process
The GCD must permit, if possible, the withdrawal of up to the total volume of groundwater that equals the MAG
Legally defined interests may petition the TWDB or TCEQ regarding the reasonableness of DFCs.

Source: Rima Petrossian, 2011

However, "reasonableness" parameters could be inferred indirectly through the statutory direction to TWDB to analyze reasonableness considering several outlined factors (see Table 1.5). For example, the petition analysis could include vague concepts of "reasonable and prudent" development to broader policy categories such as following "legislative directives." Analysis of environmental and socio-economic factors while considering private property right impacts offered high-level direction without specifying analytical methods.

In 2011, Senate Bill 660 updated TWC Section 36.108 and added a new list of nine detailed considerations (see column 2, Table 1.2) the districts must examine when deliberating desired future conditions.[85] When compared to the TWDB analysis (see column 1, table 1.2), these considerations provide some additional direction and specifications. After September 1, 2011, GMAs adopting new DFCs must provide this report with these considerations to the TWDB and to each GCD in the GMA.[34] The 2011 GMA report requirements appear remarkably similar when compared to the 2005 petition analysis requirements with expanded and detailed parameters for GCDs to consider when establishing DFCs.[34; 33] In addition, in the report GMAs must specify additional administrative components of their decision including identifying each DFC as well as providing the policy and technical justifications for each DFC.[34]

Table 1.5: TWC Section 36.108 2005 GCD Guidance Compared to the 2011 GCD Guidance

TWDB Petition Analysis (2005)	GMA Report Requirements (2011)
"the adopted desired future conditions are physically possible and the consideration given groundwater use;	" aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another;
the state's policy and legislative directives;	the water supply needs and water management strategies included in the state water plan;
(not addressed)	hydrological conditions, including for each aquifer in the management area the total estimated recoverable storage as provided by the executive administrator, and the average annual recharge, inflows, and discharge;
the environmental impacts including, but not limited to, impacts to spring flow or other interaction between groundwater and surface water;	other environmental impacts on spring flow and other interactions between groundwater and surface water;
(not addressed)	the impact on subsidence;
the socio-economic impacts reasonably expected to occur;	socioeconomic impacts reasonably expected to occur;
the impact on private property rights;	the impacts on the interests and rights in private property, including ownership and the rights of management area landowners and their lessees and assigns in groundwater as recognized under Section 36.002;
the reasonable and prudent development of the state's groundwater resources; and,	The feasibility of achieving the desired future conditions; and
any other relevant information to the specific desired future condition."	Any other information relevant to the specific desired future conditions."

Source: Rima Petrossian, 2011

The report must document the factors the GCDs considered including a discussion of how the adopted DFCs impact each factor. The report must list other DFC options considered and reasons why those options were not adopted. The report must discuss reasons why recommendations made by advisory committees or relevant public comments received by the GCDs were or were not incorporated into the DFC, even though no specific public participation guidelines are recommended or required for public input.[34]

Research Methods

This dissertation develops methods to use stakeholders' expressed and implicit preferences to improve aquifer DFCs. It extends previous GMA 9 study area research[90] by collecting additional evidence to test a hypothesis that deciding on an aquifer's DFC requires fully engaged stakeholder participation. Stakeholder preferences and groundwater data can be used to develop a decision support system of revealed groundwater valuation and results in information leading to better choices for aquifer DFCs. This research seeks to answer four questions designed to reveal people's preferences about DFCs to help formulate these critical decision elements:

- What do stakeholders believe are acceptable desired future conditions for the Trinity Aquifer?
- What do stakeholders believe are relevant data and science for making the DFC decision; what do decision makers think about the data available?
- According to the decision makers and stakeholders, who are the right people to decide about the future of groundwater extraction and groundwater availability?
- What are the financial and environmental implications, including groundwater value and cost, associated with groundwater extraction over the next 50 years?

Table 1.6 lists research methods that will be used in this dissertation. Surveys and focus groups conducted as part of this dissertation primarily revealed people's groundwater management preferences, landowners' DFCs, contingent groundwater valuation through "willingness to pay" (WTP) and "willingness to accept payment" (WTAP) analysis, a DFC systems diagram, and disconnects between landowners and decision makers. The prism for this analysis will be Texas' Hill Country, called GMA 9, described in detail in Chapter 5.

Table 1.6 Research Instruments, Methods, Related Chapters, and System Elements.

Instrument	Data Collected	Chapters	System Elements
Four Surveys	• 767 landowners answered 11 survey questions • 79 decision makers answered 45 survey questions • 64 stakeholders answered 11 survey questions • 10 decision makers answered 14 survey questions	4, 5, 6	Stakeholder's and decision maker's values, attitudes, and preferences about groundwater
15 Focus groups	64 GMA 9 stakeholders in 13 focus groups answered three questions; 6 GMA 9 decision makers answered one question	4, 5, 6	Stakeholders attitudes toward groundwater; decision makers attitudes toward groundwater management
Three Models	Contingent Valuation (CV) of Groundwater; Interactive Qualitative Analysis (IQA); Decision Support System	3, 5, 7	Stakeholders CVs expressed in dollars; DFC system elements; decision criteria.

Source: Rima Petrossian, 2012

In the Hill Country a majority of landowners surveyed for this dissertation expressed a simple preference to (a) retain their aquifer's groundwater for themselves and (b) preserve spring flow, rather than (c) leasing or selling their rights. In all counties surveyed, over 73 percent of stakeholders supported either a future aquifer condition of "no new users" to be issued permits or reducing water withdrawals for existing permitted uses to maintain water elevations, or less than 5 feet of drawdown. These preferences can be compared to the GCD decision makers adopting DFCs of an average of 30 feet of drawdown throughout GMA 9.[55] Based on the two decision maker surveys a majority of all GCD decision makers believe that the wrong entity, the GMA, was deciding on the DFCs.

This dissertation is concerned with the future of groundwater and groundwater management in Texas. Managing groundwater is a matter of personal choice of any person who pumps the groundwater under her/his land. This choice also is a matter of state policy, as Texas has created rules for managing groundwater resources. These rules may sometimes appear to be contradictory. For example, quantifying how much groundwater is available or groundwater availability contracted then expanded from being a state-level scientific planning effort[86] to individual GCD controlled efforts to the current regional participatory process[29] despite landowners controlling small-scale groundwater withdrawals. Prior to 1997, TWDB calculated groundwater availability and produced technical groundwater studies. For example, *Report 238 Groundwater Availability in Texas*[86] created from records and processes recorded in "the TWDB Black Book"[87] and proposed pumping volumes that could be sustained over time. From 1997 through 2005, GCDs without common practices and guidelines estimated *total usable amount of groundwater* for shared aquifers. These GCD estimates, presented in a management plan, or other estimates proposed in regional[88] and state water plans.[89] This process changed in 2005 as the GMAs were charged with identifying aquifer preferences and adopting a desired future aquifer condition, a DFC.

This dissertation illustrates the complexity of groundwater availability determination in its current context in Texas, and suggests a solution for successful governance through incorporating both the individual and collective preferences about groundwater use, groundwater availability, and groundwater management based on current conditions, science, and money. It reports on how Texas-sized stakes and Texas-sized personalities have influenced historical events, political decisions, financial investment, scientific principles, local and state governance, people's individual beliefs, pursuits, and actions.

This dissertation assesses methods that can address uncertainties and conflicts that can arise from insufficient stakeholder participation. If groundwater users are not allowed to provide input in the GCD's decision, distrust could lead to petitions and lawsuits against GMA decisions of Texas-aquifer DFCs. The TCEQ petition process can lead to direct resolution through enforcement actions by the agency if a particular district's rules are found to not adequately address desired future conditions.[34] TWDB petitions can result in more complex results, as a petitioner publicly airs discontent. In the petition process, the TWDB (Board) can suggest or recommend changes to the GCDs and the GMA must revise a DFC in response to Board ruling.[34] The GMA is required to revise the DFC and hold a subsequent public hearing to see if the public finds the DFCs as reasonable or objects to a change. A GMA is allowed to consider such public advice and not make changes to the DFC.[34] If the Board agrees with the petitioner that a DFC is unreasonable, and if the Board makes suggestions for the GMA to change a DFC, the GMA's only expectation is to convene a public hearing, consider public input and then decide what the GMA wishes to do.[34] A landowners may also seek a "takings claim" if she/he wants to test the court's interpretation of GCD limits of powers.[8] This chapter describes these diverse parallel paths in Texas' current GMA aquifer planning process.

Research Background

This dissertation seeks to identify what stakeholders prefer for their future groundwater conditions rather than developing controls or administrative processes. The rest of this chapter is devoted to framing the history of groundwater management in Texas including the administrative, judicial, and legislative approaches through GCDs, GMAs, RWPGs, and state agencies.

HISTORY OF GROUNDWATER MANAGEMENT

In 1949, Texas Civil Statute Title 128 authorized districts to develop rules and regulations to conserve, preserve, protect, and recharge groundwater, as well as preventing waste.[9] From 1949 continuing through to the 1960's, Texas Civil Statute Title 128 Article 7880—3c articulated rules about managing groundwater which defined underground water as being water appropriate for agricultural, domestic, gardening, and livestock purposes.[9] It did not include defined underground streams or river underflow in the early versions.[9] In order to ensure the separation of surface and groundwater regulation this statute separated surface water priorities and regulations, already in place for almost 40 years, from groundwater production provisions.[9] For the state to recognize an aquifer, any well in a defined subsurface area had to be capable of producing at least 150,000 gpd[9] The state authorized districts to issue permits for drilling, set spacing requirements, develop rules and regulations *to minimize*, if possible, drawdown or reduction in artesian pressure.[9] Statute set a permit exemption for a well capable of producing no more than 100,000 gpd.[9] Even the initial statute described the district's responsibility to develop comprehensive management plans to support efficient groundwater use, and encouraged research to establish extraction limitations but without binding regulation.[9]

In 1971, the Texas Legislature repealed Article 7880—3c, changing the name of the code to TWC Chapter 52, but did not change it significantly.[91] In 1985, the Legislature updated TWC

Chapter 52 addressing the groundwater part by changing underground water reservoirs to management areas, establishing the TWC critical area process, and requiring new districts be coterminous within a management area but allowing a management area to be delineated along political boundaries.[21] In 1989, Senate Bill (SB) 1212 required groundwater conservation districts to develop a management plan.[21] In 1995 groundwater statutes the Legislature split the law into TWC Chapter 16 (outlining regional water planning) and TWC Chapter 36 that articulated the rules governing groundwater district organization and management.[92] Chapter 36 provided new guidance for exempt wells, defined as capable of producing no more than 25,000 gpd.[93] Districts were to submit these plans to the Texas Commission on Environmental Quality (TCEQ), using the same guidance for developing the plan as the earlier Article 7880.[93] The Texas Legislature chose not to require TCEQ review or oversight.[94] Not until 1997 did a GCD have to submit its management plans to the TWDB and be consist with the regional plans on groundwater availability.[21]

In 1997, the Legislature provided specific administrative process guidelines for TWDB to assist GCDs through SB 1.[27] The guidelines directed TWDB to provide water planning data and technical help for groundwater management plans and required the agency to certify plans through an administrative review.[27] One requirement for districts was to compute groundwater availability, or *useable amount of groundwater*, defined as the "…quantity of groundwater of acceptable quality that is contained within the portion of an aquifer covered by a district's management plan and which is economically and legally retrievable for beneficial use."[95] TWC Chapter 36 specified that the groundwater availability adopted by the GCD could not be less than the amount identified through the regional water planning process but offered no specific methodology or requirements for calculating groundwater availability.[94] This definition allowed the planning groups a higher level of control over groundwater availability in the GCD. The guidelines also identified five possible management goals for districts to consider, when applicable to their district,[94] although these goals existed as suggestions in the original 1949 legislation.[7]

GCDs could choose to include any, all, or none of these five goals as being applicable to them for their newly required management plans.[33] The 75th Texas Legislature authorized and directed the TWDB to review the management plans for administrative completeness and to certify plans, if complete.[92] The Texas Legislature modified and added to Chapter 36 each ensuing legislative session through 2011.[92] After 2005 districts were to consider twelve goals. One of those goals was to address DFC quantitatively; in 2011 the quantitative test was removed. [34] TWDB subsequently reviewed the plans for administrative completeness and would approve those plans if administratively complete, including the newly adopted DFC goal and managed available groundwater (now modeled available groundwater) to replace to former "total useable amount of groundwater" reported in the plan.[33]

Throughout these changes, TWC Chapter 36 carried forward one minor vestige articulating the 75th Texas Legislature's initial efforts at requiring joint planning: a request for any GCD in a *priority groundwater management area* to review other GCD plans. Retaining this minor element foreshadowed the major legislative changes in 2005.

There is a dissonance—the specter of state control—between the language of TWC Chapter 36 governing groundwater conservation districts and what some people may believe it means. Chapter 36 allows the TCEQ and TWDB to create jointly a *priority groundwater management area* (PGMA); such a PGMA is unrelated to a GMA. The TCEQ could "form" a GCD in an area expected to experience long-term water declines. Any GCD the state "formed" would have to be locally supported, as people within the proposed boundaries would have to vote for the district to exist.[21] Any GCD board would be governed by local directors, usually appointed through a commissioner court or elected in a local jurisdiction. For example, in 1994-5 a locally-led petition effort to allow the TCEQ to form a GCD in Comal County failed, even though Comal County is located in the Hill Country PGMA.[21] The other type of so-called 'state control' is the option to dissolve a GCD that is not performing[49] which returns the area to so-called 'rule of capture' with no local regulatory oversight.

SUMMARY

This dissertation contributes evidence supporting the argument that local control of common pool resources, like groundwater is in Texas, are best managed through fully engaged stakeholder cooperation, trust, and participation in managing water resources, known as an IAD framework.[84] It also provides evidence of the nature of the people's understanding and interaction with the groundwater ecosystem through surveys and stakeholder focus groups. This research quantifies the value of groundwater in the Texas Trinity Aquifer through a contingent valuation survey method, an approach that can be useful for helping all involved know the potential value to stakeholders for developing or not developing groundwater. Another contribution of this research is providing a framework to understanding the desired future condition process, through using Interactive Qualitative Analysis (IQA) [96] to develop a system representing stakeholder's and decision maker beliefs in what the system looks like and how it works. This DFC system not only can help users and others understand how DFCs are developed but also help other researchers test questions about the flow of the decision making system and seek solutions to complex groundwater extraction issues such as competing interests, private property rights, and 'takings.'

Chapter 2 provides details about the historical path groundwater use, private property rights, and groundwater policy development followed in Texas. The historical legal cases relevant to groundwater include petitions against DFCs to provide a path illustrating how Texas courts viewed and decided on groundwater rights.

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Chapter 2: Historical Perspective on Water Resources: Focus on Climate and Groundwater

This chapter describes the administrative, legislative, and judicial approaches to groundwater management and rights. Texas water law begins in Spain and its riparian practices, then the prior appropriation principle of 'first in time-first in right'[1; 2] (see Figure 2.1) and later Mexico.[3; 4] Until January 20, 1840, Spanish and Mexican law prevailed in the area known now as Texas.[1; 3] The Texas Republic's Fourth Congress adopted English common law on January 20, 1840, which preserved Spanish and Mexican mining laws but not water law.[5; 4] The Republic of Texas (1836-1845) and the State of Texas after 1845, granted rights related to land ownership which prevailed through March 19, 1889.[6] In 1858 the State of Texas' Seventh Legislature specified areas of groundwater development through drilling wells funded by the state, legislation which made the developed artesian water free to all.[7] This nascent legislation provided sophisticated well spacing guidance as well. Beginning in 1889, Texas began to adopt a system of prior appropriation but did not repeal the common-law riparian system.[5] In 1889 and 1895 Texas legislators sought new and better ways to assist in settling and developing Texas using surface water rights as they responded to agriculturally constraining drought.[6] These approaches declared un-appropriated waters (first in the arid parts of the state, then the entire state in the 1895 Act) to be property of the state, but provided for systems of filing to register a right to use the water.[6]

In 1913, the 33rd Texas Legislature established the Texas Board of Water Engineers, formed to approve plans for water entities such as irrigation and water supply districts.[8] When Texas adopted the constitution in 1917, Article XVI, section 59(a) stated then and similarly states now that, "… preserving and conserving natural resources are…public rights and duties."[9]

It also stated, "…This section introduced the term 'conservation' as a synonym for 'use' rather than reserving the resource for future use or using much less of the resource. Some have indicated Legislative responsibility for water issues and less judicial guidance stems from this directive.[9] Some also indicate that the constitutional amendment allowed for the formation of groundwater conservation districts prior to the 1949 legislation but that no one took advantage of that authorization.[10]

GROUNDWATER USE

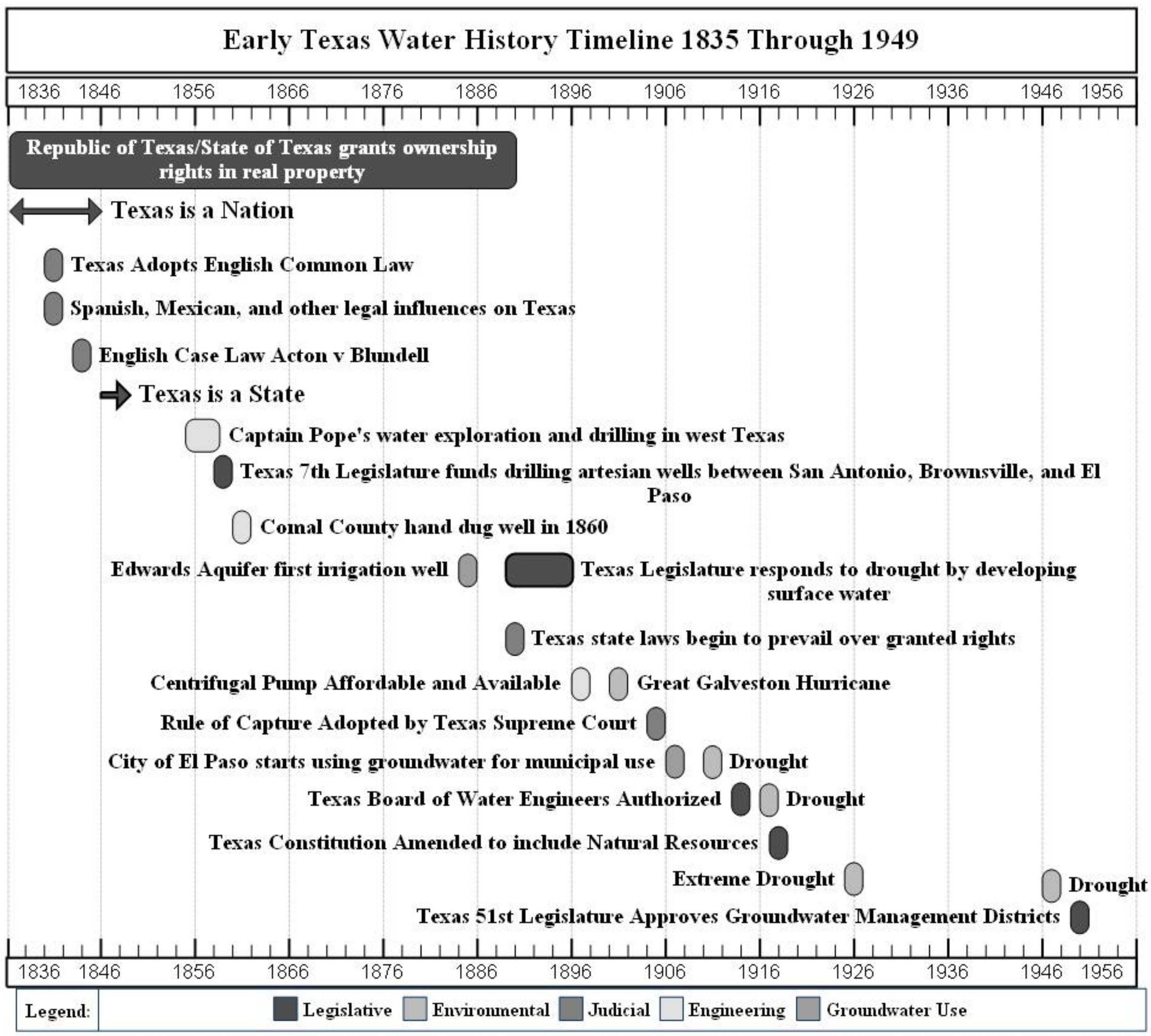
Groundwater use in Texas began developing slowly along a different path than surface water during the same time. For example, from 1855 through 1858 U.S. Army Officer Captain John Pope searched west Texas for sources of artesian water, groundwater under pressure that come to the surface naturally without pumping.[11] His group drilled a well near the Pecos River along the New Mexico-Texas border, named Pope's Well, which became a source of water for part of the Goodnight-Loving Cattle Trail.[11] Pope's associate, water well entrepreneur and legislator Forbes Britton introduced a legislative bill in 1858 authorizing artesian well drilling along various southern and western routes, including between the Nueces River near San Antonio and along the Rio Grande River from Brownsville to El Paso[12]. Texas 7th Legislature addressed groundwater for the first time by passing Britton's bill as Chapter 74, which authorized funding to pay for developing groundwater for public use, on both private and public property. Chapter 74 specified well-drilling details and restrictions related to well-spacing and water use for those particular wells.

A well north of San Antonio, west of Bulverde, Comal County, has been dated to 1860 and measured for water levels in the mid-20th century.[13] Digging or drilling efforts in the 1880's and 1890's led to dozens of wells in the area.[13] In 1884 groundwater began to enter the water rights picture with the first irrigation well in the Edwards Aquifer.[14] After 1896, groundwater pumping became more feasible,[1] primarily due to the quickly spreading use of centrifugal pumps, that could extract groundwater in large amounts at entry prices low enough for many users.[15]

GROUNDWATER DATA

Figure 2.1 shows a water history timeline illustrating early Texas historical water-related events from 1835 to 1949.

Figure 2.1 Early Texas Water History



Source: Rima Petrossian, May 13, 2012.

Texas historical groundwater-related events include that the City of El Paso, Texas started keeping municipal groundwater pumping records in 1903.[16] Today El Paso groundwater modelers rely on the 1903 water level measurements as the pre-development conditions for the Hueco-Bolson Aquifer.[17] In 1906, the United States Geological Survey (USGS) published a survey of the eastern Panhandle and reported on the geology and groundwater in 12 counties.[18] This report indicated it was unlikely this area could be irrigated extensively due to the low available water supply through windmills tapping the shallow groundwater.[18] In 1907, the USGS published a survey of the Gulf Coast groundwater in 84 counties, reporting hundreds of artesian wells sourced from about an average of 600 feet deep.[19] This report included well depth, depth to water, and production rates when available [19]. A 1939 Houston-area report discusses dropping water elevations in some wells due to increased groundwater use from population increases and economic development and the uncertainties in quantifying safe yield.[20]

Texas Water Planning Efforts

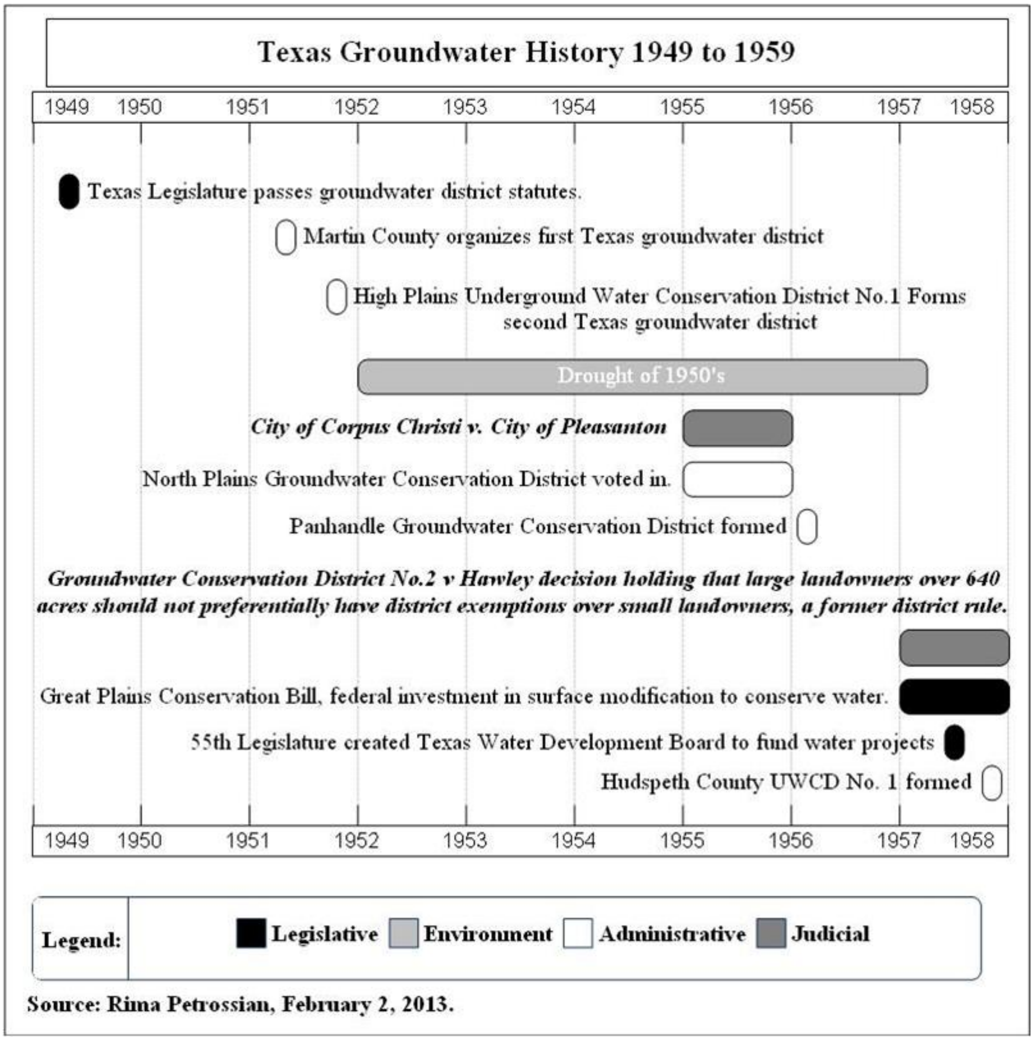
Texas administrative water planning began with the establishment of the Board of Water Engineers (BWE) in 1913.[21] The 33rd Texas Legislature authorized the BWE to regulate irrigation and water supply districts and decide how surface water would be managed.[21] Included in these duties were permitting new surface water storage and diversions rights of the state's waters, planning for surface water storage and floodwater, and oversight for districts issuance of bonds.[21] In 1931, the 42nd Texas Legislature passed Senate Bill 93, the Wagstaff Act, to encourage development of surface water supplies and prioritized uses for municipal use and domestic drinking water.[14]

As early as 1938, when three-quarters of the population relied on groundwater supplies, a Texas Planning Board Sub-Committee on Ground Water, part of the BWE, concluded that the state needed to control pumping to prevent water tables from lowering in some areas where withdrawals exceeded recharge.[22] The 1943 Texas Almanac[23] reported that crop irrigation and increasing population was leading to overuse of groundwater. In 1949 (see Figure 2.2) the 51st Texas Legislature authorized the regulation of groundwater through underground water conservation districts for the purpose of managing groundwater on a local level.[24] In 1957, after extreme flooding ended the drought of the 1950s, the 55th Texas Legislature passed Senate Bill 1 creating the Texas Water Resources Planning Division (TWRPD) of the Board of Water Engineers to enable the state to develop water resources planning expertise.[25] Senate Bill 1 also authorized the BWE to issue bonds with voter approval for water infrastructure projects, and give state and federal grants to plan for future water.[26] In 1957, the 55th Texas Legislature passed House Bill 161, creating the TWDB to forecast water supply needs and fund them through issuing state bonds.[27] Figure 2.2 shows a water history timeline illustrating water planning-related events from 1949 to 1959.

TEXAS HIGH PLAINS

In Texas' Ogallala Aquifer, a number of individuals have influenced the groundwater management path. In 1959, High Plains farmer Marvin Shurbet (later to be the Vice Chair and Chair of the TWDB) took an income tax deduction resulting in a tax savings of $377.91 for conservation improvements[28] (see Figure 2.3). Shurbet took the deduction for depletion of water through irrigation withdrawal under the natural deposits section of the Internal Revenue Service (IRS) code, which referred to oil, gas, timber, and minerals, which allows for land depreciation based on loss of land value from mining withdrawals; the IRS did not consent to his deduction.[28] In 1962, the HPUWCD No.1 funded and developed data to support a case against the federal government, based on Shurbert's denied water deduction.[29]

Figure 2.2 Water History Timeline from 1949 to 1959



In 1965, a favorable settlement of Shurbert's case against the U.S. Treasury authorized a groundwater deduction[28] to allow compensation for "the capital exhausted in the taxpayer's business".[28] Texas limited the deductions (cost-depletion allowances) for HPUWCD No.1 irrigators based on aquifer elevation declines the landowners were responsible for recording and reporting.[30] This gave irrigators benefits for depleting their own resource that was not applicable in any other Texas aquifer. Several years later, under Shurbet as Vice Chairman of the TWDB, the 1968 Texas State Water Plan stated that the then-current supplies were "grossly inadequate" for the future of Texas agribusiness and called for drastic measures to assure continued supplies and agricultural viability for the High Plains, including importing surface water from as far away as the Mississippi River.[31] Researchers in 1978 indicated that landowners who realize that groundwater under their property value is financially valuable would be more likely to conserve to preserve the value of their property.[32] Consequences could include that larger groundwater declines allow more allowance money and this could encourage increased water use resulting in more depletion. Although depletion was thought unlikely, no data supported either sustainability or depletion.[32] These deductions were available in 2012 to landowners who pay a nominal fee to HPUWD No.1, South Plains Underground Water Conservation District and in other states for water decline data for their property.[29]

FIRST STATEWIDE WATER PLANNING EFFORTS

In 1961 the BWE unveiled the first statewide twenty-year plan addressing both groundwater and surface water.[14] BWE's plan for meeting Texas' water needs twenty years into the future relied on surface water, the largest resource for most parts of the state.[14] For groundwater, TWRPD studies had already identified eight major aquifers.[14] The Texas Legislature reorganized the BWE into the Texas Water Commission (TWC) in 1962 for regulating surface water and reorganized again in 1965 to the Texas Water Rights Commission (TWRC).[21] Figure 2.3 shows a water history timeline illustrating water planning-related events from 1959 to 1985.

TWDB HYDROGEOLOGICAL MODELING

Early planning efforts quantifying groundwater availability used simple hydrogeological concepts and computational methods to quantify groundwater resources.[33] By 1974, as computational power and knowledge increased, TWDB staff modified a computer program from T.A. Prickett and C.G. Lunquist.[34] The program, called GWSIM (see Figure 2.2), originally simulated the Edwards (Balcones Fault Zone) Aquifer but could be modified to simulate recharge and withdrawals from any aquifer.[35] The purpose was to assist in calculating how much groundwater would be available for state water planning by predicting water levels using pumping rates, recharge inputs, and spring flows.

This model was a predecessor of the modern groundwater availability model GAM—based on computer codes developed by USGS staff in 1981—that TWDB developed after 2000.[36] These new GAM models assisted RWPGs in quantifying groundwater for planning and eventually aided GCDs for estimating the volume of groundwater that could be produced, called managed available groundwater.[37]

State and Regional Water Planning: Surface Water and Groundwater

The TWDB issued state water plans in 1961 followed by 1968, 1984, 1990, and 1992, and then settled into a five-year periodicity mandated by statute with the RWPGs issuing 1997, 2002, 2007, and 2012 plans[38] (see Table 2.1). A common factor throughout the 1961 to 2012 planning efforts is the need to plan for a steadily increasing population. The initial plans emphasized orderly and economic development, importing water from outside Texas, and comprehensive planning to inspire public involvement after loss of voter confidence in planning.

The 1990 plan sought to protect environmental uses and values of water. It also set funding priorities based on project needs and encouraged grassroots plans to meet all water needs, even during drought of record.[39] After an intense drought, the 1997 plan introduced participatory consensus-based planning and moved away from a hands-off approach to groundwater planning[25] (see Figure 2.4). The 1996 drought caused over 300 communities to experience water shortages[40] which led to passage of SB 1 authorizing a statewide regional planning process.[41] Sixteen regions based on river basin, county, GCD, and other considerations cover the entire state.[42]

Table 2.1 Past State Water Plan Key Issues and Proposed Solutions Summary

Year: Key Issues	**Proposed Solutions**
1961: Adequate water, unequal distribution, inadequate facilities to meet needs; can sustain agriculture but need planning; groundwater depletion; floods.	45 reservoirs added, enlarging two existing reservoirs, financing flood control; majority of communities use groundwater, increased groundwater for municipalities.
1968: Studies showed not enough water inside the state to meet demands by 1985; New Mexico deficiencies included in plan.	Need to import large quantities from Mississippi River; tension of federal spending vs. state expenditures for studies.
1984: Some areas with long-term supply problems; increase attention to floods; water quality; strain on local entities; input from 13 meetings, hearings, interviews.	Plan hiatus after 1976 voters failed to approve water development; draft 1977 plan; in 1981, voter's again failed to approve water development; plan delayed.
1990: Financing local entities having too much to do and too much financial burden was a problem.	Input from 40 meetings, interviews, two draft plans, need more flood control; review state water plan biannually.
1992: Response to TWDB 1990 state water plan recommendation to review plan biannually due to 1990 census update differed substantially from 1989 projections.	Introduction of conservation, economically distressed areas, regional groundwater management; a state water bank; updates for major water projects; local, state, and federal policy recommendations
1997: 1996 drought; consider non-traditional management approaches; balance human/environmental needs for stream flow and Gulf inflows	Plan recommended prioritizing state funding based on needs identified in state water plan; 11 key water management tools described, including water marketing.
2002: Concern about funding for regional water planning, funding for implementation, and provide clarification on unique stream segments.	47 policy recommendations for rural water issues, groundwater, surface water, conservation, innovative strategies, environmental, financing, and data.
2007: $30.7 B needed to implement strategies; need to address problems with getting the water resources from rural to urban; concern about limits on voluntary interbasin surface water transfers.	Recommended 14 new major reservoirs and 2 minor reservoirs; designated 19 unique reservoir sites and 15 unique stream segments; balance human/instream flow needs.
2012: Not enough supplies during drought-of-record; less surface water and groundwater supplies over 50 years.	562 management strategies for meeting needs during drought resulting in 9 million acre-feet/year more by 2060.

Source: Rima Petrossian, 2012, http://www.twdb.state.tx.us/publications/state_water_plan/

Figure 2.3: Water History Timeline from 1959 to 1985

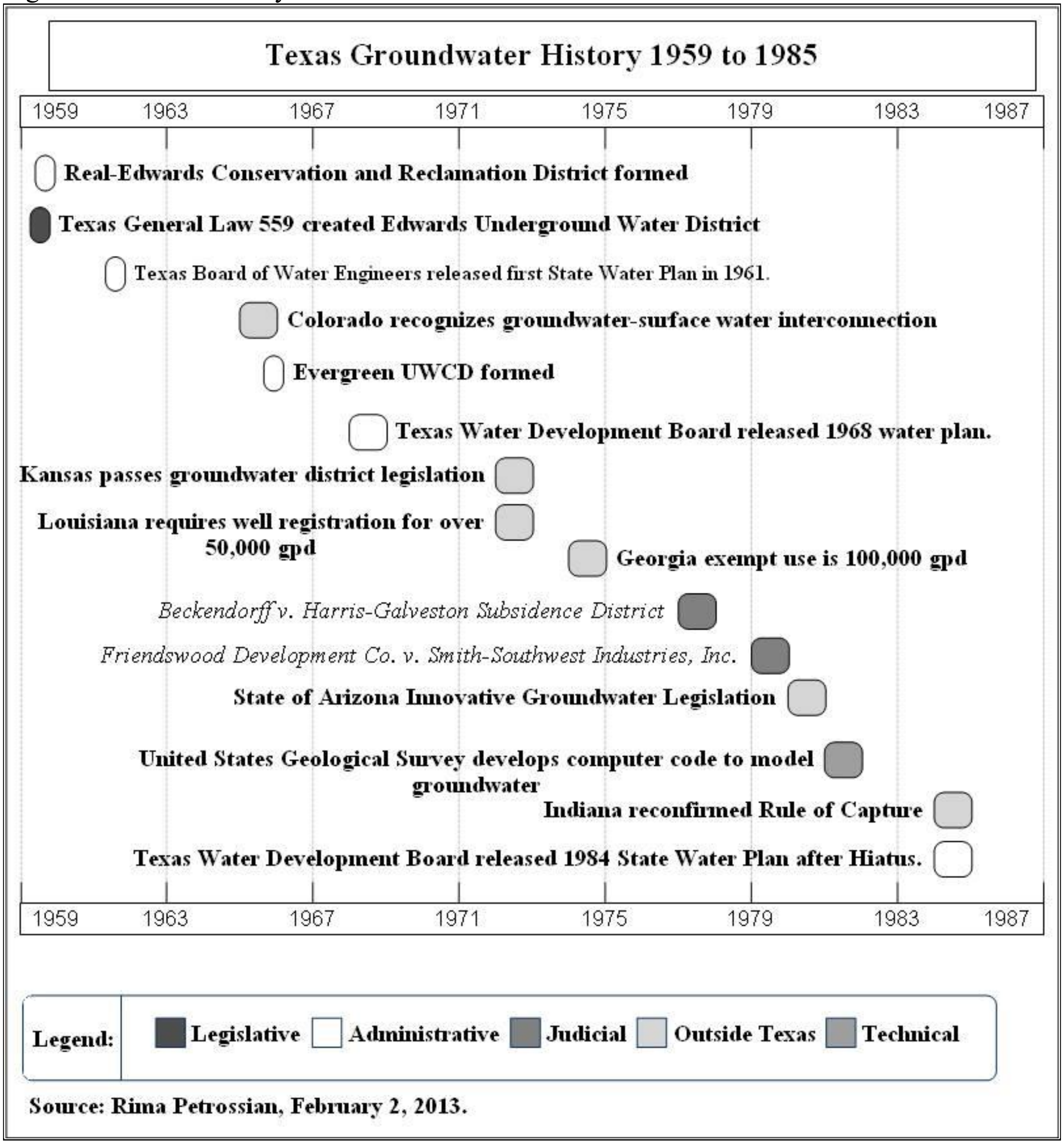
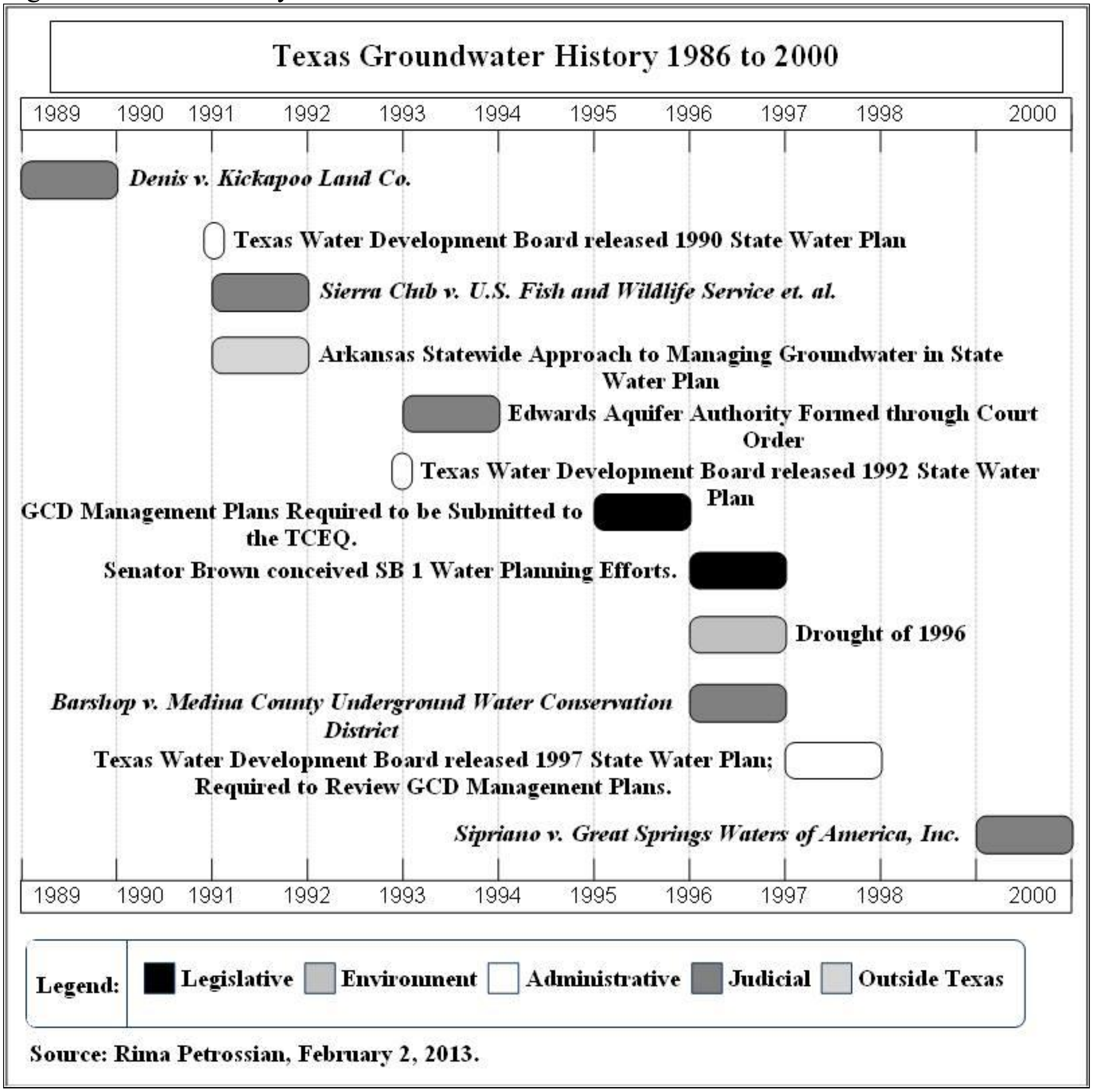


Figure 2.4 Water History Timeline from 1986 to 2000



The TWDB identified original planning groups members from 11 interests, including county, municipal, industrial, agricultural, environmental, water districts, small business, electric generating utility, river authority, water utilities, and the general public to develop regional water plans to roll up into a state water plan.[42] Another requirement had GCDs develop management plans and goals for their districts for the TWDB to administratively review and approve.[41]

REGIONAL WATER PLANNING EFFORTS

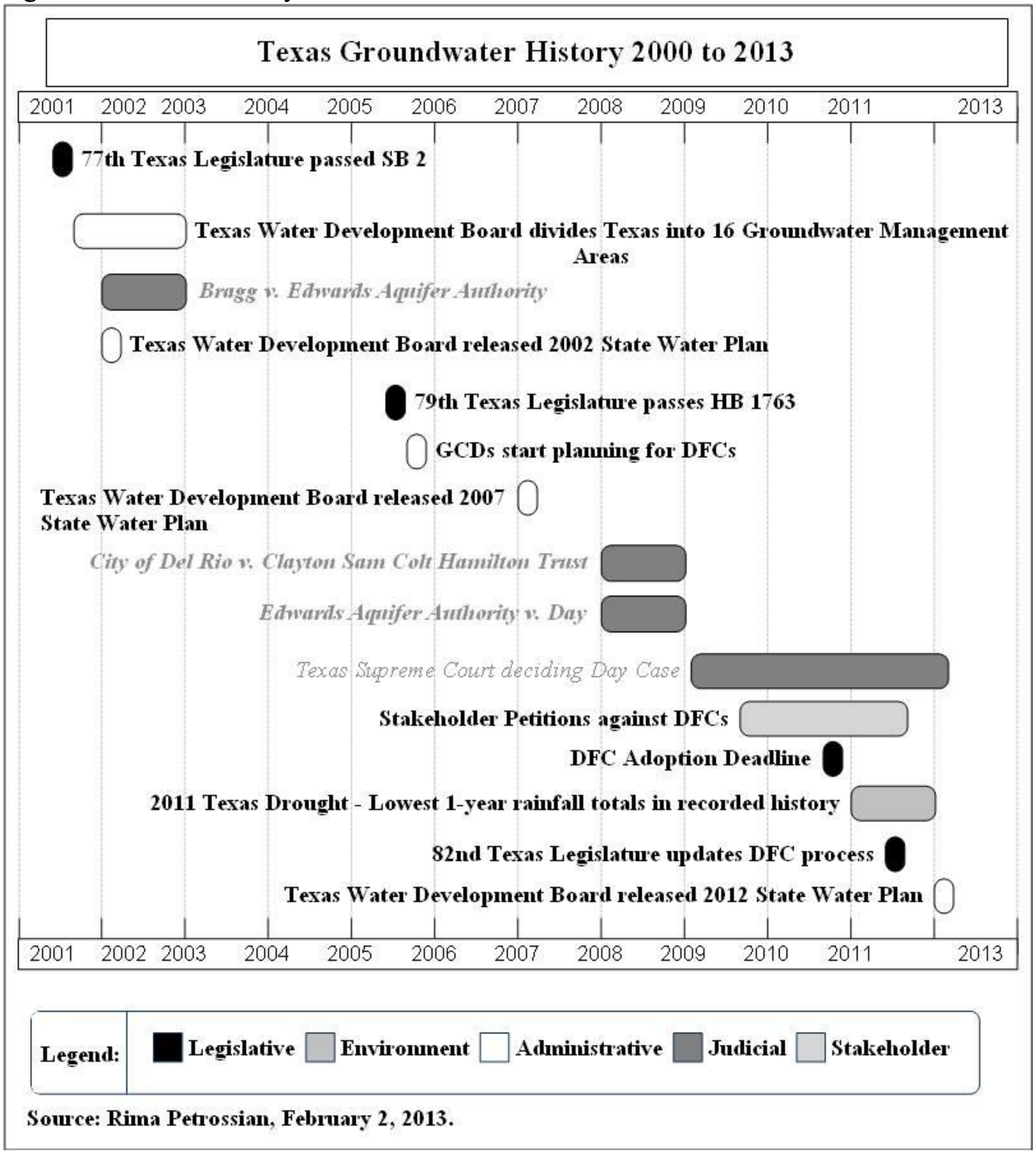
Regional water planning provides a blueprint for how water resources (both surface water and groundwater) can potentially be conserved, developed, and allocated in the future over 50 years, similar to developing a balance sheet of water resources, needs, and strategies.[43] It may identify new water resources like surface water reservoirs, aquifer storage and recovery (ASR), water reuse, desalination, conservation, and so forth.[44] This non-regulatory planning process ensures that regulatory controls on water transfers are not violated in the planning efforts.[43] Figure 2.5 shows judicial decisions and emergence of the regional and groundwater management area delineation.

EMERGENCE OF REGIONAL GROUNDWATER PLANNING PROCESS

In 2002, the key State Water Plan groundwater policy recommendation to the Legislature was to develop a plan for groundwater extraction through the newly identified GMAs.[42] Not all State Water Plan recommendations (see Table 2.1) are implemented. However, in 2005, the 79th Texas Legislature passed House Bill 1763, to establish an approach to quantifying groundwater in the ensuing 50 years by asking groundwater decision makers: 'in what condition do you want your aquifer?'[45]

Prior to 2005, the GCDs did not use State Water Plan estimates to permit because they had developed their own estimates for their management plan.[41] Planning groups consulted the GCD management plans, but when they developed water management strategies there was no direct tie between whether or not there was enough water available and whether or not the GCD would actually issue a permit for water development. The 1997 requirements directed GCDs to incorporate "total useable amount of groundwater" into their plans.[41] However, the TWDB had no authority to require a GCD to develop rules that correlated groundwater availability with permitting or use.[46]

Figure 2.5 Water History Timeline from 2000 to 2013



In 2005, the 79th Texas Legislature chose a fundamentally different approach to continue planning for Texas' groundwater resources through establishing the GMA planning group.[37] There are key organizational and functional differences between a GMA and the previously established regional water planning area, even though they both encompass groundwater resource planning.[37] A regional planning entity does not contain any inherent regulatory mandates. Plans produced under GCDs (comprising the GMA) ultimately will regulate groundwater withdrawals because the individual GCDs must adopt rules consistent with the GMA approach.[37] The power of the regional water planning process is that the TWDB may not fund a project that is not recommended in the regional or State Water Plan.[47]

These two types of planning areas differ by construction. Regional water planning groups (RWPG) integrate surface water and groundwater supplies and considers overall demands, and plans 50 years into the future.[41; 45] RWPGs have 12 interest groups specified in statute and the process is considered a representative approach to planning.[42] Each RWPG develops its own strategy from scratch each five years.[41] A GMA consists only of GCD elected officials, or their assigns, who represent only their local, primarily groundwater regulatory agency.[48] GMA participation is a district duty that is funded through existing district funding resources, usually from taxes or fees for registration, production, or export, without money directly allocated from the state. The GMA's role is to establish the "managed available groundwater," or an amount of groundwater available for extraction for districts to use as a limit when issuing permits.[46] In 2011, that designation changed to "modeled available groundwater"(MAG) to include all groundwater, including both exempt plus permitted uses.[48] Under the GMA process, the MAG volumes for an aquifer must be incorporated into a GCD's permitting review process for groundwater withdrawals.[49] Under the 2005 Legislative amendments the MAG becomes the basis for groundwater availability in the State Water Plan.[48] In the past, regional water planners developed their own estimates for groundwater availability, water supply projections, water needs and strategies[42] without any subsequent use of those groundwater availability estimates or correlated extraction rules by a GCD.

LEGAL CASES ADDRESSING GROUNDWATER

Although Texas adopted English common law in 1840, the earliest groundwater extraction case was *Houston & Texas Central Railroad Company v. East* case in 1904.[50] The Texas Supreme Court ruled that the railroad's extraction of groundwater from its property was legal and did not lead to liability for damages even though pumping might have led to drawdown of the aquifer that dried a neighbor's well.[51] Thus Texas adopted the so-called 'rule of capture'[52], citing a 1843 English case, *Acton v. Blundell.* Texas justices repeated the language about groundwater movement being "secret, occult, and concealed" from an Ohio case, *Frazier v. Brown,* decided in 1861.[53] According to the *Acton v. Blundell* case, an individual had the right to enjoy the benefit of water, including percolating water for its convenience and supplying the resource for necessary purposes. The rationale of the Texas Supreme Court's opinion in *East* has been often quoted and used as the basis for groundwater law over a hundred years later.[52] The *East* case illustrates the limits of legal liability when withdrawing groundwater in Texas.[9] The Texas Supreme Court also set boundaries on the right to withdraw by recognizing that legislative authority exists for regulating groundwater.[9] Potter indicated that three Texas cases modified so called 'rule-of-capture,' by recognizing subsidence, intentional malice to harm a neighbor, and waste as unacceptable and illegal results of unlimited pumping.[9] Texas cases have addressed a variety of legal questions including tort laws, property rights, statutory interpretation, and constitutional issues.[54] Some interpret Texas courts supporting groundwater ownership in place as a property right.[55] An opposite viewpoint is that so-called 'rule-of-capture' involved only a lack of liability for affecting neighboring wells, a tort rule.[54] When a discussion of Texas groundwater law included the words of the rule itself, the question became whether one must capture the groundwater before one can *own* it.[54]

In the 1955 case *City of Corpus Christi v. City of Pleasanton*, 154 Tex. 289, 276 S.W. 2d 798 (1955) the central argument was different. In this case, the issue was not groundwater capture and its impact on a neighboring landowner, but rather the legality of the practice of groundwater transport through a surface water channel, a practice associated with waste through loss of water to evaporation and infiltration into the soil.[9] Corpus Christi, through a contract with Lower Nueces River Supply Company, transported groundwater pumped from near Pleasanton's wells 118 miles through a natural streambed causing evaporation and infiltration losses estimated at up to 74 percent of the volume of the water.[9] State law specifically allowed this transportation method for water.[9] The City of Pleasanton argued this practice was wasteful, against the intent of Texas Civil Statute Article 7602, limiting waste of artesian water, and therefore not protected by the so called 'rule of capture.'[9] While recognizing the legislative authority in regulating groundwater, the court disagreed that this use was unlawful due to waste but noted that in the future this response might not always be the court's decision.[9]

Rice farmers in Harris County challenged groundwater management in the 1977 case *Beckendorff v. Harris-Galveston Coastal Subsidence District*, 558 S.W.2d 75.[9] They protested as unconstitutional the Texas Legislature's creation of a subsidence district with the authority to regulate pumping in order to mitigate land subsidence. The court upheld the constitutionality of the district regulation, thus perceptibly shifting the direction of groundwater regulatory authority supporting Legislative authority in regulating groundwater.[9]

Facing similar concern of responsibility for subsidence due to groundwater pumping, in *Friendswood Development Co. v. Smith-Southwest Industries, Inc.,*576 S.W.2d at 22, in 1978 the Texas Supreme Court continued supporting the so-called 'rule of capture' but with the exception that withdrawing groundwater could not knowingly cause subsidence through negligence or nuisance.[9] The court recognized the Texas Legislature had controlling authority for developing policy, and termed the so-called 'rule of capture' as old-fashioned.[9]

In a 1989 decision *Denis vs. Kickapoo Land Co.*, 771 S.W.2d 235 (Tex. App, - Austin 1989, writ denied), the Texas Court of Appeals reaffirmed the so-called 'rule of capture.'[9] A landowner had drilled a well to provide groundwater to irrigate a field next to a flowing creek, drying it up.[9] The downstream users brought suit claiming he was diverting state waters.[9] The so-called 'rule of capture' provided no special exception under this complex situation trying to define groundwater.[9] The court could have recognized and defined this water resource as a subterranean stream, causing groundwater to be regulated as surface water, but did not do so.[52]

In the 1996 case *Barshop v. Medina County Underground Water Conservation District*, 925 S.W.2d 618, 625-26 (Tex. 1996), the Texas Supreme Court considered the rule of capture in the context of the Edwards Aquifer Act.[9] The act limited groundwater permits to support protection of endangered species in Edwards Aquifer sourced springs.[9; 56] In the Barshop case, the Texas Supreme Court decided that the groundwater district had legitimate power and responsibility to limit groundwater extraction and grandfather wells, ruling against the plaintiff's arguments opposing the constitutionality of creating the Edwards Aquifer Authority.[52]

In the 1999 case *Sipriano v. Great Spring Waters of America, Inc.*, S.W.3d 75 (Texas 1999) a/k/a Ozarka, the parties effectively re-argued the same question as the East case: whether landowners in Henderson County could be liable for their neighbor's loss of water use if they withdraw large amounts of groundwater without willful intent of harm.[9] Landowner Sipriano took the argument one-step further: he requested that the state abandon the use of rule of capture and replace it with the reasonable use doctrine.[9] The court rejected Sipriano's argument but indicated that the Texas Legislature, which had passed Senate Bill 1 in1997 addressing water resource planning, had the responsibility to preserve water. The Texas Supreme Court stated that the Texas Legislature should be given the opportunity to act on any potential changes.[57; 58]

In the 2002 case *Bragg v. Edwards Aquifer Authority*, 71 S.W.3d at 730 (Tex. 2002) the Texas Supreme Court addressed additional arguments against GCDs having regulatory authority in light of the Texas Property Rights Act.[9] *Bragg* argued that the district's practice of issuing permits on an aquifer-wide basis, without analyzing and reporting on a "takings impact assessment," violated private property rights.[9] The court decided against him, supporting the authority's responsibility to prevent waste and protect landowner rights to groundwater through resource conservation.[9]

In the 2008 case *City of Del Rio v. Clayton Sam Colt Hamilton Trust*, 04-06-00782-CV, further tested the law with regard to ownership of groundwater.[21] In this case a property sale contract expressly reserved to the grantor, "… and assigns forever *all water rights associated with said tract*, however, grantor may not use any portion of the surface of said tract for exploring, drilling or producing any such water." The court looked at the contract and heard arguments about how groundwater can be tied or severed from property,[59] and concluded that groundwater rights could be severed.

In 2012 the Texas Supreme Court addressed groundwater regulation and use in the case *Day and McDaniel v. Edwards Aquifer Authority*, 08-0964. The Day case appears to strike a balance between preserving the 'rule-of-capture' and acknowledging that groundwater is subject to reasonable regulation in a GCD created according to Texas law. In that sense, the Day case preserves the status quo through both the 'rule-of-capture' and regulation by GCDs. The court response to the local GCD, the defendant Edwards Aquifer Authority's argument of the onerous financial impact of addressing "takings" alleged in the *Day* case and potentially future cases, was that, “the burden of the Takings Clause on government is no reason to excuse its applicability.”[60] The court disagreed with other arguments in the *Day* case regarding the challenge to the constitutionality of Edwards Aquifer Act, deprivation of due process, and the Edwards Aquifer Authority acting arbitrarily.[60] The court supported the State as having “…a legitimate interest in “discourag[ing] suits against groundwater districts to protect them from costs and burdens associated with such suits…” regarding a GCD being awarded payment of the attorney fees if they win the case but not awarding a plaintiff attorney fees if the plaintiff wins the case.[60]

Canseco[54] believes much of the misunderstanding about groundwater ownership in place arises from specific use or even misuse and interpretation of the language used in *Acton v. Blundell* and some of the Texas cases, particularly words such as “capture” and “absolute ownership.” She argues that the meaning of ‘absolute’ is the source of the differing interpretations.[54] She cited Corwin Johnson as stating that absolute did not mean unequivocal ownership but only relating to the same rules as land ownership because the so-called ‘rule-of-capture’ actually allowed the opposite: someone could pump water from underneath another owners land with impunity.[54]

DISCUSSION

These Texas cases cited are not an exhaustive compendium, but are among those cited by researchers as providing the flavor of the arguments about a landowner’s right to withdraw groundwater, Texas GCD authority and the so-called ‘rule of capture.’ Some groundwater cases also cite oil and gas case law and legal cases from other states. In several cases, courts refer directly to the Texas Legislature’s authority and responsibility over water resources. Although each case addressed a different situation of private property rights, both with and without a groundwater management authority in place, each of these cases has supported the so-called ‘rule of capture.' Canseco[54] indicated that the Conservation Amendment to the Texas Constitution (Article 16, Section 59), addressing the state's responsibility for conservation of natural resources forms the basis for the Texas courts deferring to the Legislature. However, she noted that Texas court criticized the rule in several cases as being archaic beginning in 1955 with the case *City of Corpus Christi*.[54] Baxtresser,[61] Brock,[62] Drummond,[63] Johnson,[52] Kaiser,[64] Lusk,[65] Opiela,[66] Shadwick,[67] and Tarlock,[68] argued that the state should abandon the rule as being antiquated and a threat to the water supply.[52] Other analysts, including Caroom and Maxwell,[55] Falk,[69] Jones and Little,[70] disagreed and argued that Texas first adopted English Common Law in 1840 and the so-called 'rule-of-capture' has been in place for over 100 years. This continuity provides: consistency to interpreting groundwater law; the incentive for forming groundwater conservation districts where needed; and allows for balance of planning, regulation, and property rights.[55] Caroom and Maxwell[55] cited the case *Friendswood Development Co.* and J.E. 'Buster' Brown, the author of the 1997 Senate Bill 1 which established the new paradigm for GCD planning, as being supportive of the reality of the so-called 'rule-of-capture,' this approach long being in place with GCDs co-existencing for over half that time. C.E. Williams, GCD manager and regional water planner, also supports maintenance of the so-called 'rule-of-capture,' arguing that it, combined with GCDs modifications to groundwater extraction parameters based on improved science, works better than other proposed solutions.[71]

PETITIONS AGAINST REASONABLENESS

When the 79th Texas Legislature developed the DFC process it included dual appeal processes to the TWDB and the TCEQ regarding the reasonableness of a GMA's adopted DFC,[46] although the TCEQ appeal process for 'reasonableness' has since been revised to solely address GCDs participation and actions in the DFC process.[49] When the TWDB Board hears a petition, their decision requires the GMA to revise the DFC and a subsequent GMA public hearing may bring forward additional opinions for consideration.[49] The GMA then is allowed to consider the TWDB Board recommendation and public input and adopt a new DFC.[49] Petitions to the TCEQ address complaints about how the district is participating in the joint planning process or acting to achieve its DFCs; the TCEQ ruling is final and a GCD must make any changes the TCEQ orders.[49]

In 2009, three petitioners in GMA 9 joined forces to petition against the adopted Trinity and Edwards aquifer DFCs.[72] Ten other petitioners in six other areas of the state have protested against the reasonableness of their locally adopted future aquifer conditions,[72] summarized in Table 2.2.

Table 2.2 Petitions against the Reasonableness of Desired Future Conditions

GMA: Petitioners/Complaint/Aquifer(s)
GMA 7, West Central Texas, 2011: • Grass Valley Water L.P./Area is more prolific than represented by model; • there is nothing to protect because San Felipe Springs will not be damaged from pumping; • underestimated production capabilities because of limited past data; • prevents export of water; private property takings; unconstitutional takings; no endangered species, • Las Moras Springs went dry in the 1950's; not allowing drawdown below an average does not allow for climate change; • reduced market value of groundwater/Edwards-Trinity Plateau (Val Verde and Kinney Counties) [73].
GMA 9, Texas Hill Country, 2009: • Kerr County Commissioners Court/Aquifer cannot be reasonably managed by zero drawdown; should have used two models instead of one; need to have considered adjacent GMA; should have considered regional water planning estimates; must be quantified and enforced by a GCD; stakeholders were not considered/Edwards Trinity (Plateau) Aquifer. • Kerr County Commissioners Court/Do not know what current conditions are, no data or monitoring wells in Kerr County; must be quantified and enforced by GCD/Hickory, Ellenberger aquifers. Upper Guadalupe River Authority/Did not consider all models; did not consider relevant data, disparate uses, and aquifer conditions; not physically possible; creates **Table 2.2 (continued)**

Table 2.2 (continued)GMA: Petitioners/Complaint/Aquifer(s)
GMA 9, Texas Hill Country, 2009 (continued): • Un-reasonable socio-economic impacts; impacts on private property rights; does not result in reasonable groundwater development/Edwards-Trinity (Plateau) Aquifer. **Table 2.2 (continued) GMA: Petitioners/Complaint/Aquifer(s)**
GMA 9, Texas Hill Country, 2011: • Flying L Guest Ranch, LTD./Current GCD-authorized pumping amounts not included in modeling, underestimating pumping; GMA adopted a single drawdown value for three subunits of the aquifer, does not meet statutory definition; average drawdown is vague, ambiguous and arbitrary; conditions not physically possible; negative impact to private property rights, petitioner will not get permits and suffer harm; adverse socio-economic impacts; ignored regional water plan estimates; conflicts with state policy encouraging economic development/Trinity Aquifer in Bandera County [74]. • Wimberley Valley Watershed Association/Difficult or impossible to use adaptive management, current pumping already exceeds proposed groundwater availability and is unsustainable; impacts on springflow and private wells; fails to consider environment and economic impacts from surface water flow declines; does not protect/conserve groundwater; average drawdown too vague; GMA adopted a single drawdown value for three subunits of the aquifer which does not account for variation among them/Trinity Aquifer in Hays County [75].
GMA 10, Edwards Aquifer, 2011: Grass Valley Water, L.P./Used wrong aquifer data; there is nothing to protect, using index well that fluctuates with no negative effects below level set; underestimated production capabilities; prevent export of water; private property takings; unconstitutional takings; index well in the cone of depression of petitioners well field; reduced market value of groundwater rights/Edwards Aquifer in Kinney County
GMA 11, Northeast Texas, 2011: Crown Pine Timber 1, L.P. and Forestar (USA) Real Estate Group/Total aquifer storage not evaluated; volume of groundwater in only four model layers significantly greater than managed available groundwater for all aquifers together; method to develop desired future conditions unclear, unscientific, and inconsistently applied; disparate and inequitable treatment to landowners within different counties from pumping scenarios used; disparity between two groundwater management areas for the same aquifer; /Carrizo-Wilcox Aquifer.
GMA 12, East Central Texas, 2011: • End Op, L.P./No adequate stakeholder involvement; average drawdown is too vague and arbitrary; "reverse engineering" does not consider aquifer health; cannot be measured; negatively impact private property rights; does not allow for development; conflict's with state's economic development policy; adverse socio-economic impacts/Carrizo-Wilcox, Calvert Bluff, Simsboro, Hooper aquifers. • Environmental Stewardship/Do not adequately consider groundwater-surface water interaction; do not protect Colorado River, Brazos River, streams and springs; have not considered future water budget to springs; based on 2007 state water plan demand projections, not scientifically valid iterative approach to estimate non-damaging aquifer yield; sustainable management not possible in one district/Carrizo-Wilcox, Queen City, Sparta, Yegua-Jackson, Brazos River Alluvium aquifers.

Table 2.2 (continued) GMA: Petitioners/Complaint/Aquifer(s)
GMA 13, South Central Texas, 2011: Canyon Regional Water Authority/Using average drawdown is not consistent with district's management zones; cannot group aquifers together for average drawdown; solution is non-unique; location and rates of pumpage do not reflect current permitted pumping; not physically possible/ Sparta, Weches, Queen City, Recklaw, Carrizo and Wilcox aquifers. Hays Caldwell Public Utility Agency/Adopting multi-aquifer condition is statutorily erroneous; computer inputs are inaccurate, misleading; significant uncertainty in outcome as adopted; not physically possible; adverse socio-economic outcomes expected; inconsistent with regional and state water plans/Sparta, Weches, Queen City, Recklaw, Carrizo and Wilcox aquifers.

Source: Rima Petrossian, 2012

The TWDB reviewed the petitions and supported the 'reasonableness' of the adopted DFCs in most cases.[76] In GMA 9, the TWDB did not consider the adopted Edwards-Trinity (Plateau) Aquifer DFC of zero drawdown to be reasonable because it was infeasible. The GMA 9 GCDs cannot control exempt pumping, so the TWDB recommended a 9-foot drawdown goal.[75] GMA 9 held a public meeting to update the Edwards Group of the Edwards-Trinity (Plateau) to be "not relevant" in Kerr and Blanco Counties, and to leave the goal at zero in Bandera and Kendall Counties due to public input, impact on springflow, and review of the modeling efforts supporting little presence or use of groundwater in those areas.[75] The Headwaters GCD rules also prohibit permitting in the Edwards portion of the Edwards-Trinity (Plateau) Aquifer.[75]

SUMMARY

As of 2013, Texas is changing the way it looks at groundwater management due to the emergence of drought-related issues of supply and doubling of the population over 50 years. Challenges to the DFCs developed in the joint planning process show that stakeholder concerns are polarized into two arguments: (1) the GCDs allow too much future pumping risking irreversible ecosystem damage or (2) not allowing enough future pumping for anticipated growth and allowing development. TWDB Board response to these arguments supported most GCD planning efforts, allowing for some median level of pumping to be permitted over the 50-year planning horizon.

Texas groundwater rules remain in flux because of the competition over groundwater in a state where surface water remains insufficient and demands for groundwater increase. Other jurisdictions face similar challenges. Chapter Three provides an overview of examples of groundwater governance in other countries and states. Although other states and countries have different experiences, they can inform Texas as it looks for ways to improve its groundwater management including future aquifer conditions.

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Chapter 3: Groundwater Doctrines in Groundwater Management

This chapter surveys each U.S. state's groundwater doctrines. This chapter also describes how other nations of the world manage their groundwater resources. One section contrasts Texas' aquifer management approach with the 'exempt use' policies of 14 key states.

The Texas Supreme Court decision in the 2012 *Day* case re-stated the primacy of 'rule of capture' and a landowner's inherent right to pump groundwater from under his/her ground in Texas. The court held that the owner had a property right in groundwater. This decision is consistent with previous Texas court cases; it differs from some administrative, judicial, or legislative decisions in other states and nations.

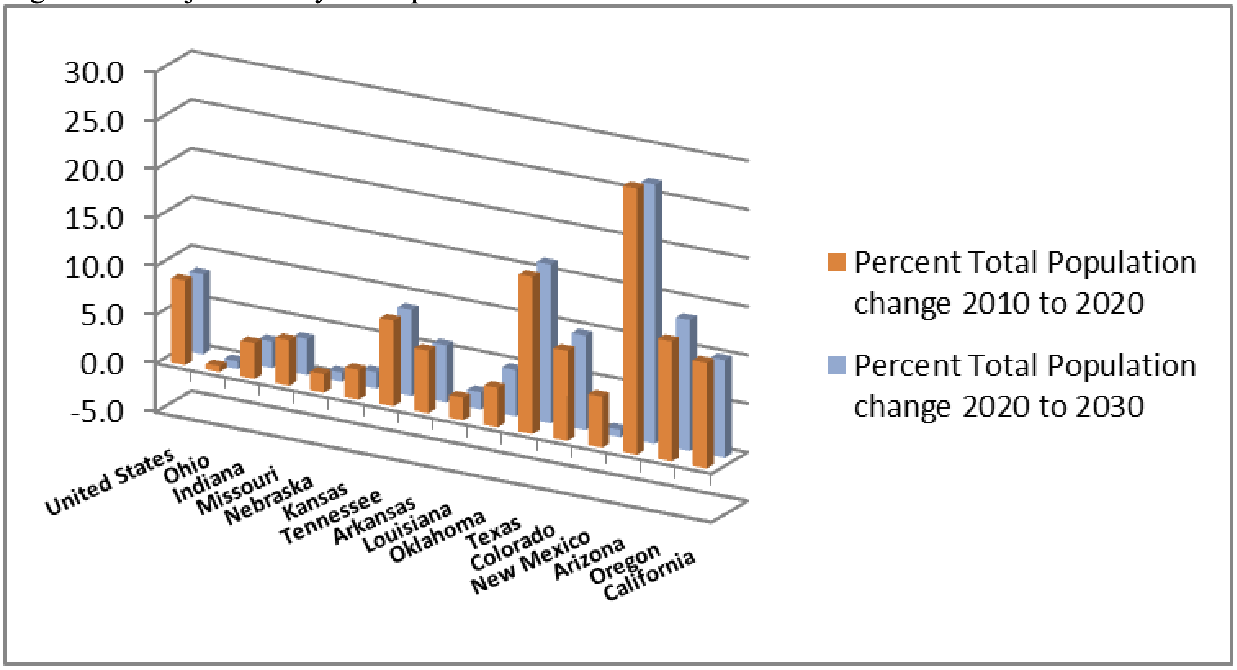
This chapter places the 'rule of capture' within a broad context of groundwater management doctrines. Johnson suggested that the Texas Legislature could solve the problem of groundwater level declines in diverse ways including through limiting pumping rather than using another doctrine in place of the 'rule-of-capture' or replacing the 'rule-of-capture' with the Restatement (Second) of Torts.[1] There are a number of exemplary groundwater management principles from other jurisdictions that may be useful for the Texas Legislature and the Texas courts as they struggle to define Texas' groundwater management principles with the reality of increasing use and fluctuating or declining aquifer levels.

The core problem of water supply in Texas is an imbalance between supply and demand: there may be enough water, but not at the time and place of need or of the appropriate quality to meet the intended need.[2] Groundwater withdrawals in the past usually did not impinge upon neighboring property because of their small magnitude, landowners did not demand governance.[2] For example, when one person's use did not draw down the aquifer enough to affect a landowner's ability to withdraw water from their well, or landowners did not perceive their neighbors as ‘taking’ their groundwater, efforts by neighbors to withdraw from an aquifer were unopposed. Due to this lack of consequences, Bowman[3] called the use of the ‘rule of capture’ a “pre-industrial approach” not involving management at all, but relying on the lack of interference with neighboring withdrawals. Bryner and Purcell[4] agreed, indicating that the increased complexity of groundwater laws due to quickly shifting land and water use, environmental awareness to sensitive areas, increasing population and the corollary increasing water demands, require management that the ‘rule of capture’ does not provide. They also observed that, in contrast to ‘rule of capture,’ if more state control exists there may be decreased costs associated with fewer private disputes. If a state controls groundwater and treats everyone to the same personal exemptions or permit levels,[3] this could bring transparency and an economy of scale to groundwater management.

GROUNDWATER MANAGEMENT

There are a number of factors that influence how a jurisdiction decides to manage its groundwater: its history, public preference for the role of government, state population, climate, and other factors. A tension exists between groundwater management principles versus the reality that more people want to use more groundwater.[5] Assumptions about groundwater availability include that the: (a) volume is not inexhaustible; (b) volume is measurable; (c) areal extent of an aquifer is regional; and (d) volume of groundwater may be ‘set’ but can vary over time.[5] Within the U.S., population growth and climate implications have begun to influence the principles that states adopt for groundwater management.[5] As water supplies become limited and uses more competitive, some states have modified their management procedures. Consider Figure 3.1 which displays the estimated population changes in the top 14 U.S. states.

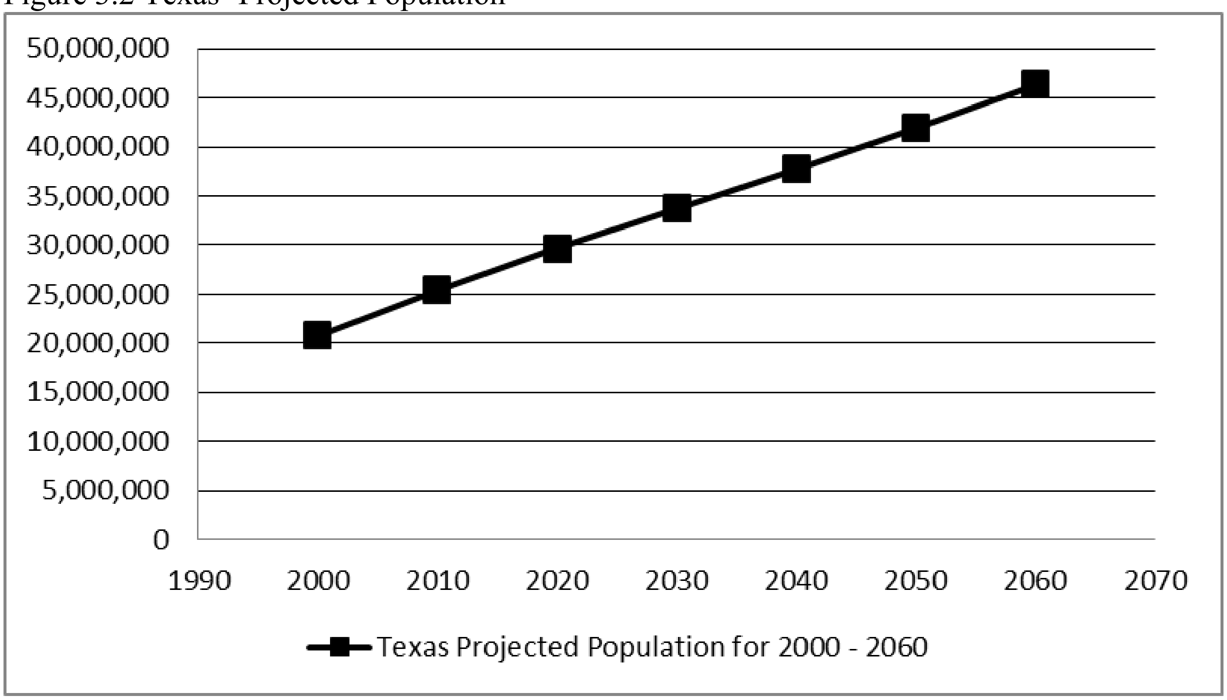
Figure 3.1 Projected 20-year Population Increases for Selected States.



Source: U.S. Census Data, Table 7, 2010, www.census.gov/population/www/projections/projectionsagesex.html

Texas has the second fastest growth rate among U.S. states. Figure 3.2 shows the expected increase in Texas population, approximately 82 percent in 50 years.[6]

Figure 3.2 Texas' Projected Population



Source: Texas Water Development Board, 2012, www.twdb.state.tx/wrpi/data/proj/2012popproj.asp

Some arid or semi-arid states, like Arizona and Texas, are growing so fast and their population growth will affect groundwater quality and supply. Other quickly growing states with milder or wetter climates in some parts, such as Oregon, California, Tennessee, and Arkansas may find it easier to balance supply with demand. In Oregon with a smaller population but large relative growth, the state regulates groundwater to sustain supplies.[7] For example, since 1989, the Oregon legislature set goals to conserve and restore groundwater and prevent contamination.[8] Three groundwater management areas in Oregon (which cover only small portions of the state), address groundwater contamination issues through forming local committees to advise the Department of Environmental Quality on reducing contamination.[9]

Groundwater withdrawals in many states are being used, as in Texas, for oil and gas resource development. An example is Wyoming, where coal bed methane and oil drilling activities increased in the last decade and use significant volumes of groundwater.[10] Wyoming's groundwater regulatory agency developed special permitting rules which consider whether to fulfill drilling permit requests.[10]

In states with large populations, such as California, Arizona, and Texas, management becomes complex and controversial due to large relative growth and relatively high agricultural, industrial, and municipal demands.[11-13] What has worked in one state to balance rural/agricultural uses versus urban, recreational, or environmental concerns may not work elsewhere due to location-specific cultural preferences, historical practices, and political influences. Other states and nations rely on different water law doctrines (see Tables 3.1 and 3.2). It is difficult to draw strong inferences from this diversity of management styles, as different governmental and legal systems may lead to distinct management outcomes, and similar policies may not yield comparable results in different jurisdictions.

GROUNDWATER LAW DOCTRINES

Groundwater managers commonly refer to five groundwater law doctrines: (a) Rule of Capture or absolute ownership; (b) Reasonable Use doctrine; (c) Prior Appropriation doctrine; (d) Correlative Rights doctrine; and (e) the Regulated Riparian method.[14] Some states use a sixth doctrine, Torts Rule or Restatement (Second) of Torts (see Table 3.1).[15]

Table 3.1 Brief Descriptions of Common Groundwater Law Doctrines

Doctrine	Description
Rule of Capture (Absolute Ownership)	Landowner has right to capture groundwater without constraints, except for intentional harm, waste or in Texas land subsidence[1]
Reasonable Use	Landowner may extract water as necessary for beneficial use on the land from which it is withdrawn and on other land if adjoining landowner is not injured[1]
Prior Appropriation	Landowner who first used water has a senior right in a shortage to use a water allotment prior to more recent users' shares[16]
Correlative Rights	Landowner's amount of land surface relates directly to the amount of groundwater extraction allowed[1]
Restatement (Second) of Torts	Landowners may use water for a beneficial purpose without liability for interference with another's use unless it causes unreasonable harm (which varies by situation) as proposed by the American Law Institute (ALI)[17; 1]
Regulated Riparian Rights	Landowner next to a water body has the right to use but does not own it, and must consider effects on other users[5]

Source: Rima Petrossian, 2013

Many states use more than one approach to controlling groundwater withdrawals. The most common U.S. approach is reasonable use.[14] Reasonable use is a management method derived from the 'rule-of-capture' which allows unlimited groundwater withdrawals on the land that produced the groundwater.[1] Use is limited when withdrawals are transported off land or interfere with neighboring wells or aquifer levels,[1] as a concept favoring larger landowners. That limitation—a test of reasonableness—could be decided by courts or through a designated agency; for example, transporting groundwater off the location where it is withdrawn may be considered unreasonable.[1] Prior appropriation holds that those with the earliest use of water have the priority in use.[16] This practice benefits long-time residents, landowners who pass property down through the family or entrepreneurs who find new uses to replace former agricultural or mining uses. A California Supreme Court decision in 1903 spawned correlative rights supporting a landowner's rights to a "fair and just" share of an aquifer for use on the contiguous property[1]; as a concept it could favor wealthy, large landowners or landowners who inherit large property tracts. Correlative rights could limit groundwater development based on property size, where smaller communities or smaller landowners would be allowed to produce less groundwater than large landholders. In an area with equally-sized tracts, correlative rights balance most landowner's withdrawals; in an area with diverse land uses, tract size or aquifer properties, regulation could be complex.[1] Some groundwater experts combined what they considered good features from diverse state laws to create a Restatement (Second) of Torts that included attributes of both reasonable use and correlative rights.[1] This approach does not restrict groundwater use to the land that produced it, nor does it specify a formula for groundwater withdrawals.[1] Restatement (Second) of Torts tries to impose fairness by imposing liability for withdrawing a greater than fair share if the groundwater is available.[1] Regulated Riparian Rights for groundwater restricts permits to time limits. The permit application review considers the reasonableness of the proposed use. A permit is issued under the commitment to protect other users and public consideration, with explicit penalties for violating permit terms or failure to procure a permit.[5] This provides a highly structured and possibly the most uniform approach to groundwater regulation due to the variety of consideration applied to permitting.

Groundwater management to control withdrawals happens at the state level, or regional and local levels through management districts. Bowman suggested a management doctrine controlling access to groundwater, the Groundwater Management Doctrine, defined by Goldfarb and Gould in the late 1980s, which also is called the New Managerialism in 1993,[18; 3] may be used with any of the approaches controlling groundwater withdrawals. The concept of Groundwater Management ties together the evolution from the so-called 'rule-of-capture' approach to state control over groundwater withdrawals, for example in Texas through the DFC process in GMAs where both approaches may be in force at the same time and create tension.[3]

Groundwater is reserved for the public in many places by placing control at the highest regulatory level, primarily to protect public access to resources.[19] While the Public Trust doctrine is used primarily for governing surface water, it can be relevant for federal groundwater governance.[20] In a few states and other countries, the Public Trust doctrine may be another doctrine governing groundwater.[20] This doctrine covers uses that might be unprotected by the other doctrines: recreation, ecosystems, community, or aquifer impacts from groundwater transfers, existence value and future generations. In Wyoming and Arizona the Federal Reserved Rights Doctrine allows water uses on federally controlled lands to fulfill the legislated purpose.[14] More details about these methods are discussed below.

Rule of Capture

Legal experts debate the exact meaning of 'capture' and 'absolute' in the 'rule of capture.' In Texas where the debate is active, adoption of the so-called 'rule of capture' in principle allows landowners to extract in principle unlimited groundwater as long as they are able to capture the water, whether or not the withdrawal causes harm to a neighbor. One exception is if a landowner intends to inflict malicious harm on a neighbor, as determined by the courts through a legal process.[21] Another Texas exception is when withdrawals cause land subsidence.[21]

HISTORICAL WATER CODES

Some scholars trace back to Roman law the concept of the origin of a landowner's owning and controlling soil and therefore groundwater.[22] However, the so-called 'rule of capture' can first be found in ancient laws from over 4,000 years ago on water and land ownership. This first citation was part of the 32 codes in the Ur-Nammu law code, in force in southern Mesopotamia in the delta area on the Persian Gulf (presently Iraq) during 21st to 20th century B.C.[23] These rules made flooding another landowner's crops and a lessee not planting and growing orchards punishable through specified fines.[23] These codes preceded Babylonian Hammurabi law code from the 18th century B.C.,[24] which likely provided precursors for Greek and later Roman law.[25] In the 6th century B.C. Greek lawmakers cited divine intervention and human views of justice as the inspiration for natural resources rules.[25] For example, poet and lawmaker Solon formed his views from Draco and Plato's writings.[26] He interpreted land ownership to signify the rise of personal wealth through successful commercial trade through land ownership.[26] Solon's laws tied the productivity of land to agriculture, most likely irrigated agriculture, and mandated prevention of agricultural exports (and thus virtual water), correlated to increased political opportunities and responsibilities for landowners.[26] Although Roman law borrowed from Greek law, the later Roman Law departs significantly by being universal rather than local in extent.[25]

Narimsihan[27] indicated that the Roman concept of public ownership of groundwater and surface water distinguished between differing natural circumstances. He cited a twentieth century translation of Roman law about inland water flow, "…*aqua profluens res communis omnium est,"* meaning water flow and river banks as recognizing groundwater and surface water as public water.[27] Narimsihan[27] interpreted Roman law to support the principles of a landowner owning the subterranean groundwater. Under this interpretation, groundwater ownership is a private property right. A landowner can withdraw water from an aquifer even if withdrawals cause a downstream shortages if the landowner intended no harm (*animo vicino nocendi*) or water flowed freely off the property (*aqua profluens*).[27] Some analysts cite the Latin quotation in the case *Acton v. Blundell* as a reason to tie the decision to Roman law,[28] although not all scholars agree on this interpretation.[22]

ROMAN INFLUENCE ON ENGLISH LAW

The influence of Roman Law on English law can be traced to Lombardian Roman law scholar and Professor Roger Vacarius' emigration to England after 1145.[29] Vacarius had previously taught law in Bologna, Italy, the center of European legal training.[29] England may have benefitted from the combination of the revival of the study of formal Roman law in Italy after 1100[30] and Vacarius' subsequent emigration.[29] Vacarius brought Roman Law in the form of a textbook he wrote and then educated law students at Oxford or Canterbury, according to Turner.[29] Because of Vacarius' textbook, the English incorporated Roman methods, such as writing down legal practices.[29] Turner cites Vacarius' textbook as a source for the distinction between property and possession from Roman law, even if England did not adopt all the elements.[29] Later, between 1180 and 1190, an unidentified author wrote English legal treatise *Tractatus de Legibus et Consuetudeinus Regni Algliae.*[31] The book is written in Latin with Roman legal terminology, mostly attributed to Chief Justicar Ranulf de Glanville, with references to both civil and canon laws.[31] Turner[29] argued that the established use of common law in England precluded the English changing to Roman law in the thirteenth century. He indicated this was despite that Henry II employed scholars of both common law and Roman law[29] and at the same time Theobald, Archbishop of Canterbury, hired Vacarius to provide legal advice.[29]

Henry de Bracton, both a priest and an attorney, wrote a seminal treatise on English law in Latin in 1235, "*On the laws and customs of England.*" This version of English law emulated the earlier book Glanville's *Tractatus*, that used the form of Roman law but not its content; Bracton also referred to the Church canon laws.[32] These two legal treatises from Glanville and de Bracton, influenced aspects of English law.[33] In a parallel but different line of historical Roman influence on English common law, Blumm and Ritchie[34] argued that since Rome, state ownership of natural resources has allowed and controlled so-called 'rule of capture.' Blumm and Ritchie[34] highlight the state's concealed power through allowing private property rights.

ENGLISH INFLUENCE ON UNITED STATES LAW

There is no mystery concerning the origins of the U.S. adopting English law when it declared independence from being a British Colony. Texas, as a child of Mexico, the U.S., and four other countries, was influenced by both U.S. and the practices of other countries.[28] In the U.S., the 1836 Massachusetts case *Greenleaf v. Francis* was the first U.S court that addressed combining drilling a well on private property using the 'malicious harm' argument from a neighboring landowner.[28] There was another groundwater mine dewatering English case in 1840.[20] Texas' Supreme Court cited the 1843 English case *Acton v. Blundell* that addressed capture of groundwater and injury to neighboring groundwater uses.[28] Chief Justice Williams quoted Roman law in his opinion citing *damnun absque injuria*—"a loss which does not give rise to an action for damages against the person causing it."[35] As U.S. courts in Ohio, California, and Texas from the mid 1800's to early 1900's cited these common law cases to establish judicial precedent of the so-called 'rule of capture,'[28] many states began to use this approach for addressing groundwater issues.[14] In Texas, the 1904 *Houston v. East* decision referred to *Frazier v. Brown* from Ohio (1861), which referred to *Acton v. Blundell.*[36] In *Frazier v. Brown*, the Chief

Justice Shauck[37] described groundwater as being “so secret, occult and concealed,” that management would be impossible.[28] Ohio operated under absolute ownership until 1984, when the courts adopted Restatement (Second) of Torts.[20] Ohio’s Legislative Commission indicated that Ohio now uses the reasonable use doctrine and the Restatement (Second) of Torts Rule requiring a reasonableness component.[38] One analyst infers that the Ohio courts may consider prior appropriation in the decision regarding ‘reasonableness’ of a use.[38] Arizona once operated under the so-called “rule of capture”; it changed in 1980 after experiencing significant aquifer depletion.[4]

WATER DOCTRINES

Interpretation of which doctrine a state uses is not necessarily settled. For example, groundwater analysts disagree on states that use the so-called ‘rule of capture’ doctrine in some form; those mentioned include: Connecticut, Georgia, Indiana, Louisiana, Maine, Massachusetts, Mississippi, Ohio, Rhode Island, and Texas.[14] This difference of opinions among sources reflects interpretations over how these states’ courts and administrations treat groundwater. Some analyst may interpret Ohio’s practices (discussed above) and Georgia (discussed below) in differing ways. Georgia’s Department of Environmental Protection issues groundwater permits for withdrawals rates above 100,000 gallons per day (gpd)[39] that may require a permittee to identify a specific beneficial use of groundwater and may include restrictions on pumping or extraction reduction from certain aquifers in the public interest.[40; 39] For example, in 1999 GDEP issued a moratorium on new permit-issuance in 24 counties[41] based on a United States Geological Survey (USGS) warning of Floridian Aquifer depletion in the southern part of the state.[42] GDEP allowed pumping in different areas to balance and offset other pumping restrictions. Although some researchers[15] interpret this system as using the ‘rule of capture,’ others also cite reasonable use as the basis for this method of groundwater extraction.[43] Reasonable use and correlative rights discussed below are permutations of the so-called 'rule-of-capture' because they retain the private property rights components, clarified in 1949 by the Kansas oil and gas capture case *Emery v. Knapp,* indicating that this "rule" is a 'right to capture' a resource but not ownership.[44]

Reasonable Use

The reasonable use doctrine originated from a 1900 case *Forbell v. City of New York,* where a high–production city well caused regional drawdowns linked to a farmer's crop failure. The ruling limited the 'rule of capture' or the absolute ownership of groundwater by requiring 'reasonable' and 'beneficial' groundwater uses on the land where it is produced, criteria common today.[3] Wehrkemp[20] described it as a reactionary rather than proactive system. In states applying this approach, groundwater captured from outside a surface property's boundaries could become 'unreasonable.' However, depriving a neighbor of water is reasonable if well spacing, extraction rates, use, and disposition of the groundwater benefit the surface landowner. One source indicated that at least eight states east of the Mississippi, some of which formerly used the rule of capture, apply this approach: Alabama, Florida, Illinois, Kentucky, Maryland, New York, North Carolina, and Tennessee.[14] The Water Systems Council (WSC)[15] reported that 21 states have adopted this approach: Alabama, Arizona, Arkansas, Delaware, Florida, Georgia, Illinois, Kentucky, Maryland, Missouri, Nebraska, New Hampshire, New York, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Virginia, West Virginia, and Wyoming.[15] Four states combine reasonable use with prior appropriation (Arkansas, Delaware, Missouri, and Wyoming).[14] Nebraska combines correlative rights with reasonable use.[15] Bryner and Purcell indicated that this doctrine is active in Arizona.[4]

Prior Appropriation

The prior appropriation doctrine use has been applied to groundwater. The earliest beneficial groundwater user has a priority for use[16] where a user's priority reflects the date the state or governing body issued a permit. For example, the Idaho case *Sand Point Water & Light Co. v. Panhandle Development Co.* in 1905 ruled that person who first used water has top priority.[16] When there is increased use or shortage, this approach usually requires an administrative permit system with some groundwater system signals, such as water elevation or water quality degradation to trigger reduced pumping.[14] Nine western states apply this approach for groundwater management: Idaho, Kansas, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, and Wyoming. In addition to the priority system, California, Arizona, and Idaho apply a modified approach.[14] California applies it only when surplus groundwater becomes available for landowners.[4] Arizona established some areas of the state experiencing groundwater declines as Active Ground Water Management Areas, which control pumping through a prior appropriation permit system.[45] Idaho limits groundwater extraction to annual recharge rates.[4] States limiting production but including further regulatory limits on those rights include: Colorado, Kansas, Montana, Nebraska, Nevada, and Washington.[14] The WSC[15] reported that Alaska, Colorado, Idaho, Kansas, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, and Washington use prior appropriation. Bryner and Purcell[4] indicated that California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming use prior appropriation for groundwater rights.[4]

Correlative Rights

Correlative rights, originating in a California legal case *Katz v. Walkinshaw* in 1902, is a fancy way to describe "shared shortages," where all landowners share equally in any groundwater shortages based on the size of land holdings.[46] This rule for groundwater is similar to a parallel application in some states for surface water rights.[14] This approach supports large irrigation practices because it ties allowances to a landowner's groundwater use according to land size. A landowner has a right to withdraw groundwater scaled to her/his acreage size.[14] If aquifer elevations decline, each user must cut back to ensure no one unfairly gets more water than his or her share.[14] This means that no one has the right to a certain water level in his or her well, within any particular stream, or anywhere over her or his property.[14] In California, if additional water exists that landowners do not need, the extra water is may not be subject to correlative rights.[14] Domestic users, such as municipalities, also have a right to use surplus groundwater.[14] One source indicates that seven states apply this approach: Arkansas, California, Delaware, Minnesota, Missouri, Nebraska, and New Jersey.[14] The WSC[15] indicates that California, Hawaii, Iowa, Minnesota, New Jersey, and Vermont apply correlative rights. Bryner and Purcell[4] indicated that California used a unique system combining prior appropriation with correlative rights, riparian rights, and basin adjudication. For example, California identifies over 447 groundwater basins statewide,[47] allowing a single aquifer to serve more than one landowner[15] under court-supervision.

Restatement (Second) of Torts

The 1978 Restatement (Second) of Torts refers to the modified and combined reasonable use and correlative rights doctrines,[46] allowing consideration of new system users.[3] It serves as a model for groundwater allocation correcting a harm: a right holder who believes she or he may have experienced loss of use of groundwater may obtain a 'fair' volume of groundwater.[17] This approach may be used to identify and resolve the liability for claims of damage from a party's groundwater extraction. ALI experts developed the ideal parameters that they thought would optimize groundwater management when using this approach. State legislatures can choose to adopt these ideal parameters to develop a groundwater permitting system for legal cases.[17] If they do so to resolve conflicts or claims, the courts would not assign liability if landowners use the groundwater for beneficial purposes, except for three circumstances: unreasonable harm; surface water damage; or unreasonable use.[48] If a particular groundwater extraction could cause unreasonable harm (falling water levels, reduced pressure head, etc.), harm may have occurred.[48] If withdrawals affect surface water or a surface water user, harm may have occurred.[48] Extraction in excess of a reasonable share of storage or groundwater storage may cause harm.[48] Johnson[1] indicated this method does not restrict groundwater use to the location of the landowner's extraction, although this method takes parts of correlative rights and reasonable use doctrines. With this approach, tract-size is not a basis for establishing reasonable permit extraction volumes and beneficial use is not defined.[1] The WSC identified only Michigan, Ohio, and Wisconsin as managing groundwater using the Restatement (Second) of Torts doctrine.[15] Aiken[49] indicated that Nebraska's Supreme Court was the first state to adopt this doctrine to resolve a case between competing water users with hydrologically-connected groundwater and surface water. A new Restatement (Third) of Torts has been in development for over 20 years.[50]

Regulated Riparian Method

Some states have begun to create groundwater permit systems, an approach more commonly associated with surface water riverine or riparian systems.[5] Four states use full permit systems for groundwater[5] but are not necessarily considered riparian systems. States where regulators use riparian methods for groundwater management, the state issues time-limited permits for groundwater use based on reasonable use tests, other users rights, and the public good.[4]This approach supports users extracting and transporting groundwater for use elsewhere, similar to a river transporting water for long distances.[5] Dellapenna[5] indicated that when using this management approach there are unresolved issues related to investment security if a permit could be issued for a relatively short time, not allowing for return on investment or if the permit could be modified to respond to future shortages or moved to accommodate differing uses. Beck's model *Regulated Riparian Model Water Code*[32] suggested a 20-year permit to support longer-term security for private infrastructure investments. No state has adopted the code in full.[32] This code incorporates water use fees to compensate the state for the use of groundwater so it differs from most approaches where groundwater has no explicit value.[32] The Ohio Supreme Court decision in the *McNamara v. City of Rittman* case in 2005 supported private property right in groundwater not being reduced under a regulated riparian approach but just regulated by the state through its police power,[20] which might be interpreted to be similar to the Texas *Day* case. Analysts may not agree on which states apply the regulated riparian approach. The State of California has some aspects of the regulated riparian approach incorporated into its administrative structure.[4] Experts dispute the inclusion of Alaska, Arizona, Illinois, Nebraska, South Carolina, and Tennessee as incorporating regulated riparian rights for groundwater management.[5; 4; 15] Dellapenna[5] cited other states as using this doctrine: Arizona, Illinois, Nebraska, and South Carolina.

GROUNDWATER REGULATION

Groundwater Regulation Doctrine, a way to administer existing groundwater doctrines, recognizes the idea that groundwater is a common pool resource. It acknowledges groundwater users' shared connection to each other. It takes the approach of using groundwater management options that are unique to each aquifer.[3] No state directly refers to or admits to using this doctrine. However, Bowman's[3] description supports ascribing elements of this approach to (a) Arizona, with their Active Groundwater Management Areas; (b) Arkansas, with their Critical

Ground Water Areas; (c) California, with hundreds of locally controlled groundwater districts managing hundreds of aquifers; (d) Oklahoma establishing aquifer continuity for at least 20 year terms by controlling groundwater availability; and even (e) Texas' GMA's. Texas GMA's decide on the desired future conditions of each aquifer within GMA boundaries. There is a shared connection of any user's ability to extract groundwater through the process as each can participate in local decision making and permitting. Under GMA planning, Texas' 'rule-of-capture' remains in place but modified under a local authority's control.

Public Trust Doctrine and the U.S. Federal Approach

Many nations use a public trust doctrine to control groundwater at a national level. The public trust doctrine preserves public rights to access certain resources inherited from previous generations and entrusts the government to manage the resources to protect the public and future generations.[44] This doctrine has its origins in ancient Roman and English common law. The public trust is used customarily at a national level to protect the public's freedom to access and navigate waterways, hunt, fish, manage wildlife, visit shorelines, and access surface water partly through the national park system.[51] Pennsylvania was the first state to include the Public Trust doctrine in its constitution, followed by a few other states.[52] Wehrkamp[20] described four states that have applied the Public Trust Doctrine for groundwater, although others do not share this view: New Hampshire and Connecticut through legislation, California and Hawaii through judicial decisions.

Federal Agencies Role for Groundwater

The federal government approaches controlling groundwater quality through regulation but has never developed policy goals or guidance for groundwater development, even in overlapping groundwater basins or aquifers or with international borders.[51] Federal agencies, such as the Department of the Interior, U.S. Geological Survey, and EPA, through federal legislation have implemented an ongoing role for protecting groundwater resources through measurement and tracking or controlling aspects of human health and ecosystems. Since 1984 the EPA has required state participation in monitoring and controlling public drinking water supply water quality, including groundwater, although federal representatives accept that state-level rules establish groundwater availability.[50] States continue to determine groundwater use, ownership, and extraction as a state law issue.[50] Each state interprets and governs its water resources, but must accept minimum federal drinking water standards for health risks as specified by the EPA for public drinking water supplies.[53; 54]

For decades the U.S. Geological Survey (USGS) identified and mapped 62 large regional aquifers that transcend state boundaries, including Texas' Edwards Trinity System, Blaine, Rio Grande aquifer system, Pecos River Basin alluvial aquifer, Ogallala Aquifers in Texas, Coastal Lowlands, Texas coastal uplands, and High Plains aquifers.[55] Although these aquifers underlie more than one state, under the U.S. system each state has the authority to manage groundwater independently. In Texas, the nationally-identified aquifers are renamed and subdivided into smaller aquifer units, and the state has also identified numerous minor aquifers.

GROUNDWATER PRACTICES IN OTHER COUNTRIES

Each sovereign nation has its own climatic conditions and exercises autonomy in controlling its groundwater resources. Island nations possess physical barriers to water flow which constrain fresh water sources, so that controls over local groundwater and surface water are central to their population's sustainable development. Nations often use rivers as surficial physical borders which may not correlate to shared groundwater resources.

Just as each country has its unique hydrology, sovereign nations define their own groundwater law. For example, Great Britain and two former British colonies Australia and South Africa have departed from Britain's own precedent, the 'rule-of-capture.' India is moving toward regulating groundwater through local management approaches. Table 3.2 lists water management approaches from Great Britain and Mexico, as well as Australia, Canada, Chile, India, Israel, Netherlands, South Africa, Spain, and fifteen U.S. states. Three of these countries (Australia, Netherlands, and Spain) used alternatives to the Texas approach to modifying the 'rule-of-capture,' as these states combined state ownership of groundwater with other approaches. A common thread in some countries' groundwater law has been that nations enact or update groundwater legislation after or during extreme drought, when the immediacy for finding reliable water resources is tangible.

Table 3.2 International Groundwater Management Approaches

Nation	Groundwater Doctrine
Great Britain	Reasonable Use Doctrine with State Ownership[56]
Mexico	Federalism with State Ownership[57]
Australia	Cooperative Federalism with State Ownership, with some rule of capture[58]
Canada	Rule of Capture[59]
Chile	Water Market, based on groundwater as private property[60]
India	Rule of Capture[61; 62]
Israel	State Ownership[63]
Netherlands	State Ownership mixed with Rule of Capture and Permitting System, no Market[64]
South Africa	Public Trust Doctrine[58]
Spain	State Ownership mixed with Private Rights and Water Market[65]

Source: Rima Petrossian, 2012

Great Britain

The British supported use of the 'rule of capture' that had allowed a landowner to withdraw unlimited amounts of groundwater regardless of harms to other aquifer users then abandoned the approach,[66] even though this rule served as the foundation for U.S. and other former British colonies' case law. Responding to a 1959 drought, Great Britain accepted state control with private investment[56] by enacting the 1963 Water Resources Act that limited each landowner's exempt water use to 2,641 gpd[66] (about 2.96 acre-feet per year). In 1997, the British Parliament revised and updated its water management system after another prolonged drought.[56]

In 2000, after joining the European Union, Britain adopted the European Parliament Water Framework Objective. This framework established a community approach to water resources management. The United Kingdom adopted this approach despite being physically separated from the other European states, where member states are obligated to manage and protect groundwater and achieve a "good status" by 2015.[67] The British Water Resources Board, established to control surface water and groundwater, instituted a permitting process that included the authority to decline to issue a permit if rights of other users or the aquifer are compromised[56] (similar to reasonable use).

As of 2012, there is a new British system of private water companies that provide and deliver water supplies to the public, replacing the prior system of individuals withdrawing groundwater from their own wells or public water systems controlling wells and groundwater supplies.[56] Although it will issue water withdrawal permits to individuals, Great Britain authorizes and permits these 26 regional retail water purveyors to produce and manage surface water and groundwater supplies together through regional conveyance systems.[56] England's 2000 Water Framework Directive included groundwater planning goals within river-basins, with the goal of maintaining groundwater levels in order to preserve habitats by strengthening biodiversity and ecology.[68] After another prolonged drought from 2004 through 2006, the British government issued a report on strategies for reducing average water use below 40 gallons a day per person to accommodate future climate change and weather extremes.[67]

Mexico

Mexico's central federal government controls all groundwater use through the Public Trust Doctrine.[57] The Mexican Water Act of 1992 established the modern legal framework for controlling water through a federal agency, the National Water Commission of Mexico (CONAGUA) created in 1989.[69] In 2004, the federal government sought to decentralize water resource control using principles of Integrated Water Resources Management (IWRM) by supporting river basin planning.[69] Hundreds of local organizations, including 78 Technical Groundwater Committees, participate in water management.[69] In some areas, these groups are using technical tools like groundwater models to develop solutions.[57] In other areas, the groups are struggling with getting organized.[57] The Commission Nacional de Agua (CNA) collects groundwater data throughout the country.[70] CNA has designated over 100 of Mexico's 647 aquifers as being over-exploited, indicated by socioeconomic impacts such as degraded water quality, high pumping costs, and reduced groundwater availability. Mexico might be failing to implement its program, possibly because the system, designed to recover administrative costs through collecting fees and incentives for ecological support, is unpopular.[57] Mexico's national system allows private water transactions among landowners holding rights, although regulations do not allow out-of-basin transfers.[57] While national control should minimize local availability issues, the government has reported that the groundwater was over-allocated, suggesting conflicts.[57] Mexico seems to have strong legislation and clear policy direction, although some analysts perceive their groundwater policy implementation just have been moderately successful.[57]

Mexico once governed Texas and Texas' initial groundwater resources were under Mexican law after Spanish Colonial rule.[71] Today Mexico shares surface water and groundwater resources with Texas.[72] Mexico's federal laws establishing groundwater as a national patrimony continues to influence Texas' groundwater availability through Mexico's control and use of shared riparian water resources (such as the Rio Grande/Rio Bravo) along the approximately 2,000-mile border. In far west Texas, the Hueco-Bolson Aquifer under the binational metropolitan area of El Paso, Texas and Ciudad Juarez, Mexico[73] suffers from increased salinity and water level declines.

Although water providers on both sides meet and discuss water use concerns, working through a memorandum of understanding[73] water levels in Ciudad Juarez continue to decline. El Paso has developed successful technical and administrative solutions addressing groundwater declines.[73] In the neighboring Presidio County, Texas and Mexico's northern State of Chihuahua, the two nations share the Presidio Aquifer.[74] Texas and Mexican officials have met to advise the TWDB on the aquifer modeling efforts and share information about pumping,[75] but the interaction is limited.

Australia

Prior to the British arrival in Australia, the Indigenous tribes managed water to support common uses and practices, including 'water in the totality of life.'[76] British settlers in the island nation adopted the British 'rule-of-capture.'[77] After about 100 years of settlement, in 1886, the Australian government accepted federal control of groundwater through the issuance of permits, although in some Australian states groundwater withdrawals remained ostensibly unlimited.[78] Just before this national change in 1895, a court ruled for allowing pumping despite acknowledgement of malicious intent.[78]

In the recent past Australia has developed different groundwater rules. In 1994 Australia required policy reforms in each state to follow 'Environmentally Sustainable Development' (ESD), a process to balance economic benefits with protecting biodiversity.[78] In 2004, Australia initiated the National Water Initiative by implementing groundwater reforms previously adopted by most Australian states supporting sustainable resource planning and development through best-management approaches.[77; 78] The Water Initiative established that any consumptive use of groundwater required a right, called a perpetual share of the consumptive pool[78]; it also recognized indigenous peoples' rights in water.[79] This trajectory of consumptive water rights supported the concept of increasing productivity and efficiency; environmentally sustainable withdrawals is the long-term goal.[78] The Water Act of 2007 requires water users to follow specific basin plans incorporating new data about groundwater conditions before authorization of future withdrawals.[78]

Canada

Canada initially adopted the British 'rule of capture' as a national policy.[59] In 1987, Canada passed legislation addressing groundwater research, but has not articulated new national groundwater rules, leaving such jurisdiction to each province.[80] Canada does not track groundwater use on a national level, even though about 30 percent of Canadians rely on groundwater for drinking purposes in varying proportions in each province.[81] Ontario has the most number of people, over 3 million, relying on groundwater.[81] Alberta has the lowest percentage, 23.1 percent relying on groundwater.[81] Canadian island provinces with small populations rely heavily on groundwater; for example all Prince Edward Island residents rely on groundwater resources, 66.5 percent of New Brunswick residents use groundwater, and 45.8 percent of Nova Scotia residents use groundwater.[81] Almost half of Yukon residents, the fewest in number, rely on groundwater, yet all will access groundwater due to conjunctive use management with surface water.[81] In the Northwest Territories , with the second smallest population, 28.1 percent of the population relies on groundwater.[81] Saskatchewan with 42.8

percent reliant on groundwater,[81] in 1959 began to regulate a moderate number of wells, and was the first province to do so.[80] Irrigation uses vary from a low of three percent of total usage in Saskatchewan to 44 percent in Manitoba.[80] About 30 percent of Manitoba residents rely on groundwater.[81] Ontario began regulating groundwater in 1961 through issuance of permits and tracking well drilling activities. In Ontario about 80 percent of rural residents use groundwater and 28.5 percent of the population overall.[80] About 27.7 percent of Quebec residents rely on groundwater.[81] British Columbia remains the only province without any regulatory requirements for groundwater extraction, even though 28.5 percent rely on groundwater.[80]

Chile

In 1855 Chile adopted a civil law system similar to Spain and other European countries, to govern its people and to address property rights, unlike Great Britain and the U.S.[82] Private investors had used public waters to irrigate about 75 percent of the irrigated acreage through 1920.[82] In 1950 Chile established central governmental control and recognized the Public Trust Doctrine as including water resources.[60] In 1951 Chile established a separate water code that authorized public and private access to water without fees and no guarantees of supply continuity.[82] In 1967 Chile again reverted when the government adopted a public trust doctrine to retain all groundwater rights through the Agrarian Reform Law and did not allow private access to water.[82] In 1981 Chile adopted a market-based approach acknowledging private property rights issues in groundwater.[60] This administrative approach allowed private investors to develop infrastructure, such as building surface water canals and procuring licenses.[60] Only after capture were the uses secured with the "rule of capture,"[24] with one exception: when a use changes, the government collects a fee and sets priorities on the uses.[60] After the change in 1981 to a market-based system, the national government let the courts settle most water issues between private buyers and sellers.[83] Some of the complaints about the new system included high transaction costs, lack of a uniform legal water rights system, and lack of systematic scientific information about the water resources and reduced groundwater availability.[60] Limitations affecting private water transfers outside of land transactions included infrastructure limitations, terrain constrictions, administrative and legal intricacies requiring expertise and expenditures, attitudes, and water pricing inconsistencies.[84] Through the mid-1990's groundwater was relatively underutilized.[84] Chilean concerns have recently focused on hydroclimate problems of drought and flooding and water quality degradation.[85]

Israel

Israel declared all of its surface and groundwater to be state property at independence and then established water management strategies in the early 1950's.[86] It has developed one state-controlled central water distribution system for all water sources, including groundwater from the Mountain and Coastal Aquifers, desalinated seawater, the Jordan River and other surface sources.[86] This integrated system includes water quality as well as quantity and water security issues. Israel shares access to all trans-boundary aquifers with neighboring states, justifying current uses based on the prior appropriation doctrine and historical uses.[63]

South Africa

South Africa enacted a National Water Act in 1988 that changed from the 'rule of capture' to the Public Trust doctrine.[87] South Africa's law now supports access to water as an expressed constitutional right[87] although that universal access has remained an unfunded mandate and is limited in practice.[87] South Africa's constitution specifically defined 'access to water' a basic human need, for activities of eating, washing, sanitation, combined with environmental needs.[87] South Africa, with its frequent droughts and less surface water than many

African countries, has only modest developed groundwater investments.[87] Water resource management has changed to support more local control, participatory decision making, and conjunctive management within a single hydrological system in order to support sustainable development.[87] The South African definition of 'sustainability' includes : economic growth, ecological integrity, and social equity.[87]

The Netherlands

In The Netherlands, located on the North Sea, groundwater is a property right[88] with a tax-free extraction for domestic use; however the national government taxes other uses.[89] National groundwater policies set a tax rate at for extraction greater than 21,712 gpd or about 24.32 acre-feet per year.[90] Fewer than two percent of farmers exceed the upper limit,[90] suggesting that many groundwater users are extracting small amounts solely for domestic use. Economists evaluating this policy indicate that it preserves low-value agricultural use and poor conservation practices due to the low price.[90] The Dutch have a substantial historical understanding of the importance of groundwater and surface water availability and administration.[64] Local water boards began cooperative water management in the 11 century, with one such board existing since 1232.[91] The local legends refer to a "salt-bearing dragon" 2,000 years ago that poisoned a Friesian chief's hand dug well near the sea where a local clan was withdrawing more groundwater than its share.[92] Dutch concerns have recently re-focused on that ancient experience of groundwater contamination, particularly by saltwater encroachment and pollution.[90]

India

India has widely varying groundwater resources, groundwater use, and climates. India's central government treats groundwater as a property right attached to land ownership.[93] The high investment costs to drill a well limits groundwater use for many. India's experience differs from western countries.[93] In many areas water users have dug 'tube wells,' shallow wells drilled into near surface alluvial aquifers. In most areas the 'rule-of-capture' dominates with no government-specified extraction limitations.[93]

Spain

Spain has documented water management systems in place since 1435. In 1985 Spain adopted the Spanish Water Act to replace an 1886 water law,[94] declaring groundwater as part of a public trust, a change from the previous acceptance of local private control.[95] In Spain groundwater provides about 20 percent of water used where groundwater withdrawals exceed recharge rates.[96] The Water Act included tools and controls to control excessive use in overexploited areas.[95] Scientific issues of understanding the groundwater quality and quantity have not necessarily contributed to controlling groundwater withdrawals.[95] When Spain established a Registry of Public Waters in 1985 and a Catalogue of Private Waters, types of water uses and amounts being used became apparent.[95] The catalogue registry allowed previously held private rights the options of ownership with registration through 2038 or in perpetuity.[95] A requirement to register new groundwater uses went unheeded in some areas.[95] Water scarcity increased in the last decade, making groundwater an attractive alternative.[96] After 2000, in order to address water issues uniformly within the newly formed European Union, the European Union Water Framework Directive established policy goals for all member states.[95] Spain is now exploring these policy goals for reducing groundwater contamination and harm to surface water from groundwater extraction.[95] Maintained or reduced groundwater withdrawals are a possible solution to minimize further environmental impacts from surface water storage projects and irrigation.[96] Some analysts have identified potential threats to achieving these policy goals by the 2015 deadline due to past irrigation practices and landowner reluctance to follow the new policy goals in some aquifers.[95] Some analysts indicate that quantifying groundwater extraction rates and volumes is complex due to policy noncompliance.[95] Solutions to areas with excessive withdrawals may include charging fees for withdrawals and increased monitoring.[96]

SUMMARY

Only a few countries worldwide, including several states in the U.S., India, Canada, and Chile, use the so-called 'rule-of-capture.' Formerly the practice reigned in Australia as the governing water law doctrine through 1896, in Great Britain until 1963, and in South Africa until 1998. In nations that experience water stress or water shortages, groundwater is primarily state-owned and controlled. Nations that recognize the idea that the people own groundwater collectively as a common resource are working toward developing new policies to address shortages and at the same time ensure that individuals have access for at least domestic use if not for livestock or minimal irrigation. In areas under severe water stress, securing groundwater might not be feasible for individuals, even if a right to water exists.

U.S. GROUNDWATER PERMITTING AND USE

Each U.S. state authorizes some state or local agency to permit groundwater uses in areas where groundwater use is regulated (see Table 3.3). Table 3.4 shows each state's regulatory limits for exemptions from permitting. The regulatory terms of "exempt" or "non-exempt" wells refer to the exemption from the permit process, when states may impose costs on landowners for the right to use groundwater.[97] State authorization of exempt uses may permit domestic use, gardening, livestock, and/or small-scale irrigation.[97]

Domestic use of about five hundred gpd is what an average North American conservation-conscious family of four would use for drinking, flushing, showering, and laundry each day,[98] estimated at one percent of national total water use.[97] Groundwater use limitations for gardening are uncommon; when they exist, usually the maximum amount of acreage that can be watered is specified. Watering livestock, which in some states is included in exempt use, could consume on average 10 gallons per head per day, depending upon the animal breed, weather, and forage,[99] a smaller volume of water compared to irrigation and municipal use. For example, California led the nation in livestock watering by using about 204,000 acre-feet of groundwater, following by Texas at about 153,000 acre-feet of groundwater each year. Within the U.S., groundwater accounted for 58 percent of all livestock watering.[100] Exempt use volumes range from about 400 to 100,000 gpd, far more than that required solely for human sustenance or health.[101] Nationwide, irrigation surpassed all other uses dominating groundwater withdrawals at 67.2 percent, followed by public supply at 18.4 percent, domestic use at 4.7 percent, industrial use at 3.9 percent, aquaculture at 2.4 percent, livestock at 1.6 percent, mining at 1.3 percent, and thermo-electric power at 0.6 percent.[102]

DISCUSSION

Each state controls groundwater withdrawals using one of the six groundwater doctrines or a combination of these approaches, with diverse exempt use rates. Due to increased use and declining water elevations, starting in the late 1990's many states began to modernize their approaches to groundwater management and regulation, including Texas. State legislatures promulgated administrative rules seeking to slow or stop water elevation declines, maintain or restore groundwater quality, while allowing exempt uses to continue in varying quantities.

Table 3.3 State Agency, Groundwater Policy and Doctrine

Regulatory State Agency, Policy and Doctrine
Alabama Water Resources Commission, Office of Water Resources, Department of Economic and Community Affairs[103]: Reasonable Use[14]
Alaska Department of Natural Resources[103]: Prior Appropriation[103]
Arizona Department of Water Resources/local districts if present[103]: Prior Appropriation and Federal Reserved Right[14]
Arkansas Natural Resources Commission[16]: Reasonable Use with Prior Appropriation[15]
California State Water Board/local districts[103]:Public Trust, Reasonable Use and Correlative Rights[15]
Colorado Division of Water Resources/Seven Water Courts in non-district areas[103]:Prior Appropriation regulated through judicial permitting[103]
Connecticut Department of Environmental Protection: Rule of Capture, permits expire in 10 years[103].
Delaware Department of Natural Resources and Environmental Control/Division of Water Resources: Rights considered usufructuary, expire in 30 years [104], Reasonable Use with Prior Appropriation [15].
Florida Five Water Management Districts: Reasonable Use[15]
Georgia Department of Natural Resources: Reasonable Use, Regulated Riparianism rules[40; 105; 15].
Hawaii Department of Land and Natural Resources[106]; Commission on Water Resource Management: Public Trust[106] and Correlative Rights[15].
Idaho Department of Water Resources: Prior Appropriation with state ownership[107 2009].
Illinois Soil and Water Conservation District: Reasonable Use[103]
Indiana Department of Natural Resources[108] High capacity facilities causing failure of smaller user might have to provide water; Rule of Capture rights attached to the land [14]
Iowa Department of Natural Resources[103]: Modified Riparian[103]. Correlative Rights[15], state ownership[109]
Kansas Department of Agriculture Division of Water Resources[110]: Prior Appropriation; vested rights other than domestic and except for non-use[110]
Kentucky Division of Water[15]: Reasonable Use[111; 103]
Louisiana Department of Transportation and Development[103]: Rule of Capture[15]
Maine Department of Environmental Protection, Bureau of Land & Water Quality; Department of Agriculture[103]:Rule of Capture[15]
Maryland Department of the Environment[103]: Reasonable Use[112]
Massachusetts Department of Environmental Protection[103]: Rule of Capture[15]
Michigan Department of Environmental Quality[103]: Restatement (Second) of Torts[15]
Minnesota Department of Natural Resources[103]: Correlative Rights[15; 113]
Mississippi Department of Environmental Quality[103]: Rule of Capture[15] Sole Source Aquifer designation for all or part of 14 southwestern counties[114].
Missouri Department of Natural Resources[103]:Reasonable Use with Prior Appropriation[15], state goal is sustainable use[103]
Montana Department of Natural Resources and Conservation[103]: Prior Appropriation[15].
Nebraska Department of Natural Resources/local districts[103]: Reasonable Use[15], Correlative Rights[115].

Table 3.3 (continued) Regulatory State Agency, Policy and Doctrine
Nevada Department of Conservation, Natural Resources/Division of Water Resources[116]: Prior Appropriation, vested rights prior to 1913 for artesian or 1939 for percolating groundwater[103]
New Hampshire Department of Environmental Services[103]: Reasonable Use [117].
New Jersey Department of Environmental Protection[103]: Correlative Rights[15]
New Mexico Office of the State Engineer[103]: Prior Appropriation[118]
New York Department of Environmental Conservation: Reasonable Use[15]
North Carolina Department of Environment and Natural Resources[103]: Reasonable Use[15]
North Dakota State Water Commission[103]: Prior Appropriation[15]
Ohio Department of Natural Resources[15]: Restatement (Second) of Torts[15; 38]
Oklahoma Water Resources Board[15]: Private property right with Reasonable Use[119].
Oregon Water Resources Department[120]:Prior Appropriation[103]
Pennsylvania Department of Environmental Protection[103]: Reasonable Use[15]
Rhode Island Water Resources Board[103]: Rule of Capture[15; 121]
South Carolina Department of Health and Environmental Control[103]: Reasonable Use[103]
South Dakota Department of Environmental & Natural Resources[103]: Prior Appropriation[15; 122].
Tennessee Department of Environment and Conservation[103]:Reasonable Use[15].
Texas Groundwater Conservation Districts[123]:Rule of Capture[15] modified by districts rules only where there are districts[123].
Utah State Engineer[124]: 50 management areas[26], Prior Appropriation[15; 124]
Vermont Department of Environmental Conservation[103]: Correlative Rights[15]
Virginia Department of Environmental Quality[103]: Reasonable Use[15]
Washington Department of Health/Department of Ecology[103]: Prior Appropriation[15]
West Virginia Department of Environmental Protection[125]: Reasonable Use[15]
Wisconsin Department of Natural Resources[103]: Public Trust doctrine controls use,[126] Restatement (Second) of Torts[15]
Wyoming State Engineer's Office[103]: Reasonable Use[15].

Source: Rima Petrossian, 2012

Several states (including western states Arizona[13] and Utah[55]) quantify aquifer safe yields and reference those as a policy goal. Missouri[103] and Arkansas chose sustainability as a rule[103]. Water-rich states, usually areas with both higher rainfall and more surface water available, tend to choose a higher volume exemption limit, but this is not always the case. Texas ranks at the median all the states of domestic or livestock exemptions, below the estimated average of 44,290 gpd in 45 of the 50 states. The median and mean estimate included two values each for Alabama, Alaska, Delaware, Florida, Kansas, Maine, Maryland, and New York due to differing requirements within each state.

Table 3.4 State Exemptions for Groundwater Use

State: Exempt Amounts Upper Limits in gallons per day (gpd)
Alabama: Coastal area, 72,000 gpd[127]; up to 100,000 gpd for irrigation or non-public use[103]
Alaska: 500 gpd for any use, 1,500 for domestic use, eight other categories types specified[103]
Arizona: 50,400 gpd (35 gpm)[128]
Arkansas: 50,000 gpd, meter required for a sustaining aquifer[103]
California: No statewide value[103], withdrawal fee for each acre foot above 10 acre-feet[129]
Colorado: No statewide value; outside watering for under 35 acres; livestock watering for more than 35 acres[130]
Connecticut:50,000 gpd[103]
Delaware: 50,000 gpd (100,000 gpd in Delaware River Basin)[131]
Florida: State-wide: 100,000 gpd; District-based, Northwest WMD, 2 inch diameter[132]; St. Johns, 100,000 gpd[133]; Suwanee River, 10,000 gpd[134]; Southwest Florida, 2-inch diameter or less[135]; South Florida, not specified[136]
Georgia: 100,000 gpd on a monthly average[39]
Hawaii: Domestic use exempted, no value given; Water Management Area: 25,000 gallons per month[106]
Idaho: Domestic use exempt including irrigation of up to ½ acre; limit of 13,000 gpd[107]
Illinois:100,000 gpd[103]
Indiana: 100,000 gpd[103]
Iowa: 25,000 gpd[103]
Kansas: Domestic use, livestock, irrigation less than 2 acres exempt, no expressed maximum value[110]
Kentucky:10,000 gpd, domestic use and agricultural use exempt[103]
Louisiana: 50,000 gpd[78]; reporting required over 1,000,000 gpd[103]
Maine:50,000 gpd reporting base for more than 500 feet from surface water; 20,000 gpd for less than 500 feet from surface water[137]. 50,000 gpd for within 500 feet of surface water, 144,000 gpd use more than 500 feet from surface water[138]
Maryland: Domestic use, no value given; 5,000 gpd other uses or 10,000 gpd agricultural[139]
Massachusetts: 100,000 gpd or 9,000,000 gallons in a three-month period[103]
Michigan: reporting over 100,000 gpd, permitting for over 2,000,000 gpd[103]
Minnesota: 100,000 gpd or 1,000,000 gallons in a year[103]
Mississippi: 20,000 gpd in water use caution area, no limits for wells drilled prior to 1985, no permit for domestic use only, no value given[103]
Missouri: 100,000 gpd[103]
Montana: 50,400 gpd domestic or 10 acre-feet per year for livestock on over 40 acres[140]
Nebraska: 72,000 gpd[141]
Nevada: 1,800 gpd[116]
New Hampshire: 57,600 god[103]
New Jersey: 100,000 or combined pump capacity of 100,800 gpd[103]
New Mexico: Domestic use and small livestock 893 gpd[142]
New York: 100,000 gpd in the Great Lakes Basin and 64,800 gpd in Long Island counties[103]
North Carolina: Non-agricultural use 100,000 gpd; agricultural use more than 1,000,000 gpd[103]
North Dakota: 11,159 gpd domestic, livestock, fish, wildlife, or recreation[103]

Table 3.4 (continued) State: Exempt Amounts Upper Limits in gallons per day (gpd)
Ohio: Registration over 100,000 gpd, permitting over 2,000,000 gpd[103]
Oklahoma: Domestic users exempt under 4,465 gpd; 2 acre-feet per acre of land where incomplete yield studies[103]
Oregon: Domestic use 5,000 gpd, irrigation less than ½ acre, industrial or commercial less than 15,000 gpd, livestock watering, and down-hole heat exchange[120]
Pennsylvania: 10,000 gpd[103]
Rhode Island: 10,000 gpd[121]
South Carolina: Approximately 100,000 gpd (3,000,000 gallons per month)[143]
South Dakota: 25,920 gpd[103]
Tennessee: 10,000 gpd[103]
Texas: 25,000 gpd[123] (modified by GCDs, 10,000 – 100,000 gpd)[144]
Utah: Domestic use based on indoors 402 gpd; irrigation/outside 2-6 acre-feet per acre per year; livestock 0.00005 – 0.028 acre-foot per year[124]
Vermont: Commercial and industrial withdrawals greater than 50,000 gpd or 57,600 gpd; farms except those larger than 57,600 gpd and domestic uses exempt[103]
Virginia: 10,000 gpd (300,000 gallons per month)[103]
Washington: 5,000 gpd domestic, industrial, including irrigation use; livestock no limit; no limit for watering lawn less than ½ acre[103]
West Virginia: Any use, no specified value[103]
Wisconsin: 100,000 gpd or 70 gpm[103]
Wyoming: 36,600 gpd for well or 25 gpm domestic or stock [103]

Source: Rima Petrossian, 2012

Four states are not included in the estimate because these states do not have exemption values clearly specified or volumes were complicated by formulas for livestock exemptions depending on herd size. States like West Virginia, Mississippi, Louisiana, and Hawaii appear to have no apparent specified volumes for exempt domestic use. California seems to have no uniform, specified withdrawal limitations. Most water-poor, semi-arid states choose lower exempt volumes. Two coastal states are exceptions, Washington[145] and Maryland[146], with low exemptions of 5,000 gpd for domestic use, although these states have very different inland climate conditions compared to the coastal areas. Only Maine differentiated between properties near surface water, at 50,000 gpd versus property at greater than 500 feet away from surface water, at 20,000 gpd. Drier interior states quantified domestic groundwater uses for regulatory purposes. States that restrict domestic use (mostly limited to inside uses) included Utah at 402 gpd, New Mexico at 892 gpd (or one acre-foot per year), Nevada at 1,800 gpd, Oklahoma at 4,464 gpd, and Oregon at 15,000 gpd. In Tennessee, the domestic use limit is set at 10,000 gpd, but this state does not limit or charge fees for larger extractions.[147] In neighboring Georgia, the exemption is set at 100,000 acre-feet to accommodate small agricultural uses.[105] There are multiple cases of states with shared aquifers differing in the exempt withdrawal limits, which may cause interstate issues similar to international groundwater disputes.

COMPARING FOURTEEN U.S. STATE MANAGEMENT METHODS TO TEXAS

The previous overview of groundwater doctrines and exempt uses in all 50 states reflect qualitative and quantitative differences in managing groundwater. This section is designed to illustrate the path dependency outcomes of a cross-section of 14 state-level historic and current approaches toward managing and quantifying groundwater. Each state's varying geographic, climatic and political conditions provides a context for analyzing Texas' current approach including: Arizona, Arkansas, California, Colorado, Indiana, Kansas, Louisiana, Missouri, Nebraska, New Mexico, Ohio, Oklahoma, Oregon and Tennessee.

Arizona

History and Background

In 1948 Arizona's Legislature developed groundwater legislation for regulating irrigation,[4; 148] based on prior appropriation,[46] but this early legislation did not ask the question of how much groundwater existed statewide. In 1980 Arizona authorized the Arizona Department of Water Resources (ADWR) and passed innovative legislation to respond to water level declines in heavily used aquifers.[13] Arizona's new tiered approach established groundwater basin management areas in the parts of the state where 80 percent of the population reside and 70 percent of the aquifer overdraft occurs, where groundwater withdrawals exceed recharge rates.[13]

Since 1980 Arizona's planning approach addresses three issues through four 10-year planning cycles with the last plan projecting five years through 2025: limiting groundwater extraction; allocating groundwater based on changing needs; and increasing the water supply through resource development. The plan for each successive planning period has been more stringent in reducing withdrawal rates.[13]

Status

Arizona, an arid western state with concentrated agricultural areas, leads the nation in projected percentage increase in population growth.[149] The first tier of groundwater management is statewide, followed by Irrigation Non-Expansion Areas (INAs) and Active Management Areas (AMAs). Five AMAs, including 9 groundwater basins in Tucson and Phoenix, cover about 13 percent of the state.[45] The three INAs cover a much smaller area.[45] The public also may vote to form a new area.[13] In AMA areas, Arizona can issues seven types of permits including mine or other types of dewatering, associated mineral extraction, industrial, brackish or saline extraction, steam or hydroelectric power generation, drainage, or for monitoring purposes.[4]

Permitting

Permitting requirements differ in each managed area. A well not capable of producing more than 35 gallons per minute is exempt in groundwater areas with the most restrictive rules.[103] Grandfathered rights for irrigation reflect extraction rates between 1975 and 1980. There are several different use categories associated with specific amounts.[45] When a landowner sells her land, she may retain the groundwater rights separately from the land.[13] The state reserves another type of groundwater right, called Service Area Rights, specifically for municipal and domestic use.[13]To qualify for this right developers must prove that the aquifer can provide water for 100 years.[13]

Arkansas

History and Background

In its 1991 Water Plan Arkansas developed a statewide approach to managing groundwater that emphasized education, conservation, conjunctive use, and surface water development to supply the state's water needs.[150] Because of relatively low population, plentiful surface water resources,[150] and an average annual rainfall of 49 inches,[151] Arkansas relies less on groundwater than some states. Over-pumping from agricultural use has led to aquifer drawdown in the extreme southern part of Arkansas extending into Louisiana, and in the east-northeastern part of the state.[150]

Status

Sustainability is a fundamental tenet of groundwater management in Arkansas, which means that a user is expected to assure a sustainable yield and maintain aquifer levels, while protecting any future generation's rights. The Arkansas administrative method for achieving this balance was to establish Critical Ground Water Areas that issue groundwater withdrawal permits.[152] The Arkansas Natural Resource Commission holds public hearings before designating a Critical Area.[152] Less than half of the state has been designated, primarily in the eastern area encompassing the Mississippi Valley Basin, based on a combination of aquifer and county boundaries.[153] Some of the benefits to being in a designated area include having priority for federal and state programs, targeted educational programs, and tax credits for conservation practices.[150]

Permitting

The State of Arkansas owns the groundwater, studies and monitors the aquifers, and issues extraction permits without restrictions.[14] Arkansas laws use correlative rights so that each user has a right to reasonable use while depending upon other users' actions.[14] Arkansas defines groundwater to include both subterranean streams and percolating water. Landowners using groundwater for domestic purposes can extract up to 50,000 gpd without regulation.[14] Grandfathered wells are exempt, but they could lose that exemption if a substitute source exists that costs less or the same. Conservation practices for groundwater users might also allow exemption from regulation, otherwise permits are available at a nominal cost without restriction.[14]

California

History and Background

Californians first irrigated orange groves using groundwater in the Los Angeles basin in 1868.[22] By 1871, due to increased irrigation and groundwater elevation declines, the California Supreme Court adopted the so-called "rule of capture." Californians continued to increase groundwater use until 1889 when almost 90 percent of crops irrigated with groundwater in the U.S. were near Compton, which was later engulfed in Los Angeles sprawl.[22] After enjoying extensive groundwater development from irrigated agriculture in the latter half of the 19th century, in 1903 the California Supreme Court reversed California's original adoption of the rule of capture to using correlative rights.[154] Southern California was most likely the first area in the U.S. to realize that extensive irrigation with groundwater was not well-adapted to arid climates due to draw-downs in the San Diego area.[22] The courts based their decision to use the rule of correlative rights on other landowner's rights as well as the common pool nature of groundwater when considering groundwater disputes. In 1944, after a state study, the court ordered groundwater extraction to be adjudicated in certain basins.[22]

Status

The California Department of Water Resources (CDWR) indicates there are three ways that Californians can choose to manage groundwater resources: (a) through California Water Code and other statutes authorizing local entities; (b) local ordinances or agreements, and, (c) basin adjudication [154]. CDWR identified 10 primary hydrologic regions and 515 groundwater basins covering about 40 percent of the state. California relies on groundwater for 30 to 40 percent of municipal and agricultural water supply needs, depending upon the weather.[154] Although the CDWR does not regulate groundwater quality or use, they developed a Conjunctive Water Management Program, providing financial and technical assistance to stakeholders and local districts which prefer this management approach.[155] California courts have prescribed the limits and rights to groundwater extraction in parallel with a state-based system under CDWR identifying and monitoring groundwater resources. Local entities and the courts establish policy while statewide policy goals encourage limiting or preventing irreparable damage to aquifers. State statutes do not assert specific requirements on basin-wide management approaches.[14]

Permitting

As of 2010, California had not formalized groundwater rights, instead relying on agencies to deliver water and exercise authority over groundwater.[156] Over 20 types of local districts exist encompassing over 2,000 agencies.[156] The courts manage groundwater use with no state-level requirement to report activities to the CDWR.[156] Over 200 agencies statewide adopted various water management plans under California's water code. Thirteen agencies have regulatory authority over groundwater extraction and numerous agencies have some component of authority to regulate groundwater use. Twenty-seven counties have local ordinances regulating groundwater. California's courts have created a process within 19 groundwater basins allocating water via adjudication. Local ordinances restrict groundwater exports in order to limit groundwater depletion, land subsidence, and water quality declines. Court decisions describing basin boundaries and safe yields have led to basin adjudication limiting extraction.[154]

Colorado

History and Background

For a 125 years Colorado allocated groundwater based on 'first in time, first in right,' or prior appropriation, based on a first-use date. In 1965, Colorado recognized the interconnection between groundwater and surface water and distinguished two types of groundwater, tributary and non-tributary, based on how it affects surface water availability. Water hydraulically not connected to flowing streams is called "designated groundwater." This groundwater flow does not affect surface water, is non-tributary, and the state does not require users to replace this water. State law requires users to replace tributary water or water connected to stream flow. Four years later, in 1969, the state articulated differing sets of rights and standards for each groundwater basin it identified based on natural characteristics and use.

Status

Colorado has seven water courts responsible for adjudicating water rights. In addition, the Colorado Ground Water Commission identifies, regulates, and controls designated groundwater basins.[157] Like many states, Colorado recognizes beneficial use as a criterion for groundwater extraction, with 20 such uses officially recognized.[158; 157] Colorado has three avenues for regulating groundwater: the court system, a state agency, and the State Engineer's office (SEO). Colorado's prior appropriation regulatory approach has support within the state constitution, as two articles give the public property rights in groundwater.[159] In times or locations of scarcity, the state can mandate domestic use withdrawals as the highest priority, followed by agriculture and manufacturing.[4]

Permitting

After May 8, 1972, Colorado permitted groundwater wells for residential and livestock use.[159] In 1973, the ability of a landowner to appropriate unlimited groundwater was restricted to a case where a withdrawal did not impinge on another's right.[159] In such a case a water court would decide the right, limited to no more than one percent of what is available under the land owned.[159] The SEO issues groundwater extraction permits statewide.[158] The SEO permits exempt small wells in two-year increments.[158] It permits non-exempt and large capacity wells in perpetuity, as long as the owner signs a statement certifying the water's beneficial use.[158] Newer laws limit groundwater withdrawals to equal the amount owned beneath the land as determined by the state.[158] Colorado established subdivision rules requiring water supply studies for less than 35-acre tracts in subdivisions drilling a residential well.[158] A single lot less than 35 acres may also require additional information reported on the application regarding a proposed well location.[158]

Indiana

History and Background

In 1983 Indiana adopted state statutes limiting groundwater extraction and production.[160] In 1984, the Indiana Supreme Court reconfirmed the so-called 'rule of capture' by finding that groundwater is part of the land.[14] In 1991, the Indiana General Assembly adopted a bill requiring the Department of Natural Resources to develop a state water plan, called "Indiana's Water Shortage Plan."[161] As a reflection of that planning emphasis, citizens have a right to complain to the Indiana Natural Resource Commission if their extraction rate or water quality decreases.[14] Like most other states, this management approach does not allow malicious or unnecessary withdrawals.[14]

Status

In 2006 the Indiana General Assembly authorized a Water Shortage Task Force composed of 10 representatives from specified interests to update and implement the state water plan.[162] For groundwater, the Indiana Natural Resource Commission (INRC) collects information and monitors water levels.[163] The INRC defined seven categories of potential rate of extraction or well yield based on aquifer characteristics, such as groundwater availability.[163] A map of the entire state shows potential withdrawal rates ranging from less than 10 gpm to greater than 1,000 gpm.[164] Other agencies regulate mining water use.[164] If the groundwater situation meets certain criteria, the commission could declare an emergency and restrict extractions from larger producers. This policy also extends to potential extractions that exceed the local recharge rates.[14]

Permitting

The Indiana Department of Natural Resources (IDNR) issues permits for water use. The IDNR issue exceptions based on tract size for smaller landowners.[163] Each well on more than 5 acres for residential use or one acre for any purpose is designated as a Significant Water Withdrawal Facility (SWWF), capable and likely to interfere with smaller users; these facilities must report their water use to the Natural Resources Commission every year.[165] Individuals may withdraw up to 100,000 gpd as a small user.[163] Large groundwater users can withdraw unlimited amounts without a permit after registration, although they can be liable if small water users suffer.[163] The state is obligated to investigate complaints about groundwater from landowners.[163]

Kansas

History and Background

Legislation establishing groundwater management districts in Kansas covering the entire state dates back to 1972.[166] The legislature authorized "groundwater management districts," when such districts are confirmed by the voters in a proposed district.[166] This act recognized the value of conserving groundwater resources, supporting local control, and preserving the economy.[166] Districts, where formed, are subject to statewide policy goals. Each district issues groundwater permits based upon priority dates.[166] Rules governing these districts state that to help minimize depletion they may designate an intensive groundwater use control area where groundwater is being depleted at faster rates.[166]

Status

The prolific and ancient Ogallala Aquifer underlies most of western Kansas.[166] Of the five existing groundwater management districts covering a large portion of the aquifer, two western districts have planned depletion practices in place, one western district has zero depletion, and the two central districts have sustainable practices.[166]

Permitting

Groundwater districts currently cover less than half the state.[167] The law favors larger landowners in districts by limiting voting eligibility to users who own more than 40 acres.[168] Prior appropriations govern groundwater extractions for areas outside districts, other than domestic use, including watering gardens, orchards, or lawns less than 2 acres.[169]

Louisiana

History and Background

Although Louisiana is developing a statewide approach to groundwater management, its current system maintains a French-influenced, laissez-faire style of groundwater governance.[170] Louisiana's stated goals include long-term aquifer sustainability, economic benefits, as well as addressing water level declines, land subsidence, and salt-water intrusion.[170] The Ground Water Resources Commission (GWRC), a state agency, may designate critical ground water areas to monitor, called Areas of Groundwater Concern, and try to control aquifer depletion and other problems.[170] In 2005, the GWRC designated one area as critical due to aquifer level declines: the transboundary Sparta Aquifer located both in northern Louisiana and southern Arkansas.[170] In 2011, the GWRC declared parts of the Carrizo-Wilcox and Upland Terrace Aquifers in a groundwater emergency, requiring reductions in withdrawals and conservation efforts to manage groundwater availability sustainably.[170]

Status

Louisiana adopted civil law in 1808, which recognized the absolute ownership concept.[170] Louisiana's legal framework recognized the similarity of groundwater to oil and gas.[170] In 1963 the Louisiana Supreme Court applied the so-called 'rule-of-capture' rather than absolute ownership in *Adams v. Grigsby* to address groundwater ownership.[170] Its courts have recognized that groundwater travels unpredictably under natural circumstances, so that groundwater ownership may change as it moves from property to property.[170] Once groundwater migrates, the landowner loses ownership.[170]

Permitting

In 1972 the Louisiana Legislature authorized the Department of Public Works to register wells producing greater than 50,000 gpd, although Louisiana has yet to issue permits.[14] Act 49 passed in 2003 created the Ground Water Resources Program,[170] which requires landowners or drillers to file a notice of intent to drill to obtain a well registration.[14] In 2010 the Louisiana Legislature imposed requirements for wells producing more than 1,500 gallons per minute.[170]

Missouri

History and Background

The state addressed private groundwater wells in its Water Well Driller's Act of 1985, although the general intent of the act established well construction standards to ensure safe drinking water rather than regulating groundwater extraction volumes.[171] In 1989, the Missouri Legislature authorized the Department of Natural Resources to develop a state water plan.[171] Although the state indicated in its water plan that the aquifers should remain at a stable volume, the state policies in place do not support aquifer management, so landowners may use water in any reasonable way.[171]

Status

Missouri acts under riparian rules, which allows landowners to extract unlimited volumes of groundwater and export if there are no consequences to other users.[172] Missouri also supports the idea that water conservation is for the benefit of future generations.[172] Although subsurface or groundwater is considered "water of the state," it is also controlled through the "rule of reasonableness," where most disputes are solved in court on a case-by-case basis, not through regulatory processes.[172]

Permitting

The Missouri Department of Natural Resources administers all groundwater permits, groundwater studies and projected use.[172] Missouri landowners have a right to pump up to 100,000 gpd of groundwater without a permit, registration or reporting, and have the right to give others the right to use their groundwater, but they cannot sell or trade that right separate from land ownership.[172]

Nebraska

History and Background

Until 1975 Nebraska utilized a modified reasonable use doctrine with correlative rights for its groundwater laws that holds groundwater in trust for the public. In its Groundwater Management Act of 1975, Nebraska addressed the Ogallala Aquifer's high levels of extraction for irrigation and groundwater level declines.[173] The act established local regulatory districts called Natural Resource Districts (NRDs), which control more than just the groundwater extraction.[173] These local districts encourage stewardship and best management practices for irrigation, and some supply rural areas with water.[174]

Status

Nebraska's jurisdiction for groundwater rests with local districts that can issue well drilling moratoriums, restrict well spacing, and allocate groundwater to users.[175] Nebraska's locally controlled NRDs are similar to Texas' GCDs; both are required to submit a groundwater management plan to the state.[175] Currently 23 districts cover all of Nebraska.[175] In 1996, the Nebraska legislature recognized the surface water and groundwater connection and sought to integrate their management in four districts.[173] In 1999, state law changed to require conjunctive management in all districts.[173]

Permitting

Landowners in NRDs are subject to state groundwater laws.[173] Permits are required for groundwater withdrawals for industrial uses over 150 acre-feet per year and are subject to other local laws where they exist.[176] State statutes require well registration for all types of wells drilled since September 9, 1993. There are two fee levels, as a user pays a lower fee for a well capable of producing less than 72,000 gpd.[176]

New Mexico

History and Background

Since 1912, the Office of the State Engineer implemented a prior appropriation system for withdrawal of New Mexico's groundwater,[177] defined as water beneath the ground in a reasonably defined channel.[118] Bracketing that adjudication system, irrigated agriculture flourished with the discovery of artesian pressure near Roswell in the late 1800's, then waned when overuse led to water level declines by the 1920s.[22] In 1927, additional statewide legislation targeted those local water level declines due to a USGS investigation in the Roswell area supervised by Oscar Meinzer, known as the 'father of modern groundwater hydrology,'[178] that determined artesian water groundwater should not be used for irrigation but shallower supplies could be developed.[179] This legislation sought to address the connection between groundwater and surface water and increasing groundwater use.[179] However, New Mexico courts declared the legislation unconstitutional in 1929.[179] In 1931, the New Mexico Legislature established the foundation for New Mexico's groundwater laws.[180] In 1953, the state began to permit groundwater applications of less than 3 acre-feet without prior appropriation.[14]

Status

In 2006, the State Engineer designated 40 underground water basins for the entire state; this designation revised an earlier decision (2005) adding six basins and extending nine basins.[181] Within each basin, if there is enough groundwater available for new permit applicants, the State Engineer can allocate water with withdrawal rights to 19 types of permit applications.[142] Water users may also request to change a surface water right to a groundwater withdrawal and vice versa through a permit application.[142] Based on a 2003 legislative directive the Interstate Stream Commission, responsible for water planning, develops regional and state water plans.[180]

Permitting

Landowners must apply for a permit to the State Engineer to extract groundwater based on prior appropriation and junior/senior water rights.[14] Water must be put to beneficial use.[14] Withdrawals are allowed if there is un-appropriated water available or if the proposed use will not affect existing right holders.[14] In 2006 the ceiling of permitted but un-appropriated water permits was reduced to 1 acre-foot [180], where the State Engineer issues a permit without the usual hearing, except for mine dewatering which is exempt.[14] Groundwater withdrawals are not allowed if they are found to affect more than 0.1 acre-foot of recharge to surface water flow in a fully appropriated stream.[118]

Oklahoma

History and Background

In 1949, the Oklahoma State Legislature authorized but did not enact a groundwater permit system designed to protect and conserve groundwater.[182] This clarified an 1890 statute linking groundwater rights to property ownership and reasonable use.[182] By 1962 non-exempt landowners could apply to the state for a permit to pump groundwater.[183] Prior to 1973 Oklahoma used prior appropriation for groundwater rights.[184] After 1973 the Oklahoma Water Resources Board (OWRB) began issuing correlative rights types of groundwater use permits for withdrawals equal to two acre-feet per acre owned or leased.[14] Permits are restricted to a landowner or lessee, and apply only for groundwater existing beneath the property, beneficial uses, with a limit that no water is allowed to be wasted.[185]

Status

The OWRB conducts technical studies of groundwater availability in order to establish the maximum amount of groundwater extractions in each basin.[186] By definition groundwater must be available for a minimum of twenty years and is allocated on a per-acre basis.[185] Groundwater availability, called maximum yield, is quantified through calculations using surface land area, recharge and discharge rates, amount of water in storage, transmissivity, and water quality.[186] In minor aquifers, the calculation includes water use type, recharge and discharge, geography, and other relevant variables.[14]

Permitting

State law allows landowners the right to withdraw groundwater at five acre-feet each year for non-household use or for domestic uses including grazing animals and irrigating up to three acres for a garden.[186] The landowner must put the groundwater to beneficial use, which may include selling it.[14]

Ohio

History and Background

Although Ohio abandoned the so-called 'rule-of-capture' in 1984,[38] its case law shares a historical commonality with Texas case law, as the Ohio courts linked groundwater extraction to private property rights with the English case of *Acton v. Blundell* (1843).[38] Unlike Texas, the Ohio Supreme Court indicated explicitly that any governmental control could result in a unconstitutional taking, strengthening the property right.[20] Each landowner has a right to extract unlimited groundwater; if a neighboring user also has such a right, then neither user could effectively claim they had an exclusive right to the groundwater, because both did simultaneously.[20]

Status

Since 1990, the Ohio Revised Code Section 1521.17 articulated the ALI Restatement (Second) of Torts method of evaluating the reasonableness of groundwater use and established criteria for groundwater management. The Ohio Legislature authorizes the Ohio Department of Natural Resources to quantify groundwater availability, register wells, and develop maps of the aquifers. Ohio considers recharge to be the standard basis for a determination of groundwater availability. Current water resource management is a stakeholder process based on individual watershed delineation and planning.[187]

Permitting

For groundwater extraction, if a landowner produces more than 100,000 gpd, then a landowner must register that well with the state.[188] If the state declares an area as being under stress, the state can establish groundwater extraction thresholds triggering well registration in that area.[188] The state considers nine use parameters: (1) purpose, (2) suitability to the aquifer, (3) economic value, (4) social value, (5) level and magnitude of harm caused, (6) feasibility of circumventing harm by changing use or process by affected parties, (7) feasibility of changing volumes extracted by affected parties, (8) guarding existing use, land, financial interests, and businesses, and (9) fairness in loss by parties affected.[188]

Oregon

History and Background

Since 1909, the Oregon Water Resources Department (OWRD) controlled the water rights and issued permits for surface and groundwater according to the Oregon Water Resources Commission (OWRC) directives.[189] Water rights originate with land ownership, but are considered state-owned, state-controlled, and appropriated by date.[190] Groundwater and surface water regulations are linked, and both require permits for use, to ensure that entities consider conjunctive management options.[14]

Status

In 1989, the Groundwater Quality Protection Act[190] authorized the Oregon Department of Environmental Quality to designate critical groundwater management areas based upon geographic features or geologic or hydrogeologic formations.[191] Groundwater management areas currently do not cover the entire state because the state designates areas only after a local area experiences water quality problems or over-drafting issues. The Oregon Administrative Code defines economic pumping levels and expresses parameters to define waste or injury to other users. Withdrawal requests can be limited by public health, safety, or welfare, with municipal use, agriculture, commercial, industrial, geothermal, or recreational uses.[4] The Water Resources Commission designates three types of regulatory approaches: (a) Classified Areas restricting classes of permitted use; (b) Critical Groundwater Areas may limit or reduce permitted amounts to stabilize groundwater levels declines, and (c) Groundwater Withdrawal Areas where groundwater is designated as not available for additional permitting.[192] The state uses sustainable management principles, called sustainable annual yield, to determine if it has appropriated the aquifer completely by measuring groundwater level changes to see if basin users are withdrawing more water than the aquifer is recharging.[192] Users can be restricted from using the permitted amounts.[192]

Permitting

Permits are required for well construction and use. Once a permit is issued the user must demonstrate five successive years of extractions or the permit might be revoked, but there are specified exceptions.[14] Oregon must view the water use as beneficial and may limit permits based on potential well interference. Limiting groundwater use to certain categories or users, may be used or rotating allowed pumping days may be used when regulation becomes mandatory for any reason.[4] Exemptions from regulation include watering livestock, domestic uses less than 15,000 gpd, and commercial or industrial uses less than 5,000 gpd.[4]

Tennessee

History and Background

Tennessee follows a regulated riparian model that allows each landowner to use the amount of water from any source that they need as long as a neighboring landowner is not injured through that use.[14] Surface water and groundwater are treated in a parallel manner by the legislature and the courts.[65]

Status

The Department of Environmental and Conservation (DEC) requires public water suppliers to report monthly pumpage, no matter what the water source.[65] The DEC regulates water quality issues such as subsurface sewage disposal systems. Nine counties have developed local programs, which included bacteriological well testing, soil analysis, technical consulting, land use and development, groundwater protection, and promotion of public sewers.[65] Tennessee publishes public participation opportunities on a public notice section on their website and encourages feedback through an email application.[65]

Permitting

In 2002 the Tennessee Legislature passed the Water Resources Information Act that requires the DEC to regulate landowners through reporting any annual groundwater extractions greater than 10,000 gpd. Agricultural use, water purchased from a business or utility, emergency or one-time uses are exempt from regulation, no matter how much is withdrawn. The state does not issue use permits and the courts have not defined a landowner's water rights.[14]

DISCUSSION

Groundwater resource management initially followed an expansion trajectory in the U.S. Water development practices and rules supported withdrawing as much groundwater as possible to increase economic opportunities up to the late 19th century and first half of the 20th century. These practices changed rapidly in the second half of the 20th century as many states observed declining water levels. Currently states are considering factors such as ecosystem services, contamination, conserving agricultural withdrawals rates to extend aquifer continuity, to considering rights and fairness to landowners within permit systems. Each of the 14 states listed above considered groundwater issues during different times in their statehood development. Each state's legislatures chose differing, path-dependent approaches, specifications, and levels of implementation of groundwater regulation. Common groundwater issues in many of these states include increased groundwater use through mostly urban growth, increased irrigation use, and declining groundwater quality. For the multi-state Ogallala Aquifer, for example, the Kansas Legislature set policy for groundwater use in the entire state where the prior appropriation doctrine prevails, favoring larger and historical landowners and users in groundwater districts. This system has more restrictive management methods than Texas' planned depletion under the so-called 'rule of capture.' Researchers cite Nebraska's groundwater conservation districts, in contrast to Texas, as self-regulating the Ogallala Aquifer conservatively with consideration for current farming profits not overwhelming future generation's rights. Oklahoma and New Mexico govern much smaller areas of the aquifer with differing approaches as well. New Mexico employs prior appropriation groundwater basin permitting, with domestic withdrawals limited to one acre-foot per year[118] or 893 gpd. Oklahoma adopted the reasonable use doctrine with a domestic exemption equaling five acre-feet per year[119] or 4,465 gpd, compared to Texas' 25,000 gpd or 17 acre-feet per year.[123]

Exceptions to statewide aquifer management exist within a state such as California, similar in physical size, population, and ecosystem diversity to Texas. California has a fragmented and local approach to groundwater management and compares in some ways to Texas' local and regional approach. Unlike Texas, California and Colorado are similar in that they use their legal system through the courts to decide groundwater issues on a case-by-case basis, although the underlying regulations in each state are opposites of each other, as California has private property rights and in Colorado the state owns the water. Unlike Oregon's concerns about water quality and contaminants, Texas current approach can only broadly address salinity impacts on groundwater availability in limited areas.

Almost every state restricts exempt use to a certain volume, specifically for household or domestic use with limited irrigation, with varying requirements for groundwater extractions above the exempt levels. Texas' 25,000 gpd exemption from permitting is unusual because it does not apply to that slightly less than 30 percent of the state without groundwater conservation districts. Most states (with exceptions such as Texas, Louisiana, Florida, North Carolina, and California) establish statewide withdrawal exemptions.

In several states, the state specifically prohibits landowners from profiting from their right to capture groundwater. Texas use of limited local control, property rights, and the rule of capture doctrine could support a water market. Australia, Chile, and the U.S. seem to be the best examples of countries embracing water marketing. Mexico, Peru, and Argentina are also experimenting with this management approach. In India, like Texas, people can drill their own well and market their water, although entry into a water market in India is expensive for the average person due to well-drilling prices. In contrast, in South Africa, groundwater is a constitutionally guaranteed public or common right. One South African could be denying someone else their fundamental rights if she or he withdraws more than another and a neighboring well's water levels drop significantly. Texans debate whether an individual should be prevented from or strongly supported in selling his or her groundwater for profit through the desired future conditions process. When compared to other states and countries, Texas' private property rights complicate groundwater management because decisions will reflect stakeholder and groundwater owners' actions.

SUMMARY

Texas groundwater law has a unique history and context that fits within the six competing doctrines currently controlling groundwater resource extraction in the U.S. and the framework of the groundwater regulation doctrine. Texas' new desired future condition process aligns closely to groundwater regulation due to the newly established groundwater management area process of GCDs deciding on the groundwater availability for an aquifer or part of an aquifer. When the Texas Supreme Court chose the so-called 'rule-of-capture' method for addressing property rights to natural resources that freely move across ownership boundaries, it applied that system to wild animals, oil and gas, and groundwater.[21] The approach implied absolute ownership. With the addition of groundwater conservation districts in 1949, this approach became something closer to groundwater regulation. One rationale for keeping the so-called 'rule-of-capture' is that the doctrine has a history, possibly developed first in ancient Rome or before and consistently applied for over 1600 years, as a means to assure what people expect as vested property rights. Other states (Ohio, California, and Utah) or countries (Australia and South Africa) preceded Texas courts in establishing groundwater legal precedence using English common law.[22] It is interesting that each currently uses a different doctrine to manage groundwater.[14; 4] In Texas 'rule-of-capture' is what people have been operating under for over a hundred years.[28] As statewide rainfall averages from under 8 inches (in) in the far west to over 48 in toward the far southeast,[193] Texas remains the farthest west and possibly the driest of all of the states using the rule of capture. Regional ecosystems which reflect rainfall patterns and constrain what resources are available must be the starting point for stakeholders and decision makers considering regulatory reforms.

Texas' original choice of the so-called 'rule-of-capture' is the basis for today's GCDs management approach and legislative directives. In Texas, GCDs have modified this rule with one or any combination of three additional doctrines: correlative rights, reasonable use, and prior appropriation.[194] Management under any doctrine limits groundwater use through combinations of five parameters: time, tract size, reasonable and/or beneficial use, future generations, and harm to the water resource or others. Statewide management approaches in some states do not address specific constraints defined by hydrogeology. For example, if a landowner is located so that if there is little or no groundwater available, none of these parameters will help the landowner extract groundwater. State groundwater management concerns and changes also reflect rural growth in the U.S.; in rural areas most landowners are relying on groundwater, so groundwater use may affect groundwater availability. The U.S. Geological Survey estimated that 24 and 59 percent of total water used is groundwater, nationwide[100] and in Texas, respectively.[98]

Groundwater managed through prior-appropriation favors landowners who began earliest to pump groundwater, in contrast to reasonable use or correlative rights. This would favor descendants of pioneers, or those who have stayed on the land of their ancestors and used the groundwater through the generations. If a municipality had the foresight to buy up water rights or land before they needed the water supply, they too would gain a longevity advantage in a location. Proponents of this system might argue that people who settled an area generations ago or municipalities with foresight deserve to be rewarded for their tenacity, patience, and planning. Others might counter with issues of inequality and unfairness toward new growth and development. Depending upon how people used the groundwater in the past, if the oldest users were also the biggest users, their continued use could drain the aquifer. With prior appropriation practices, though, smaller landowners may be able to use more than larger landowners, depending upon their past groundwater extraction. If significant drawdown occurs, then new smaller users would have little financial incentive for market entry if they had to drill deeper wells to accommodate current drawdown. This sort of system, based on the advantage of landowner stability and inheritance over time, might not be easy to support once another method was in place and aquifer levels had fallen from pre-development conditions.

The practice of issuing correlative rights, where groundwater is allocated based on per acre production rates, favors the larger landowners, and in particular a group producing a lot of groundwater. Tract size directly determines groundwater allocation. In Texas and elsewhere, most parcels get smaller as they pass through generations of owners. In addition, as more people relocate to rural areas, smaller or newer landowners would not be able to capture as much groundwater, which might limit using large amounts groundwater for industrial purposes or for inter-basin export. For irrigation, the acre-foot of groundwater amount allocated per acre would usually be sufficient for most crops, except for possible flood irrigation practices or intense applications. Under correlative rights all resource users share in cutting back or extracting less as use depletes the aquifer.

Reasonable use, the most common practice in the U.S., seems to consider 'fairness' as the main criterion to conserve the resource. Only uses determined as reasonable are allowable. Landowners may own and capture only groundwater existing directly beneath her or his property, which favors larger landowners. As with correlative rights, everyone using the resources shares equally in cutting back use or extracting less as their use depletes the aquifer. Restatement (Second) of Torts Rule seems fair due to the tests of beneficial use but seems to favor groundwater-rich areas that may not suffer from groundwater depletion. Because users are responsible for maintaining aquifer quality and quantity while using a reasonable share and not affecting surface water, this is far more restrictive than the other methods. Riparian rights seem to protect the public as a whole by considering the public good when allowing groundwater extraction whereas none of the other methods addresses this concept.

This chapter showed examples of U.S. states and other nations derived and currently govern groundwater in order to provide context to the common struggles and continued evolution of groundwater management approaches. Each jurisdiction employed methods inherited through past practices, yet some chose to move forward using approaches that limit withdrawals under water scarcity. Chapter 4 presents the methods used to uncover the stakeholders and decision makers voices surveyed statewide and in GMA 9

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Chapter 4: What Do Water Users Prefer and How Do They Value Groundwater?

Texas' 'desired future condition' (DFC) process has been difficult to implement because each stakeholder perceives the value of groundwater in her or his own way. Texas has developed its approach to developing groundwater availability statewide through the DFC process due to its 'rule-of-capture' history and its Legislature's preferences for development versus resource protection. Previously the law and practice asks diverse stakeholders to articulate, reconsider, and discuss previously unstated preferences or beliefs about use or value of their groundwater. Legislation in 2011 requires the decision makers to develop a report discussing the socioeconomic impacts of the chosen aquifer conditions. This consideration occurs with imperfect information about the present or future value of water. Stakeholders do not know how their 'future conditions' choice could affect future pumping within an aquifer system. Groundwater models that simulate how groundwater uses may interact provide a source of information about how pumping trends may affect user's ability to withdraw groundwater. However, such models cannot predict future groundwater levels at a local or landowner level, which concerns many stakeholders and decision makers nor do they address the economic aspects.

Decision makers charged with evaluating this new aspect of quantifying and considering the economic implications of groundwater availability decisions will need input from the water owners and users. This dissertation seeks to provide methods suitable for evaluating what is essentially a non-market good that has many aspects that are not easily financially quantified. An England's privatized demand management method for providing water has an easy financial evaluation of metered water delivered and price paid, a non-metered fixed cost per month without an associated volume, or a system such as in the Curu catchment in Brazil where the electricity demand per acre farmed for farmers irrigating crops could indirectly determine groundwater's financial implications.[1] Texas has no such uniform purveyance system due to private control of groundwater resources.

Table 4.1 lists a selection of methods useful when evaluating financial implications for natural resources include the contingent valuation method.[2] Financial implications of natural resources could be quantified using use and non-use values in what is called Total Economic Value (TEV) where use values are comprised of direct use, indirect use, options.

Table 4.1 Methods for Evaluating Environmental Financial Considerations

Method	**Example Advantages**	**Example Disadvantages**
Hedonic pricing (HPM)	Based on observable behaviors and easily found data	Cannot determine small price differences
Travel cost (TCM)	Based on observable behaviors and easily found data Inexpensive	Need easily observed behaviors Limited to behaviors with travel
Replacement cost	Based on observable behaviors and easily found data Inexpensive	Need easily observed behavior or averting reaction Does not measure non-use
Production function	Based on observable behaviors, water as an input, and easily found data Inexpensive	Understates WTP Does not measure non-use
Market price	Based on observable behaviors in a market or sales	Does not provide information for all valuations
Contingent valuation (CVM)	Measures non-use No need for observing behaviors	Many survey biases Controversial for non-use Expensive
Choice experiment (CEM)	Measures non-use No need for observing behaviors Eliminates CVM biases	Controversial for non-use Expensive Complex to interpret

Source: Birol, Ekin, and others, *Using Economic Valuation Techniques to Inform Water Resources Management: A Survey and Critical Appraisal of Available Techniques and an Application*, Science of the Total Environment, 365, Vol.1-3, 2006, 105-122.

This chapter introduces two methods used to explore groundwater valuation in this dissertation, including Contingent Valuation, and Interactive Qualitative Analysis which has components of Rational Choice Theory and Grounded Theory. These methods take advantage of the relatively low cost of surveying a large number of landowners, observable data is not needed for determining preferences, and offer an ability to estimate non-use values such as for Jacob's Well.

DESIRED FUTURE CONDITIONS DECISION PROCESS

Texas designates that its 99 or so GCD presidents choose the DFC of each aquifer within each GMA to determine the groundwater availability For example, four people within the Texas Panhandle Groundwater Management Area (GMA) 1who chair GCDs, the presidents of the North Plains GCD; the High Plains Underground Water Conservation District No.1; the Panhandle GCD; and the Hemphill County GCD, make the decision about DFCs. The number of decision makers in a GMA range from one GCD in GMA 3 to 21 in GMA 7; for most of the GMAs the GCDs number from 5 to 9.[3]

These decision makers are charged with making a decision about groundwater as representatives of all their local stakeholders, either through election or by appointment. Previous University of Texas at Austin research used film and interviews to identify seven narrative parameters of 23 GMA 9 stakeholders participating in the DFC process. Table 4.2 shows the five concerns stakeholders identified through the students' filming efforts and interviews.

Table 4.2 GMA 9 Stakeholder Narrative Parameters

Groundwater Decision Issues
Concerns in the groundwater management area
Consequences of no changes to the current process
Potential ways to deal with the concerns
Means and obstacles toward addressing concerns
Best potential policy outcome

Source: Eaton, David, Schwartz, Suzanne, and Sharp, Jack, *What Do Groundwater User's Want*, 2008, Policy Research Project Report, University of Texas Lyndon B. Johnson School of Public Affairs, Number 161, Austin, Texas, 239 p.

Two financial factors, economic impacts or ecosystem services, could be helpful to consider when deciding about future groundwater availability. Most groundwater exists unused, in a hidden or private market, or as multiple agricultural inputs making groundwater value difficult to discern. Groundwater can also be valued for its existence rather than use. Groundwater valuation can be created through aggregating user's choices expressed in focus groups. This chapter discusses five methods for identifying how water users value water: (a) value-based choice; (b) grounded theory; (c) rational choice theory; (d) interactive qualitative analysis and (e) contingent valuation. Table 4.3 lists these methods and approaches used for interpreting user's values.

Table 4.3 Methods and Approaches for Estimating User's Values for Water

Groundwater Valuation Methods and Approaches in GMA 9
Value-based Choice
Grounded Theory
Rational Choices Theory
Interactive Qualitative Analysis: DFC System Development and Analysis
Contingent Valuation: Willingness to Pay and Willingness to Accept Payment; Payment for Groundwater Management

Source: Rima Petrossian, 2013

This chapter assesses strengths and weaknesses for each of these methods. Chapters 5, 6, and 7 present the implementation of these methods through a mail survey, focus groups, and online surveys as instruments to collect water users' opinions and preferences.

ON RISK

Risk is one underlying factor that affects people's decisions about their groundwater resources. Swiss Scientist Daniel Bernoulli[4] reported one form of human aversion to taking risks in the 1700's: how people make decisions to avoid risk. Part of choosing to take risks includes a person taking into account their own values as part of risk-taking.[5]

DFC decision makers consider a number of factors controlling or restricting their decision. They must consider the potential risks of allowing too much groundwater extraction (possibly causing irreversible harm to an aquifer) or too few withdrawals that could harm the economy. They must balance the challenges of not accounting correctly for exempt uses and over-permitting or under-permitting because of it. They also reflect or fail to reflect landowner preferences, with the risk of not being re-elected or re-appointed to a groundwater conservation district board. A board member's economic or environmental preferences may affect a landowner's vote. Each person can manage their personal groundwater extraction and water uses to allow for continued use of the groundwater based on an expectation of future availability or loss of the resource. Kahneman and Tversky[4] tested the psychology of preference through scenarios where the threat of loss is more powerful that the possibility of gain. They noted that in 1738 Bernoulli first described risk aversion as the human characteristic that prevailed in decision making.[4] They argued that rather than a defined level of financial gain driving the utility of a decision, people select an option based on perceived value of that decision as measured by a departure, either gains or losses, from a reference that the person selects.[4] This results in inconsistencies in subsequent decisions because the decision reflects a perception versus an absolute financial gain or loss. For example, if Texas landowners do not sell groundwater or pay for it, they may withdraw groundwater with no gains or losses until a severe drought occurs. If landowners make choices based on perceptions and values rather than cost versus benefits, this ambiguity could lead to mischaracterization of the groundwater's utility or worth because any harm or good is not quantified prior to a choice.

DECISION MAKING AND VALUE-BASED CHOICE

Whether the Texas Legislature intended or not to elicit water-user preferences or values regarding groundwater, Section 36.108 created an expectation for a local- and preference-based process for deciding on groundwater availability and did not articulate any state –level policy goals. House Bill 1763 requires each small group of decision makers in each GMA to decide aquifer DFCs, based on specific scientific, financial, and stakeholder considerations.[6]

Mancur Olson's[7] research suggests that small groups (averaging 14 members) compared to larger groups (averaging 65 members) can be more effective at taking action to further a common interest rather than offering points of view or reactions. In a large group the individual participant may not take the trouble to understand the issue being addressed due to the reality of the small percentage of her voice in the greater chorus.[7] Hare [8] argued that a leader of a small group, for example of five members, influences the outcome more than a leader of 12 members. This suggests that the size of the group deciding about the desired future conditions is an appropriate issue to consider. This research will show that the current DFC process obscures stakeholder voices necessary to accomplish the development of a transparent DFC choice or one that reflects popular preferences.

VALUE-FOCUSED CHOICE IN DESIRED FUTURE CONDITIONS

People's environmental, financial, and social values influence their groundwater resource choices: what water they use, how much they use and for what purpose(s), how long they plan to use it, and how human uses influence the ecosystem. In 1992, Keeney[5] argued that the process of choosing a desired outcome is based in people's values; the process of choice of a desired outcome can be independent of perceived alternatives.[5] Keeney[5] developed a value-based choice framework for understanding how people make choices based on common values without policy directives or guidance. These ideas can be used to explore how voting members from GCDs could determine DFCs.

In the DFC decision, the Texas Legislature allowed GMA decision makers flexibility in their choices for Texas aquifers DFCs[6] rather than prescriptive alternatives (such as sustainability or aquifer mining), or numerical withdrawal quantities (as is the case in the Edwards Aquifer).[9] A DFC decision requires the set of GCD presidents to select what they prefer or would want to happen, rather than identify what is possible or necessary. A DFC is defined as groundwater conditions used as the basis to scientifically calculate "managed available groundwater" (now "modeled available groundwater") or MAG volumes.[10]

A value focused decision differs from an alternative-based approach (choices available) given as specific policy guidance, such as mining aquifers at a certain rate or withdrawals specified to obtain a certain volume or to sustain the aquifer at a certain level. Table 4.4 lists four recent examples of value-based decision research and outcomes. These outcomes can be applied to the DFC process. For example, the framework for value-based decisions includes methods to identify, measure and quantify objectives.[5] The original DFC framework did not require decision makers to define groundwater uses considered highest or best when establishing groundwater availability. The DFC process did not ask how much would be used or what is beneficial use. It did not require anyone to examine the financial implications of a range of decisions that would further define and help to quantify the objectives.[6] Section 36.108 DFC guidelines set one objective: make a decision about the desired future condition of a relevant aquifer.[6] By 2011 new legislation in Senate Bill 660 required each GMA to explain DFC guidelines economic implications, environmental impacts or other choices considered, and why they were rejected.

Table 4.4 Value-based Decisions and Risk Research

Outcome	Author(s), Year, Topic
A method called integrated water resource management (IWRM) increases people's acceptance of policy decisions by allowing different ways of valuing water.[11]	Ben Orlove, Steven C. Caton, 2010, Anthropological assessment of water sustainability and governance
The pressure to avoid guilt and blame and pressure to conform to norms prevails when groups make decisions that may affect others welfare.[12]	Ming Gong, Jonathan Baron, Howard Kunreuther, 2009, Evaluating group and individual responses using the prisoner's dilemma and uncertainty
Americans support policies to mitigate climate change and have a moderate risk perception of climate change, however, Americans also oppose carbon-tax proposals.[13]	Anthony Leiserowitz, 2006, Assessing climate change risk perception by considering the roles of affect, imagery, and values
Value-belief-norm theory can help explain pro-environmental behavior in general but each target behavior needs its own explanation because there are a wide range of causal factors that might preclude creating a general theory to help alter people's damaging behaviors.[14]	Paul Stern, 2000, Identifying factors of environmentally significant behavior that may cause or contribute to environmental problems using the value-belief-norm theory

Source: Rima Petrossian, 2012

The explanation does not set objectives or seek to quantify the desired future condition decision.[15] It is not possible to know whether decision makers sought to conform to perceived social pressure to social norms or to avoid guilt over making a decision, as the process requires neither popularity nor sound or logical decision making.[16] After the decision is made, if a DFC is significantly different than past groundwater practices, the decision makers will have to identify specific and measurable objectives in order to cause people to change their behavior and expectations.[17] After the GMA decision makers identify the DFC objectives they wish to pursue, their water users may or may not agree.[18]

GROUNDED THEORY AND INTERACTIVE QUALITATIVE ANALYSIS

Grounded Theory is a term that refers to theory built from surveys or interviews of people experiencing a phenomenon: human responses drive theory, rather than external presuppositions.[19] This method allows an analyst to use people's behavior, words, and descriptions of their environment and experiences to define relationships within a system. These descriptions better explain the phenomenon than a researcher's pre-conceived ideas about the components of an experience or system.[19] This dissertation provides a theory about the desired future condition process through compiling landowners and decision maker's reactions to the process.

Interactive Qualitative Analysis (IQA) incorporates grounded theory as well as quality theory (from Total Quality Management) ideas about power and knowledge within systems theory.[20] This approach intends to capture how respondents answer a set of research questions designed to describe a familiar phenomenon.[20] Some of the questions IQA seeks to answer would be: (a) what are the components of the system; (b) how are they related to each other; (c) if data are available, how do two or more of these systems compare; (d) what drives the system, and (e) what is the relationship among drivers and outcomes.[20]

Table 4.5 illustrates examples of research framed using the IQA process to help to show the breadth of the method's application. For example, researchers use IQA to describe systems such as being an elementary school teacher, careers counselors' attitude toward students and the effect on their advice to students, seminarian's research choices, and school environments forming teacher motivation.

Table 4.5 Interactive Qualitative Analysis Studies

Author, Year, Reference, Description
Shannon Lasserre-Cortez, 2006,[21]: In an elementary school setting, teacher's articulating their views indicated that a school principal drives the system of the typical elementary school; teacher's identified the primary outcomes of being an elementary school teacher as stress and keeping the job/school culture.
Daniel Lodewyckx, 2006,[22]: In a school's career counseling center, the school counselors identified that their attitude toward the students and counseling drives the system of student career counseling; counselor's identified the primary outcome of counseling students as the authenticity of their approach leading to successful career choices.
Timothy D. Lincoln, Laura M. Lincoln, 2011,[23]: At a seminary, seminary students identified self-care or the process of preparing to do research driving the system of seminarian's research; revising is the primary outcome of research efforts.
Ruth Mampane, Cecilia Bower, 2011,[24]: In a school setting, teachers perceptions revealed in four separate case studies indicated that school environment, school resources, socialization and school curriculum are the teachers primary drivers; positive future goals, ensuring care and safety, future goals, and reaching goals are the four primary outcomes, respectively.

Source: Rima Petrossian, 2012.

Northcutt and McCoy[20] designed a process for convening focus groups, interviewing people and interpreting resulting data. Their approach to selecting focus group participants starts from members chosen for their experience; participants describe the subjects' system as a phenomenon called here as *the subject.*[20] A facilitator leads a group through a form of guided imagery to establish people's perceptions and preferences regarding the subject matter [20]. Each person has 10-15 minutes to write in silence [20]. Each person then writes down single phrases or sentences in response to a question, asking some permutation of "tell me about your experience with *the subject*" [20]. Together the group posts their ideas on a wall as the facilitator groups responses into similar ideas or categories, and the group develops and agrees on a sentence or several words describing the subject.[20] Ideally the phrases can be allocated into a system with 8-12 elements or categories [20]. After this exercise is over, the facilitator interviews each person individually and asks for an interpretation of the relationship of all possible pairs of elements, or identify which item of the pair is driving the relationship.[20]

These elements serve as the foundation for developing a flow diagram modeling the subject, including how each element interacts with other elements. Drivers, on the left of the flow diagram, lead to outcomes (on the right depicted by boxes labeled with categories), as connected by one-way arrows. These interviews, designed to reveal stories about people's experience of the subject, serve as the basis of composite narratives.[20] Each person's interview provides part of the composite narrative. The narratives do not distinguish among different voices, but help define what people mean when discussing their experience with each element.[20] The concept is that IQA can capture how the majority of people define their experience with the subject and what drives a system.

The IQA researcher develops several tables capturing the count and direction of the interaction among all element pair combinations after all persons have been interviewed.[20] These tables are used to sort relationships from the most often cited, with the same relationship driving the connection to the least often cited case, with no relationship recognized by any of the participants.[20] In these summary tables, the cumulative frequency, cumulative percent (relation), cumulative percent (frequency), and power of the relationship is reported for each element pair comparison.[20] The method then selects and includes 80 percent of observations that determine the direction or causality of the relationship, called the Pareto Protocol, to ensure that the relationships chosen to describe the system explain total system variation.[20] Those relationships are illustrated as a flow chart, called a Systems Information Diagram (SID), using single-headed arrows to represent the direction of action, from driver to outcome.[20] Redundant arrows are eliminated from the diagram.[20] What remains is a parsimonious representation of the subject as a system with at least one driver and one outcome.[20] Flow diagrams can be used to identify and categorize focus group outcomes, which in turn can be tested for relationships that illustrate recursion or feedback loops within the system.

DECISION MAKING AND RATIONAL CHOICE THEORY

The DFC decision process involves both evaluating forces behind stakeholders' personal decisions and the GMA decision maker group DFC decision. An underlying assumption and motivation in this research is that people are rational and self-interested as they are make economic or financial choices. Stakeholders are expected to be influenced by each other's beliefs within a small group and yet make rational choices to support their own interests.
Rational Choice Theory (RTC) emerged out of Max Weber's categorizing people's actions into four orientations coupled with Talcott Parsons' research[25] addressing the theory of the structure of people's interactions.[26] RTC addresses people's action of habit, emotion, values, and rationality[25] and uses two of the four orientations Weber developed.[27] The two rational actions used are called 'instrumentally rational' and 'value-rational' versus the other two orientations, affectual or emotional, and traditional or habitual actions [28]. RCT assumes that peoples' cognition, judgment, and intelligence control their decision-making because people are more sophisticated than Weber's premise that habits or emotion per se control rational choices.[27]

Aquifer DFC comments resulting from landowner and decision maker surveys indicate that groundwater use decisions may result from both rational and emotional or habitual actions, indicating that more complexity might help better describe the DFC process. George Homans observed in groups of people forms of social obligation and reciprocal behaviors driving interactions[25]; this reflected interactions of behavioral psychology, economics, influence dynamics, and small group interactions.[29] For example in a group tasked with deciding a DFC there would be one public meeting required each year for discussing the DFC process.

Technically a public meeting means that stakeholders are observers and participate only when invited to be part of these organized discussions. Decision makers may participate for longer than the five-year decision cycle due to their term length or district employment. Their interactions at the meetings with other GCD representatives may activate new views carried back to the home district. Stakeholders attending the meetings may or may not be a good gauge of the support or opposition for these new views.

Homans found that outside of laboratory experiments, quasi-experimental field tests simulated basic social behavior well.[29] Wassinger[30] indicated that Homans' research revealed that peoples' interactions in small groups reflected exchanges of both material and emotional goods; those who 'gave' a lot expected much in return. Homans argued that in any small group each person wants to get more than the others, which reveals the financial nature or peoples' tendency toward valuation of the social or emotional part of exchanges, not necessarily the material gain.[29] Although these premises are not tested for the decision makers, stakeholders' financial choices and hand-written comments in surveys reveal some emotional reactions about GCDs controlling groundwater use. Homans drew upon Festinger's theories about groups: people evaluate their own behaviors and compare others' behaviors to themselves.[31] When comparable social and physical quantitative data are not available, these subjective self-evaluations can be inconsistent in a small group setting.[32] Future research about the decision maker's motivations could help to add to theories about group behavior and further define the DFC system, but is beyond the scope of this research. Table 4.6 lists examples of research using the RTC framework. These examples, such as action from a group is greater than the sum of individuals' actions, help to frame the DFC decision process.[33] Another aspect of the DFC process reflects the outcome that long-term decisions are based on values rather than interests.[34]

Table 4.6 Rational Choice-based Research

Outcome	Author, Year, Title
Action from a group is greater than the sum of individual actions, but participants narrowly see their choices as what should happen and break down decisions into the smallest actions[33]	Talcott Parsons, 1949, The Structure of Social Action[33]
Social behavior is an exchange of goods related by the theories of behavioral psychology, economics, influence of dynamics, and structure of small groups[29]	George C. Homans, 1958, Social Behavior as Exchange[29]
Long-term processes or decisions are based on values rather than interests[34]	Stephen Kalberg, 1980, Max Weber's Types of Rationality: Cornerstone for the Analysis of Rationalization Processes in History[34]
Weber's ideas of rational action and non-rationality are being questioned through modern ideas of American Pragmatism, feminism, and postcolonial studies[27]	Mustafa Emirbayer, 2005,Beyond Weberian Action Theory[27]

Source: Rima Petrossian, 2012

CONTINGENT VALUATION (CV)

Prior to this research, neither GMA 9 board members nor GCD staff had sought to develop market valuations of aquifers. This project has developed diverse means for eliciting how landowners value groundwater and the financial implications of the DFC process based on contingent valuation (CV).

During the period prior to the 1970's federal dam and irrigation project decisions were based on cost-benefit evaluations for "making the desert bloom."[35] The federal government sponsored studies to uncover the value of natural resources other than the water.[36] CV methods were developed during the 1970's and 1980's to estimate the economic damage or projected economic impact from large environmental disasters. Federal laws holding the offending parties responsible for cleaning up after disasters obliged those responsible to determine how much money should be spent to clean up. Arrow and others[36] developed a direct method using surveys to induce people to value a resource. When there are little or no data available to value a resource directly,[37] their goal was to create a reasonable estimate of financial consequences in environmental changes, such as increased tourism or reduced natural resource production.[35] Arrow and others[36] acknowledged arguments against the use of CV, such as the influence on the outcome depending upon the survey details or the tendency of respondents to inflate a valuation. Arrow and others[36]developed guidelines to ameliorate some risks that (a) the survey instrument does not measure exactly what the researcher expects to measure; (b) people may not answer rationally; and (c) respondents may not take the survey seriously because their answers are not intended for use by officials or institutions.[37]

In the past, some CV surveys arose out of litigation, concerns about environmental problems, or past disposal practices.[36] Researchers created studies to measure future potential environmental losses or damage in order to measure the effectiveness of government programs and policies.[36] These studies elicited opinions from potentially affected persons through survey instruments because they could not rely on consumer behavior in the marketplace.[37] Researchers wished to increase the validity of CV to provide reliable information about future losses[36] and address gaps between generating non-market valuation and natural resource production and function.[38]

There are variables useful for CV surveys to determine a non-market value. Boyle and others[39] analyzed eight CV studies and identified three variables for valuing groundwater: resource characteristics; respondent attributes; and survey question formats. They found that respondents assumptions or beliefs about the groundwater conditions (how much groundwater exists or contamination levels) influenced survey responses.[39] These results suggest that respondents need to understand the current and future groundwater conditions to value the resource. Six of the studies provided cost of substitutes for groundwater.[37] Open-ended questions compared to dichotomous choice formats resulted in different responses, suggesting that question format matters.[37] People's source of drinking water, owning a well or getting water from a public provider, was a significant personal attribute determining people's valuation of groundwater.[37] Table 4.7 lists examples of research using the CV framework.

Table 4.7 Leading Contingent Valuation-based Research

Authors, Year, Reference, Contribution
Kenneth Arrow, Robert Solow, Paul R. Portnoy, Edward E. Leamer, Roy Radner, Howard Schuman, 1993[36]: Developed guidelines to assess/report environmental damages, used economic considerations without specific market values; used people's resource valuation, through survey questions, to quantify program budgets and costs.
Terry L. Anderson, Donald R. Leal, 1998[35]: Compared case studies nationwide to develop policy options. States addressed groundwater management issues such as the damage to the soil in the Central Valley, California, from irrigation and Ruby River, Idaho fish kill to support Bureau of Reclamation transition to water conservation and efficiency agency rather than surface water development.
Kevin J. Boyle, Gregory L. Poe, John C. Bergstrom, 1994[39]: Produced analyses of several case studies about how peoples' assumptions about water resource issues such as supply or contamination will influence their willingness to pay.

Source: Rima Petrossian, 2012

SURVEY METHODS: FINDING PEOPLES' PREFERENCES

This project used CV through mailed surveys to elicit landowners' groundwater valuation where no market exists. Most people in GMA 9 own their wells and pay for well drilling or pumping costs, not the water resource. The initial survey question (see Appendix A) established whether each respondent owned a well and how they used it. Additional survey questions had both dichotomous and open-ended questions. A short explanation about the resource, alternatives, and/or costs prefaced the three cost-related questions. The CV method proved to be adaptable to this analysis. The additional methods of convening contemporaneous focus groups responding to parallel questions helped to address DFC risks.

Surveys

This project developed CVs from surveying 4,604 landowners in GMA 9. Surveys instruments include brief background descriptions. Previous research had indicated that peoples assumptions about water resource issues (such as supply or contamination) can influence their willingness to pay for interventions.[39] By providing introductory explanations about groundwater management in their district and GMA 9, participants could have a better idea of the concerns and criteria for groundwater management decisions and possible alternatives. Surveys use sampling to develop insight into common traits, practices, or beliefs of a large population using sampling: through mail, telephone, or the Internet.[40] According to Arrow and others,[36] the most valuable survey questions are close-ended. They also indicated that surveying stakeholders in person (followed by telephone interview and mail) is the best approach although it is usually the most expensive.[36] Callegaro and others[41] reported that caller identification, answering machines, and voice mail might be contributing to lower response rates. An advance letter appears to increase response rates and enhances legitimacy by reducing suspicion and surprise, although it effectively doubles the cost of a mail survey and increases the cost of a phone survey.[42; 43]

Focus Groups

Focus groups held in GMA 9 allowed landowners and decision makers' to convey their DFC preferences and knowledge in a controlled setting at a low cost. Focus groups allow participants to express views without feeling pressure to take a position. Focus groups emerged as a marketing feedback tool through Richard K. Merton's work starting in 1942 at the Bureau of Applied Social Research at Colombia University.[44] A focus group can be defined as a meeting of a group of people sharing some common phenomena. They meet and are asked research questions in an interactive framework.[45] IQA focus groups require that participants be part of the phenomena or have a shared experience with a phenomenon in order to produce relevant results.[20] The focus group facilitator poses only one simple issue statement: "tell me about *the subject*" to answer two research questions: (a) 'What are the components of the phenomena or system' and 'How are the components related to each other.'[20] If there are more than one group surveyed, a third research question might be, 'How are these systems related.'[20] This process provided a useful and reliable methodology to help interpret, integrate, and summarize stakeholders' and decision makers' experience with the DFC process.

CONCLUSION

One goal of this research has been to understand how people make groundwater decisions and how they react to the decision making process. A related goal has been to evaluate and suggest improvements to the groundwater availability quantification called the DFC process. This chapter has explained the key methods and theories used to gather and evaluate stakeholder and decision maker experiences and opinions about the DFC process and groundwater management in Texas. One operational hypothesis of this project has been that it is possible to develop a plan for future groundwater availability using the desired future condition process based on capturing peoples' ideas about what they prefer. Surveys and focus groups represent the tools to build those preferences. Chapter 5 describes the study area for this dissertation (GMA 9 in the Texas Hill Country) as well as how the DFC process progressed in GMA 9 and its final outcome. Chapters 6, 7, and 8 provide the results of the data collection from the focus groups, mailed and online survey distributed from 2008 through 2012 with raw data reported in Appendices A and B, and in attached database.

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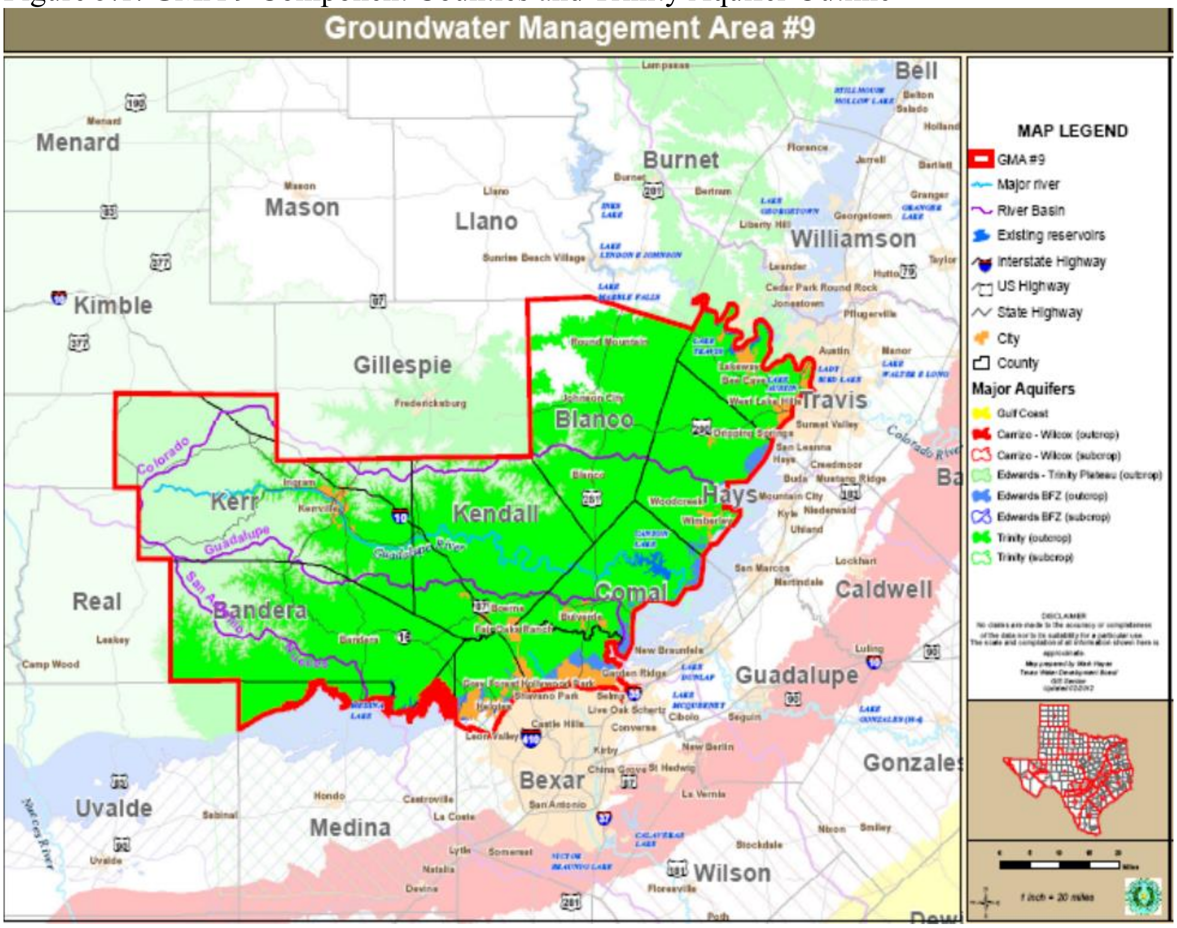
Chapter 5: Groundwater Management Area (GMA) 9 Exemplifying the GMA Role

INTRODUCTION

Texas asks each of its 16 GMAs to make decisions concerning regional aquifer groundwater planning and management such as how much groundwater is available. In central Texas west of Austin and San Antonio the GMA 9's landowners and decision makers participated in this research to explore whether people's preferences about groundwater could be collected and reported. Chapter 4 introduced the key theories and methods explored in this research, including ways to capture people's groundwater CV without a water market and building theory from people's experience with the DFC process. This chapter describes and explains how one GMA, GMA 9, uses regional scientific and technical information to determine its aquifer's DFCs. This chapter reports on information used by the GMA leadership to adopt its DFC as well as local factors that affect that decision. This chapter describes the GMA9 aquifers, the groundwater science supporting the models, the climate, land uses, and population predictions, in effect the 'science' behind how the TWDB quantified groundwater through its groundwater modeling and regional water planning efforts. GMA 9 modeling reports described here detail the TWDB GAM results for the proposed DFCs. This chapter concludes with an explanation of how climate change might affect Texas water groundwater resources, how predicted groundwater availability depends upon changes modeled, and how models can address climate changes. This chapter which describes the past methods GMA 9 used to develop DFCs, as a preface to highlight the value these new approaches could add to the DFC process described in Chapters 6 and 7.

GMA 9 includes nine GCDs located in all or part of nine counties within Texas' so-called Hill Country (see Figure 5.1). GMA 9's eastern boundaries reflect the underlying aquifer strata, and reflect county boundaries in the west.

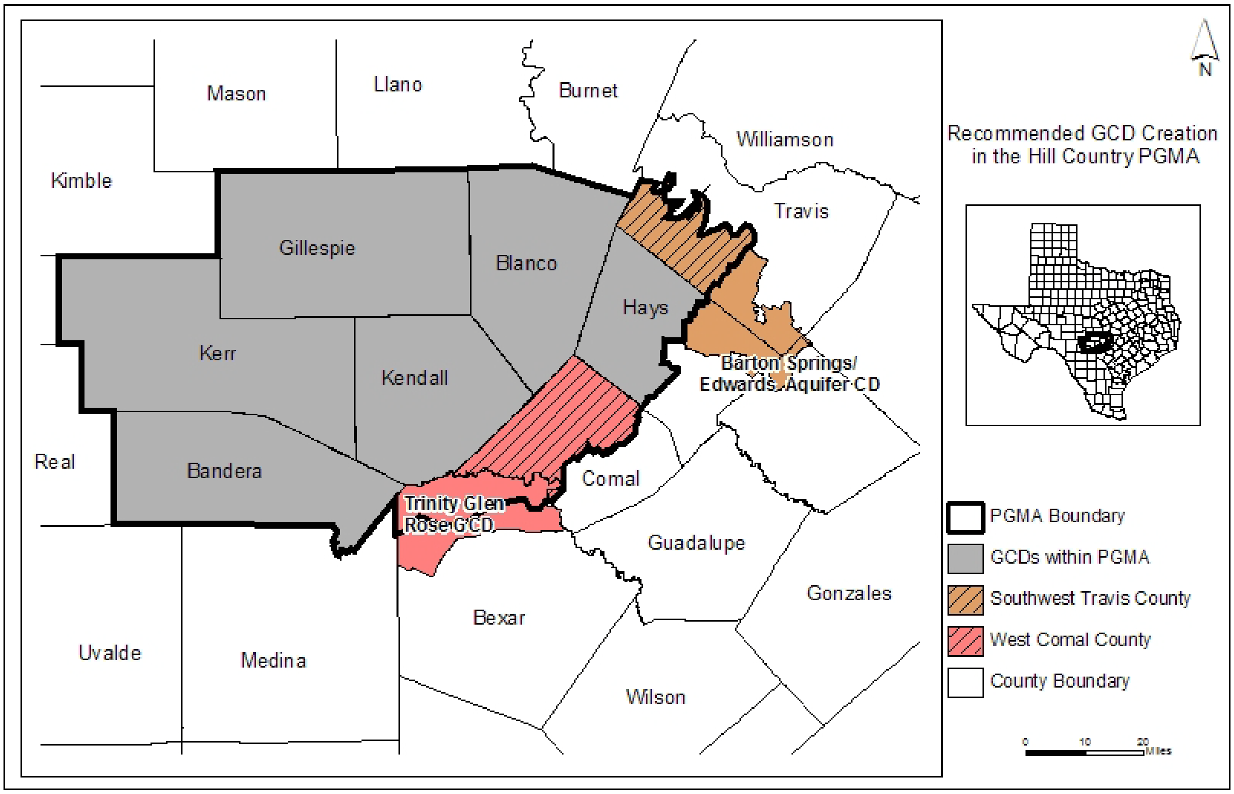
Figure 5.1: GMA 9 Component Counties and Trinity Aquifer Outline



Source: http://www.twdb.texas.gov/mapping/doc/maps/gma/GMA_9.pdf

Although some districts began forming in GMA 9 as early as 1987,[1] four formed after 2000.[2] This is likely due to the Texas Water Commission (now the TCEQ) declaration of the Hill Country as a groundwater critical area from a 1987-1989 study, likely to have problems with demand exceeding supply in the ensuing 20 years and high levels of nitrates in shallow groundwater.[3] In1997 TCEQ renamed critical areas as priority groundwater management areas (PGMA)[3](see Figure 5.2). The TCEQ updated the study term from 25 to 50 years[4; 5] coinciding with available regional planning data.

Figure 5.2: Hill Country PGMA Recommended GCD Creation [6]



Source: http://www.tceq.texas.gov/assets/public/permitting/watersupply/groundwater/pgma/hill_ctry_pgma_map.pdf

This designation meant that the area was expected to experience declines in the water levels or the water quality in the following 25 years (1997 to 2022).7 The Hill Country in GMA 9 contains three major and three minor aquifers managed by seven GCDs, and includes the western part of Austin metropolitan areas and northwest San Antonio suburbs. The Hill Country area, a popular area for retirement and second homes, is projected to grow over the next 50 years which affects the water supplies. Table 5.1 lists the 2011 population estimates and 2060 projections of GMA 9 component counties.

Table 5.1: GMA 9 2011 and 2060 Population Estimates and Projections

County (percent in GMA 9)[8]	2011 Estimate[9]	2060 Projection[10]	Percent Change
Bandera (100 percent, one GCD)	20,538	60,346	193 increase
Bexar (24.3 percent, two GCDs)	1,756,153	2,500,731	42 increase
Blanco (100 percent, one GCD)	10,600	18,544	75 increase
Comal (partial county, no GCD)	111,963	326,655	192 increase
Hays (55 % percent, two GCDs)	164,050	493,320	201 increase
Kendall (full county, two GCDs)	34,781	99,698	187 increase
Kerr (100 percent, one GCD)	49,783	62,252	25 increase
Medina (partial county, two GCDs)	46,367	81,104	75 increase
Travis (11.5 percent, one GCD)	1,063,130	1,918,135	80 increase

Sources: Rima Petrossian 2012;[11]; Stephen Allen, 2012[12] http://quickfacts.census.gov/qfd/states/48/48029.html;[13] http://www.twdb.texas.gov/wrpi/data/proj/popwaterdemand/2011Projections/Population/2CountyPopulation/pdf

Planning & Regulatory Efforts

Regional plans from 2006 and 2011 did not incorporate GMA 9 new groundwater availability values because they were not available for planning prior to 2011. The 2016 regional plans will include modeled available groundwater (MAG) values. Three regional water planning groups are responsible for developing water management strategies for shortages within GMA 9, Region L, Region K, and the Plateau Region. Each region had the option of planning for their shared aquifers in different ways. According to their 2006 regional plans, all chose to use the GCDS groundwater availability amounts reported in their management plans, when available.[14; 15]

Region L

The 2006 Region L plan (including Bexar, Comal, southern Hays, Kendall, and Medina counties) indicates that they used groundwater availability estimates and the 2001 plan estimates, if no GCD existed. The only aquifer the Region L plan addressed in GMA 9 is the Trinity aquifer,[15] which locally spans Regions J, K, and L.

Table 5.2 lists the groundwater availability for the full counties. The regions projected available groundwater to drop, from 9,563 acre-feet per year in 2010 to 8,207 acre-feet per year in 2060. For the Trinity Aquifer in Comal County, available groundwater totaled 1,800 acre-feet per year from 2010 through 2060. For the Trinity Aquifer in Bexar County, available groundwater totaled 1,175 acre-feet per year from 2010 through 2060. For the Trinity Aquifer in Hays County, available groundwater totaled 1,213 acre-feet per year from 2010 through 2060. For the Trinity Aquifer in Kendall County, available groundwater totaled 3,935 acre-feet per year from 2010 through 2060. Three districts in GMA 9 that are in Region L did not have estimates when the planning group generated their estimates, so previous groundwater supply estimates from the 2001 regional water plan served as the basis for potential supplies.[15]

Table 5.2: Trinity Aquifer Groundwater Availability from 2011 Regional Planning

County	2010 Trinity Aquifer Groundwater Availability	2060 Trinity Aquifer Projected Groundwater Availability
Bandera	18,558 acre-feet per year	18,558 acre-feet per year
Bexar	1,175 acre-feet per year	1,175 acre-feet per year
Comal	1,800 acre-feet per year	1,800 acre-feet per year
Hays	1,213 acre-feet per year	1,213 acre-feet per year
Kerr	17,324 acre-feet per year	17,324 acre-feet per year
Kendall	3,935 acre-feet per year	3,935 acre-feet per year
Medina	8,900* acre-feet per year	8,900* acre-feet per year
Travis	6,456** acre-feet per year	7,057 ** acre-feet per year
Total	59, 361*** acre-feet per year	59,962*** acre-feet per year

Source http://www.twdb.texas.gov/wrpi/rwp/3rdRound/2011_RWP/RegionJ/Chapter_3/Tables
http://www.twdb.texas.gov/wrpi/rwp/3rdRound/2011_RWP/RegionL/
http://www.twdb.texas.gov/wrpi/rwp/3rdRound/2011_RWP/RegionK/

For the 2011 plans, the three planning groups made assumptions to project the groundwater supply available (see Table 5.3) rather than using MAGs due to timing issues with the adoption of DFCs and resulting MAGs. The newly adopted DFCs, most due by 2015, may not be ready in time for the 2016 regional plans.

Table 5.3: Regional Planning Assumptions for Groundwater Availability

City groundwater supply is based on well capacity
Rural groundwater supply is increased 125 percent of the 2000 use estimates
Industrial groundwater supply is increased 130 percent of the 2000 use estimates
Steam-electric groundwater supply is increased 130 percent of the 2000 use estimates
Irrigation water groundwater supply is increased 130 percent of the 2000 use estimates
Mining water groundwater supply is equal to projected demand
Livestock groundwater supply is equal to projected demand

Source: South Central Texas Regional Water Planning Group, Regional Water Plan, July 2006.[15]

Region J

The 2006 Region J regional plan defined groundwater availability for Bandera and Kerr counties.[14] Although the plan acknowledged only the GCDs have the authority to permit withdrawals,[14] Region J developed a future aquifer condition goal which considered sustainability and regional economic welfare:

> "…a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions."[14]

This plan indicates that the river and stream flow, generated primarily from groundwater base flow, is vital for providing drinking water, irrigation and livestock needs, maintaining environmental habitat, supporting eco-tourism, and recreation.[14] The 2006 Region J plan linked groundwater availability to pumping withdrawals in the TWDB GAM simulations rather than recharge.[14] The region indicated that they recognized the close surface water-groundwater connection in this planning area, as the human and animal residents rely on groundwater to some extent.[14]

Region K

The 2006 Region K regional plan (including parts of Travis, Hays and all of Blanco counties), used GCD information regarding groundwater availability where provided.[16] In areas without a GCD or if the GCD wished to revise their estimates, the region used the GAMs to determine groundwater availability.[16] The Region K approach sought to prevent lower spring flow during a drought of record occurrence by using the model to estimate groundwater availability while maintaining 90 percent of spring flow compared to no pumping.[16] The 2006 Region K regional plan projected groundwater availability to remain the same at 8,375 acre-feet per year in 2060 (see Table 5.4) over the Balcones Fault Zone segment of the Edwards Aquifer present in the region.[16] The region projected the availability using a modified Barton Springs Edwards Aquifer Conservation District GAM and the Northern Edwards Aquifer GAM.[16] The model projected groundwater availability to remain the same at 6,400 acre-feet per year in 2060 (see Table 5.4) for the entire Trinity Aquifer present in Region K.[16] The region projected the availability using both the Edwards-Trinity GAM and the Northern Edwards Aquifer GAM.[16] Over the small part of the Edwards-Trinity Aquifer present in Region K, the groundwater availability is projected to increase only two acre-feet to 159 acre-feet per year in 2060 (see Table 5.4).[16] The region projected the availability using the prior regional water plan data from 2001.[16] Over the small part of the Hickory Aquifer present in Region K, the region projected groundwater availability to remain at 912 acre-feet per year through 2060 (see Table 5.4), using the local groundwater management plan data.[16] Over the small part of the Ellenburger-San Saba Aquifer present in Region K, the region projected the groundwater availability to remain at 3,874 acre-feet per year through 2060 (see Table 5.4), using the local groundwater management plan data.[16] Over the small part of the Marble Falls Aquifer present in Region K, the region projected the groundwater availability was projected to remain at 300 acre-feet per year through 2060 (see Table 5.5), using the local groundwater management plan data.[16]

Table 5.4: Region K Groundwater Availability from 2006 Regional Water Plan

Aquifer	2010	2060
Edwards (Balcones Fault Zone)	8,375 acre-feet per year	8,375 acre-feet per year
Edwards-Trinity	157 acre-feet per year	159 acre-feet per year
Ellenburger-San Saba	3,874 acre-feet per year	3,874 acre-feet per year
Hickory	912 acre-feet per year	912 acre-feet per year
Marble Falls	300 acre-feet per year	300 acre-feet per year
Trinity Aquifer	6,400 acre-feet per year	6,400 acre-feet per year

Source: Lower Colorado Regional Water Planning Group, Region "K" Water Plan for the Lower Colorado Regional Water Planning Group, Volume I, January 2006.

UNIVERSITY OF TEXAS POLICY RESEARCH PROJECT

In fall 2006 and spring 2007, the second year of the 5-year DFC process, students at The University of Texas assisted GMA 9 under a grant from the TWDB.[17] They developed model runs, based on the Trinity Hill Country Area model, using pumping files from the TWDB model. These initial pumping runs predicted a drawdown of the aquifer. The runs served as a basis for the GMA 9 decision makers choosing to pursue an initial area-wide desired future condition. After a student-led groundwater modeling training session on July 9, 2007, GMA 9 decision makers at their August 23, 2007, public meeting agreed to approximately a 35 feet starting point for future area-wide decline in the Trinity Aquifer.[18] This value came from an interpretation of the water elevation drawdown graphs from each county, projected onto a single graph at the training session.[19] Stakeholders shared their thoughts through student-led confidential "narrative elicitations" regarding groundwater.[17] Each student coded their subject's interview responses into seven narrative codes (problem, cause, no action, actions, resources, barriers, and ideal).[17] Students further reduced the responses into common themes (see Table 5.6). In addition, several students reviewed and compiled information about each districts data, data collection methods, and compared all of the districts approaches to measuring water levels.[17]

Table 5.5: Summary of GMA 9 Stakeholders Narratives

Current Problems	Some dry wells, some dry springs, some contaminated water supplies, urban encroachment
Causes of Water Problems	Population growth, limited water resources, drought, legal interpretations on use of groundwater, limited authority of district
Consequences of No Action	More dry wells, more dry springs, more water contamination, litigation
Possible Actions	Cooperation, responsible development, market incentives, public education, alternative sources and conservation, infrastructure investment
Barriers to Action	Limited resources: money, data, staff, education; mistrust, costly alternatives, resistance to change, resistance to regulation
Ideal Outcomes	Assured water availability for domestic use, spring flows, maintenance of groundwater levels

Source: Eaton, David, Schwartz, Suzanne, and Sharp, Jack, *What Do Groundwater User's Want*, 2008, Policy Research Project Report, University of Texas Lyndon B. Johnson School of Public Affairs, Number 161, Austin, Texas, 239 p.

SCIENCE AND GROUNDWATER MODELING

Frenchman Henri Darcy of Dijon and Jules Weisbach of Saxony developed an empirical model of fluid flow in 1857, derived from Prony's equation describing liquid flow through a smooth-sided pipe.[20] Darcy based his work on his former teacher Gaspard de Prony's experiments, as did Prony from his former teacher Antoine Chezy[20] to estimate simulated flow in pipes or open channels. Newer 20th century groundwater flow equations address flow through the subsurface porous media to simulate non-steady flow in a non-homogeneous aquifer[21] and have become the foundation for Texas' groundwater flow mathematical equations.[20] The original TWDB groundwater simulation model developed in the 1970s, GWSIM-IV, based on the Prickett and Lonnquist code from 1971,[21] used calculations and an equation based on Darcy's Law, called the finite differences method for predicting water level changes. This equation, a set of three partial differentials, described the water movement as vectors in each of two dimensions independently, distance x and y, over time t, while accounting for transmissivity or how quickly water flows, Q, through porous media, the aquifer. This equates to a number representing how the aquifer stores water, S, multiplied by water pressure head height in feet h determined over time t added to water flow Q over time through the porous media. The equation is:

$$\frac{\partial}{\partial x}\left(T\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T\frac{\partial h}{\partial y}\right)= S\frac{\partial h}{\partial t}+ Q \qquad \text{Equation 1}$$

where T is transmissivity (Distance^2/Time), h is head (Distance), S is the aquifer storage coefficient, t is time (T), Q is flux per unit time (Distance/T), and, x, y are spatial coordinates (Distance).

GROUNDWATER AVAILABILITY MODELS (GAMS)

The current TWDB groundwater models are called groundwater availability models or GAMs.[22] They can simulate groundwater flow using the United States Geological Survey modifiable computer code, called MODFLOW 96 or 2000 to incorporate a partial differential equation using to simulate three-dimensional groundwater movement through an aquifer, or a cube.[23] This equation simulates how water would flow in a perpendicular vector into and out of six faces of a cube, represented by *x*, *y*, and *z*, while accounting for a change in elevation of the water flowing, represented by *h*, and K, a function of the geologic architecture controlling speed and direction of flow, or

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)- W = S_S\frac{\partial h}{\partial t} \qquad \text{Equation 2}$$

where, K_{ii} is the hydraulic conductivity in each of three axial directions in units of length over time, h is the hydraulic head in units of length, W is the volumetric flow per unit volume, representing sources or sinks, S_s is the specific storage of the porous material and *t* is time [24].

This equation applies to a heterogeneous, anisotropic aquifer with hydraulic conductivity expressed along three orthogonal directions.[24]

To construct groundwater models using these equations, several assumption are useful, such as geologic layers exist in perfectly horizontal intervals (orthogonality of aquifer parameters) and those layers are divided into equal volume cubes where the hydraulic properties are the same within each aquifer cube.[24] Groundwater flow through each aquifer cube or cell is represented in the finite differences equation, or:

$$\sum Q_i = SS\ \frac{\Delta h}{L} \Delta V \qquad \text{Equation 3}$$

where, Q described groundwater flow rate into a cube from each of three directions, SS is volume of water going through an aquifer cube as the hydraulic head changes, ΔV is the volume of the aquifer cube and Δh is the changing hydraulic head over length L.[24]

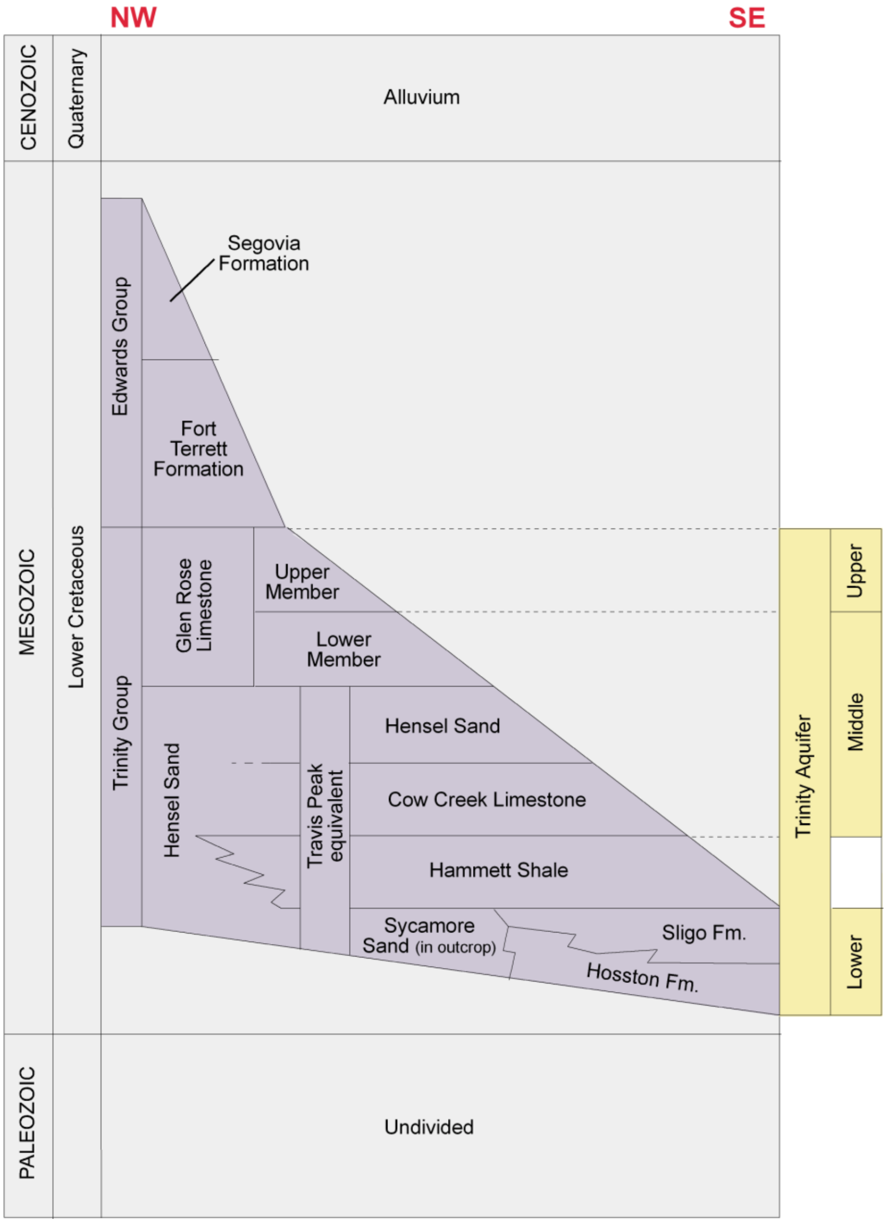
Analysts can evaluate the quality of the simulation by calculating an error term, called the root mean square (RMS) error, as a measure of how well the three-dimensional model simulated water levels from the measured water levels. To develop a model that represents water flow well within the modeling constraints, the analyst tests different scenarios to find the lowest error term possible. This RMS error term is represented by:

$$\text{RMS} = \left[\frac{1}{n} \sum_{i=1}^{n} \left(h_m - h_s \right)_i^2 \right]^{0.5} \qquad \text{Equation 4}$$

where n is the number of calibration points, h_m is the measured hydraulic head at point i and h_s is the simulated hydraulic head at point i.[25] Mace and others reported the 2000 Hill Country model's error at 56 feet, or approximately 5 percent of the total head difference in the entire model area.[25] Stakeholders articulated concern in several of the public meetings over this error term because they interpreted that in any one well the model could erroneously predict 21 feet of increased head; it might predict 91 feet of estimated drawdown for a DFC of 35 feet of drawdown. Eventually, many of the stakeholders and decision makers understood that the model error term was within reasonable limits for a regional model and ought to be applied to the entire area, as it was not reasonable to use the model to predict error at a singular location.

In the early 2000's, the TWDB reported that groundwater availability simulated through 2050 using the Trinity Aquifer Hill Country Area GAM—using regional water planning projections and under drought of record conditions—revealed severe drawdown of up to 100 feet centered in Kerr, Kendall, and Northern Bexar counties, and potentially affecting Drippings Springs in Hays County.[25] Travis, Hays, southeastern Kerr, and eastern Bandera would also suffer drawdown between 50 to 100 feet, some as early as 2010.[25] This simulation occurred prior to the GMA process with smaller initial pumping estimates than current GCD estimates.[26] In order to simulate these regional groundwater changes, scientists begin with a conceptual model.[26] This conceptual model is the basis for simulating groundwater flow in a GAM.[26] In GMA 9, groundwater flow in the GAM is through the Trinity Aquifer geologic strata (see Figure 5.3) and these strata are represented mathematically in a GAM. The cross-section of the geologic formations and related aquifers modeled in GMA 9 taken from TWDB Report 353 shows how the geologic units are related in two-dimensions. The GAM models the upper, middle, and lower Trinity. Most groundwater wells are drilled into the Hensel Sand and Cow Creek Limestone in the middle Trinity Aquifer or the Glen Rose Limestone formation in the upper and middle Trinity Aquifer. Although the results can be translated into realistic pictures of groundwater flowing underground, groundwater modeling can be confusing by using mathematical equations to represent three-dimension geologic strata rather than portraying it accurately in space such as a weather model.

Figure 5.3: Stratigraphic Cross-Section of Groundwater Management Area 9



Source: Robert E. Mace, Ali H. Chowdhury, Roberto Anaya, Shao-Chih (Ted) Way, 2000.

Starting in the 1970's, TWDB staff used numerical models to estimate future groundwater conditions and compute groundwater availability in the Hill Country. Scientists at the TWDB now use multiple methods to quantify groundwater including newer versions of GAMs, the older GWSIM model, and two-dimensional modeling methods using maps and cross-sections, geologic properties, and groundwater elevations. The variety of methods reflects the paucity of data, lack of three-dimensional models, as well as limited time and funding. The GMA decision makers used a combination of these models and calculations, some of which incorporated climate change scenarios and extensive pumping ranges, to quantify future aquifer conditions in the joint planning process. However, groundwater predictions remain an uncertain science for many decision makers and stakeholders because groundwater is not visible and complex to monitor.

FLOW COMPLEXITY

To someone watching a morning rainstorm, the immediate results of the creeks and rivers filling up that afternoon and evening are tangible. Unlike rainfall, people can only observe underground flows through the slower and sometimes imperceptible input of rain soaking into the ground and the correlated output of springs. GMA 9 residents see evidence of spring flow through Jacob's Well and Cedar Creek, the Blanco River, Comal Springs, and numerous unnamed springs and seeps in the Hill Country. Another part of this conceptual difficulty in understanding groundwater flow is time-based. Groundwater movement can be slower than surface water, where both the input and the output could occur over intervals that can range from days to thousands of years. Another part of the conceptual difficulty in understanding groundwater flow is that one cannot see the path through which the water flows, via the earth or the bed and banks of a stream. Even a child can easily predict stream flow direction and speed through a simple experiment of throwing a floating toy off a bridge into a stream and seeing where it goes and how long it takes to get to the next bridge, or conversely if there is no water in the stream to gauge flow. With the same groundwater experiment, the results are not so simple. If the same child poured some food coloring dye onto the ground, it may soak in quickly but it could be difficult or even impossible to determine what happened that afternoon to the dye and when it would reappear at the surface, if ever. Groundwater scientists have developed mathematical equations and computer models, including the GAMs, to simulate groundwater behavior indirectly, even if stakeholders and decision makers indicated they had little trust in the results.

CLIMATE

GMA 9 is part of the subtropical subhumid climate zone in Texas, with hot summer temperatures and dry winters.[27] People are moving to this area, with the population expected to increase from about 25 to 201 percent in each county over 50 years (see Table 5.1). Although past cultures might have reacted to a changing climate by moving, Theoharides and others[28] indicated that institutional adaptation, rather than individual response, is the modern key to successfully managing natural resources when facing climate change. They argue that an unambiguous shared meaning of climate change as well as an understanding of effective adaptation methods coupled with identified management strategies will assist in planning for natural systems.[28] Adaptation in this case means people predicting, organizing, and responding to climate change impacts. This extends to understanding the financial implications for both studying the potential impacts as well as reacting to these impacts.[28] They surveyed 68 authorities in the U.S., particularly those agencies managing water, many of whom identified the necessity for revision of conservation and management plans to properly incorporate climate change.[28]

Other policy alternatives are climate-proofing practices or adaptive approaches. Initially emerging in the 1970's, and later gaining cachet in the late 1990's and 2000's, programs developed to deal with climate variations encompass a trilogy of planning tools.[29] Veraart and Bakker[29] describe the tools as including (1) sustainable water management and land use policy objectives, threshold criteria or risk-based standards, (2) accounting for uncertainty in climate change through a decision support system for changing water management and land use, and (3) accounting for future risks, opportunities, and uncertainty through new water management planning approaches recognizing "future claims." Similarly, Hutchison[30] described El Paso, Texas municipal water supplier's four policy choices to anticipate water resource constraints in the future: (1) rate restructuring; (2) increased dependence on implementing conjunctive use strategies; (3) reusing reclaimed water; and (4) providing economic incentives for water conservation.

Gautier[31] suggested that privatization and water markets are policy tools to enhance more effective water use, social equality, and ecosystem sustainability in response to climate change. She also suggested the interdependency of ever-increasing oil production and associated increased water use will be an area for improvement of various inefficiencies in infrastructure, transportation, energy and water management practices.[31]

There is strong linkage between oil, water, climate and population affecting global environmental security; the elements may not be considered explicitly in GMA 9 planning.[31] Insecurity about water resources stems from unsustainable practices like exhausting the easily extracted near-surface groundwater resources without excessive energy consumption or population increases draining or polluting water resources while demanding more energy consumption to produce water. This circular linkage between increased energy use and climate change, may lead increased repair and construction costs due to aging infrastructure. Although fresh water is a globally finite resource users may treat it as renewable and infinite because it is recyclable through the earth and water treatment processes. Water, existing in three phases within the global cycle, can be reused, cleaned, and conserved but costs money to do so, and at some point those treatments many become cost-prohibitive.[31]

Climatic Forces in Texas

Climate factors affecting central Texas include: (a) the El Niño-Southern Oscillation (ENSO) phenomena of ocean water warming in the Pacific along the eastern equator and off the coast of northwestern South America, (b) seasonal wind direction reversals, and, (c) the Intertropical Convergence Zone (ICZ), the shifting between Northern and Southern Hemisphere trade winds where 40 percent of global rainfall occurs.[32] These three forces alone do not explain global temperature and rainfall shifts. However, the reoccurrence of 40-50- and 90-year ENSO and annual seasonal shifts drives people's perceived social memory of weather.[32] These changes are consistent with human generations and life spans cycles and the tendency for people to communicate about these natural phenomena, such as the drought of the 1950's with their relatives and neighbors.[33; 32] These more short-term occurrences affect people's adaptation to accommodate the shifting weather and climate patterns.[32]

The 1967 TWDB report *The Climate of Texas* categorized Texas' climate into 10 geographic divisions that represent Texas' physiographic regions where the meteorological measurement values are within the same range.[34] Three climatic regions dominate annual rainfall patterns statewide: (a) wet summers the upper Gulf Coast, (b) dry summers in the west, and (c) May-September peak monthly totals in the central third of Texas.[34] From the 1931-1960 records normal climate fluctuations occur, such as total annual rainfall varying more than 20 to 25 percent and up to 50 percent in any chosen year west of the 99th meridian (roughly equating to a north-south line through Abilene and San Antonio in Texas).[34] Variations of more than 25 percent could occur in one out of every three years. In the 29 years tabulated, only 1945, 1947, 1955 were within normal rainfall ranges in all ten divisions,[34] supporting the anecdotal observations of Texas' weather extremes. In the 1983 Climatic Atlas for Texas, the data are presented in a series of rainfall, temperature, and humidity maps averaging for each month for 1960 through 1980, and for the entire year.[27] Data collected after the 1983 publication shows rainfall for each month in regions rather than the entire state average and does not correlate well with the older data.[35]

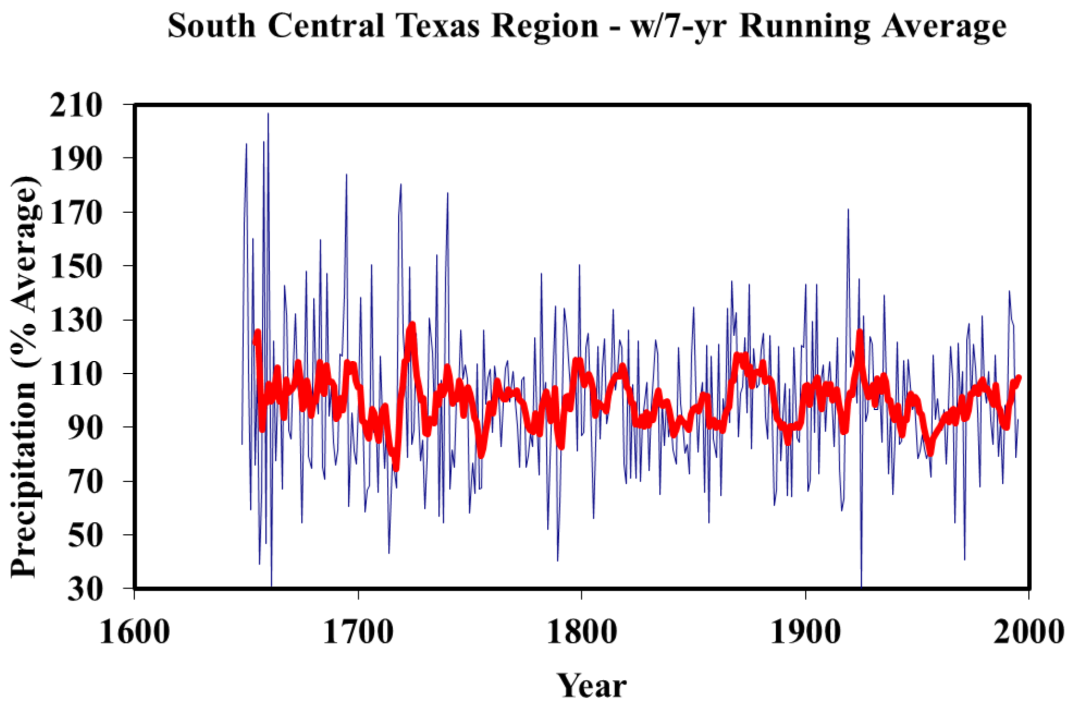
Assessing Climate Change Implications and Impacts to Groundwater Resources

The vulnerability of an aquifer to changes depends on a variety of natural factors such as changes in precipitation, evapotranspiration, infiltration, runoff, and storage.[36] People understand that unconfined groundwater elevation changes caused through climate change and recharge rates may affect groundwater availability in the future. In some places rainfall could increase and temperatures could moderate, causing a positive effect on the water resources available and the growing season,[31] although Barnett and others refer to increasing population and higher per capita water use as outpacing any marginal climate change impacts.[37] In some already-depleted aquifers, the compaction of the geologic material may cause the aquifer not to be able to recharge fully.[38]

Effects may also include failed crops from flooding or drought or, in uncultivated areas, wild animal migration or death, changes in water availability, and wildfires.[32] A changing climate intensifies climate extremes and location of rainfall.[32] Near the Texas coast, for example, rising sea levels could contaminate fresh groundwater through lateral infiltration and progressively propelling the saline-freshwater contact inland.[39] The Edwards Aquifer, is expected to be affected by climate changes, even if population growth and increased withdrawals are predicted to have a greater effect than climate change.[36] Hutchison[30] indicated that the municipal water supplier in El Paso, Texas, may not have to change their policy approach to meet demands through 2060 due to the volume of groundwater in storage remaining at 75 percent and above the 2002 groundwater storage quantity in all simulations.[40] He simulated climate variation using 21 IPCC model rainfall averages in the USGS Hueco Bolson groundwater availability model.[40] These scenarios incorporated Rio Grande River stream flow, recharging the aquifer along with rainfall. Hutchison used different predictions of increasing stream flow ranging from five to 20 percent, decreasing stream flow ranging from five to twenty-five percent, and temperature increases from 1-5° C, and compared those to a base flow analysis.[40]

GAM models used for modeling groundwater in GMA 9 vary climate by a changing rainfall. Modelers can change rainfall, expressed as a recharge rate, in the model. Recharge rates, derived from regional studies and incorporated into each model, are assigned to each cell by the model developer or analyst. Changing those inputs to reflect a wider range of possibilities and running the desired future condition scenarios results in a range of results. Model parameters, adjusted to accommodate for potential or predicted climate change through recharge or pumping rates, are not changeable in current models with respect to temperature changes. Temperature can be a significant variable in predicting groundwater withdrawal changes because of increased lawn and crop irrigation during periods of increased temperatures. GMA 9 decision makers have discussed not including the drought of record in the groundwater model runs because some argued that the average pumping applied each year in the model would not exist during a drought due to demand cutbacks and voluntary curtailment of pumping. GAM run 10-005 included over 350 years of climate variations in the model run (see Figure 5.4) to accommodate both the drought-of-record and worse droughts as recharge inputs to simulate a widely variable climate.

Figure 5.4: Groundwater Management Area 9 Task 10-005 Climate Data for Model



Source: William R. Hutchison, GAM Run Task 10-005, 2010.

BIODIVERSITY AND CLIMATE IN GMA 9

Texas ranks second among all 50 U.S. states in biodiversity,[41] with the climate varying from subtropical arid in the west to sub-tropical humid in the east, continental to subtropical steppe from the Panhandle in the north to the Rio Grande Valley.[42] Biodiversity is concentrated along the entire length of the border with Mexico in the Rio Grande River Basin because of the size of the area and associated topographic and climate variability. On the western edge of Kerr County on the Edwards Plateau, GMA 9 is host to a portion of one of ten global biodiverse hotspots for geographically isolated species.[41] This concentration could change in the future depending on private and public land use policies and decisions, particularly as resident species adjust to migrant or invasive species due to climate change.[41]

There are three primary numerical inputs in the GAM model: rainfall, streamflow, and groundwater elevations. The recharge rate is one GAM model component that can be used to represent climate change. Climate models normally use two primary gauged inputs, temperature and rainfall, to estimate future scenarios. Current climate models are better predictors of temperature change, but not rainfall in Texas. GAM models do not include temperature changes. Resulting rainfall change predictions included in a GAM may simulate climate change but also add increased uncertainty. The climate affects groundwater availability through the quantity of groundwater available over time and the use rate.

DECISION MAKING WITH PREDICTIVE MODELING

No one knows exactly how the climate will change in Texas, so the challenge is how to represent future risks. For example, groundwater modelers may use real-time, one-year, 100-year or greater climate data in their modeling efforts in order to assess water resource changes [43]. Climate model variables may include precipitation, temperature, wind speed, humidity, and number of days of sunshine [44]. In the GAM models, the climate data includes only recharge rates [45].The current climate models are rough estimates due to the initial assumptions driving the outcomes, non-linear climate feedback, global interactions (on micro and macro-scales), models with low climate sensitivity, and data gaps [36; 46].

GAM models do not address how users might changes groundwater withdrawals due to climate change. If GAM models were to model climate change other than changing rainfall inputs, as McIntosh and others [32] suggest, a model would need to incorporate interactions and system functions addressing human perception of nature, environmental variability, and information management to understand the cultural response to climate change. Both the environmental and cultural aspects of adaptability are critical to understanding change [32]. Models that include social memory, such as the drought of the 1950s, might either have a positive or negative influence controlling people's adaptability. Ascribing causality to one particular influence may not be possible due to innumerable interactions [32].

GMA 9 Model Run Reports

GMA 9 decision makers elicited stakeholder concerns and feedback expressed in public meetings to help guide successive Trinity Aquifer DFC modeling requests. After the initial model runs exploring spring flow and pumping variations GMA 9 stakeholders requested model runs (see Table 5.6) for seven changes of the Trinity Aquifer conditions. The TWDB GAM reports listed responded to the GMA 9 decision maker DFC model run requests. Simulation requests spanning the three-year TWDB staff effort ranged from changes to inputs addressing spring flow and discharge to surface water, increasing, decreasing, and stable pumping rates, climate data, and updating pumping estimates. These data requests reflect the decision makers' efforts to consider and respond to stakeholders concerns, Hill Country development forces, groundwater use trends, as well as climate limitations. The final two model run requests show that characterizing and accounting for climate forces emerging as driving the concerns for the decision makers to factor into their final decisions.

Table 5.6: Model Run Parameters and Related Issues Addressed

GAM Run	Issue Addressed	Model Run Parameters	Source
7-18 [47]	Detail spring locations and discharge to surface water	Use 2002 State Water Plan pumping estimates compared to simulated 1997 water levels	Ali H. Chowdhury, July 15, 2007
08-15 [48]	Current average pumping trends	Estimate a 35-foot average water level decline	Ali H. Chowdhury, July 8, 2008
08-20 [49]	Cutting back on current average pumping trends	Estimate a 15-foot average water level decline	Ali H. Chowdhury, July 28, 2008
08-30 [50]	Current average pumping in recharge zone with greater drawdown in deeper aquifer zones, and no changes for untapped or exempt wells in the Edwards Aquifer	Estimate a combination of average declines of 35-feet in Bandera, Blanco, Kendall, and Kerr counties, 55-foot declines in Bexar and Medina counties with no declines in the Edwards Group	Ali H. Chowdhury, August 19, 2008
08-70 [51]	Simulate population increasing in Hill Country; estimate pre-pumping steady state conditions	Increase Middle Trinity pumping for 25 and 50 percent and run steady-state conditions	Ali H. Chowdhury, December 2, 2008
09-011, 09-012, 09-024 [52]	Show the effects of drought through supplementing previous scenarios; simulate average recharge, and increased pumping under average recharge; develop drawdown options based on current pumping to quantify deviation from baseline	Increase and decrease 2008 baseline pumping by 10, 20, and 30 percent; using constant pumping and 33 percent reduced pumping during drought while allowing up to 45-foot declines in the Lower Trinity; increase and decrease 2008 baseline pumping	Ali H. Chowdhury, September 14, 2010
10-005 [53]	Show larger effects from drought, based on a longer drought record	Combinations of no change, 150 percent, to 200 percent of 2008 baseline pumping, reducing to 2008 pumping levels only during drought, all using recharge inputs simulated from tree-ring data.	William R. Hutchison, September 3, 2010

Source: Rima Petrossian, 2012

The model runs listed above in Table 5.6 generated pumping predictions listed below in Table 5.7. The numbers in Table 5.7 reflect the amount that could be pumped from the Trinity Aquifer each year which reflected the water level declines in the Trinity Aquifer specified in the model run requests, listed in the Table 5.6 model run parameters column above. Predicted pumping listed in Table 5.7, also a proxy for groundwater availability, compares all seven run pumping results for the Trinity Aquifer in sequential request order. Table 5.7 shows that as the aquifer declines increase (or water elevations in the aquifer drop), pumping amounts may increase. In GMA 9, this is a key decision concern for decision makers as landowners worry that their wells will become non-functioning as water levels decline in their wells below their screens or well bottom, spring flows or artesian pressure will decline or cease, or developers will not be able to build subdivisions, industrial or commercial complexes due to lack of available long-term groundwater supplies. GMA 9 decision makers chose Scenario 6 in GAM 10-005 as representing their DFC, approximately 30 feet of drawdown across the area, which was similar to their initial consideration of 35 feet of drawdown in 2008, shown in GAM 08-15. GAM Run 7-18

In 2007 GMA 9 the student consultant Michael Ciarleglio requested that TWDB groundwater modelers modify the two-layer Trinity Hill Country Area model from its original format. After gaining an initial understanding of the 2006 groundwater elevations in the Trinity Aquifer, the students requested this change to help reveal the nature of the springs and river baseflow in the model because stakeholders voiced concerns as decision makers were not considering these critical aspects of the Hill Country. This approach simulated water level elevations using drought-of-record recharge beginning in 2034 through 2040 [47].

Table 5.7: GAM-Predicted Total Pumping Using Desired Future Conditions in the Edwards Group, Upper and Middle Trinity aquifers

County	Initial Baseline Pumping	GAM 08-15/ 35 foot aquifer decline	GAM 08-20/ 15 foot aquifer decline	GAM 08-30/ 35 and 55 foot aquifer decline	GAM 08-70 25 % rise in use	GAM 08-70 50 % rise in use	GAM 09-011, 012, 024 Baseline Pumping	GAM 10-005 Average Pumping, Scenario 6
Bandera	4,215	10,075	4,550	7,268	5,052	5,889	4,693	7,910
Bexar	18,112	18,112	18,112	39,541	22,395	26,681	18,228	24,856
Blanco	1,564	4,166	1,713	4,538	1,936	2,307	1,554	2,573
Comal	6,255	16,384	6,834	9,542	7,702	9,149	6,186	10,214
Hays	4,842	12,553	5,282	7,335	5,945	7,048	5,278	9,115
Kendall	6,336	16,319	6,336	11,323	7,763	9,189	6,657	11,450
Kerr	7,513	7,513	7,513	8,540	9,079	10,644	13,045	15,952
Medina	403	1,034	439	2,928	493	584	1,136	2,500
Travis	5,596	8,118	5,596	8,461	6,857	8,118	5,519	8,697
Total	54,836	94,274	56,375	99,476	67,222	79,609	62,295	92,261

Source: Rima Petrossian 2012

Nineteen sources of spring flow, including Bee Cave Spring, Lynx Haven Spring, Ellebracht Springs, Kenmore Ranch Spring #9, Edge Falls Springs, Rebecca Springs, Jacob's Well Spring, Bassett Spring, and Cold Spring, and 10 unnamed springs are included in the model, having flows varying from 20 to 9,000 gallons per minute [47]. River base flow and spring discharge accounted for about 216,000 acre-feet per year [47]. This model comparison was useful to determine differences between the 2006 groundwater elevations and predicted changes from the 1998 model. The modelers developed five predictive simulations, beginning in 2010 through 2050, which included the seven-year drought of record recharge values occurring 2034 through

2040 [47]. The results predicted similar drawdown values as noted in Report 353, including the steady state and predictive runs reported after each five decades of groundwater extraction [47]. The model predicted over 100 feet of water declines in an oval area centered in Northern Bexar County, including parts of San Antonio [47]. Stakeholders and decision makers criticized these results as possibly being excessive compared with some recently available recharge data from the U.S.G.S. This report also provided decision makers with predicted aquifer conditions resulting from the previously established regional planning policy goals, including a water budget describing aquifer conditions changes in volumes (acre-feet per year) for rivers, springs, lakes, wells, cross-formational flow, and storage, including the general head boundaries [47].

GAM Run 08-15

GMA 9 requested that the model released July 8, 2008 include baseline pumping estimates to establish an understanding of what could happen to groundwater levels with updated pumping estimates. These estimates from Hays Trinity Groundwater Conservation District reflected exempt users, and excluded new pumping from near Lake Austin and Lake Travis in Travis County, and in the middle Trinity in the Barton Springs/Edwards Aquifer Conservation District. The Hill Country portion of the Trinity model ran from 2008 through 2060 in order to test several future aquifer conditions:

- Simulate average water level declines in the Middle Trinity Aquifer in all counties of no more than 35 feet, and no declines in the Edwards Group;
- Provide water elevations, water budgets, and water level change maps, for 2008 and 2060, which would produce the average 35 feet of decline; and
- Provide, for each decade, each district's managed available groundwater estimate.

These model run results, shown in Table 5.7, provided managed available groundwater estimates for each groundwater conservation district in Groundwater Management Area 9 for each Trinity

Aquifer layer. Because of the requested aquifer conditions, pumping increased by about 44,000 acre-feet over 50 years or approximately doubled.

GAM Run 08-20

GMA 9 requested a GAM model run using the same baseline pumping estimates in the Hill Country portion of the Trinity model from 2008 through 2060 in order to test decreasing the declines allowed on future aquifer conditions compared to current pumping:

- Simulate average 15 foot water level declines in the Middle Trinity Aquifer in GMA 9

Decision makers requested water levels and water budgets for 2008 and 2060, water level change maps, and managed available groundwater estimates using updated pumping values for the Trinity Aquifer in Hays County and the Middle Trinity Aquifer in Travis County. These model run results (see Table 5.7) provided MAG estimates for each GCD in GMA 9. Because of the requested aquifer conditions, increased pumping slightly reduced surface water baseflow which resulted in an average 13 feet of water level declines, and just slightly increased allowable pumping over 50 years from 54,836 acre-feet in 2006 to 56,375 acre-feet in 2060.

GAM Run 08-30

GMA 9 requested a subsequent model run using GCD supplied initial pumping estimates to adjust the baseline pumping in the updated three-layer Hill Country Trinity model from 2008 through 2060 using a mix of aquifer declines in order to test several future aquifer conditions:

- Simulate average water level declines in the Middle Trinity Aquifer in Bandera, Blanco, Kendall, and Kerr counties of 34 feet;
- Simulate average water level declines in Comal, Hays, and Travis counties of 15 feet;
- Simulate average water level declines in Bexar and Medina counties of 44 feet; and
- Simulate no declines in the water levels in the Edwards Group.

Decision makers requested water levels and water budgets for 2008 and 2060, water level change maps, and MAG estimates. These model run results provided MAG estimates (see Table 5.3) for each GCD in GMA 9 for each Trinity Aquifer layer. Because of the requested aquifer conditions, pumping over 50 years almost doubled from 54,836 acre-feet in 2006 to 99,476 acre-feet in 2060.

GAM Run 08-70

GMA 9 requested a subsequent model run using groundwater district supplied initial pumping estimates to adjust the 2008 baseline pumping in the updated three-layer Hill Country Trinity model from 2008 through 2060 using a mix of aquifer declines in order to test several future aquifer conditions:

- Simulate 25 percent increase in average pumping in the Middle Trinity Aquifer with no increase in the Edwards Group and Upper Trinity Aquifers;
- Simulate 50 percent increase in baseline pumping in the Middle Trinity Aquifer with no increase in the Edwards Group and Upper Trinity Aquifers; and
- Simulate no pumping (pre-development) using the steady state part of model.

Decision makers requested water levels and water budgets for 2008 and 2060, water level change maps, and managed available groundwater estimates. These model run results provided managed available groundwater estimates (see Table 5.7) for each groundwater conservation district in Groundwater Management Area 9 for each Trinity Aquifer layer. Because of the requested aquifer conditions, the 25 percent pumping scenario compared to the previous 08-30 GAM run decreased significantly in almost every county from 90,936 to 58,143 acre-feet and increased only in Kerr County by 539 acre-feet. The 50 percent pumping scenario showed the same pattern, decreased somewhat in almost every county from 90,936 to 68,965 acre-feet and increased only in Kerr County by 2,104 acre-feet.

GAM Runs 09-011, 09-012, and 09-024

GMA 9 requested subsequent model runs which used groundwater district developed 2008 pumping estimates to adjust the baseline pumping in the updated three-layer Hill Country Trinity model through 2060 using a mix of aquifer declines in order to test a variety of future aquifer conditions:

- Assess interaction between pumping to drawdown and flow by increasing and decreasing baseline 2008 pumping amounts 10, 20, and 30 percent in the Middle Trinity Aquifer with no increase in the Edwards Group and Upper Trinity Aquifers; and
- Determine pumping conditions allowing water level declines of up to 45 feet in the Lower Trinity Aquifer.

Decision makers requested water levels and water budgets for 2008 and 2060, and water level change maps. These model run results allow the decision makers to see how the increases and decreases from baseline pumping potentially affect MAG permitting, but produced water budget results for the entire area rather than reported by county.

GAM Task 10-005

TWDB modelers modified the updated Hill Country Trinity model in order to incorporate historical climate variability patterns and offer seven desired future condition scenarios from no pumping to double 2008 pumping in 20,000 acre-feet increments, assuming no drought restrictions are in place. The model results (see Table 5.7) provided information on how recharge estimates based on tree-ring precipitation coupled with a DFC could affect a range of groundwater availability.

GAM Run10-005 included rainfall data from much further back in time than the regional planning so-called “drought-of-record.” For this run Hutchison created 387 individual aquifer recharge GAM input records in 50-year running rainfall averages beginning in 1648, modified from Cleaveland’s[54] Edwards Plateau tree-ring dating analysis. In two other study areas estimated tree ages span 1537 to 1972 or to 1995.[53] According to the tree-ring precipitation estimates interpreted from Hutchison's data used in Task 10-005, drier 7-year averages and single year rainfall estimates occurred compared to the so-called "drought of record" in the 1950's in these three different areas surrounding the Hill Country. In the Edwards Plateau rainfall estimates from 1537 through 1972, the lowest seven year average rainfall years, in order from the lowest, occurred in 1956, 1824, and 1585; the driest single years, were 1748, 1847, and 1904. In south Texas rainfall estimates from 1648 through 1995, the lowest seven year average rainfall years, in order from the lowest, occurred in 1717, 1755, and 1956; the driest single years, were in 1656, 1661, and 1925. Near north-central San Antonio rainfall estimates from 1648 through 1995, the lowest seven year average rainfall years, in order from the lowest, occurred in 1717, 1755, and 1956; the driest single years, were in 1925, 1661, and 1656.

DISCUSSION

Running a GAM model using different pumping inputs or recharge values reveals an estimate of what happens to the aquifer on a regional scale. One challenge to any simulation is that water users have not provided to modelers the location of every working well, both exempt and non-exempt, and the volumes pumped through either metering or annual withdrawal data from every pumping well. This is a problem if exempt use growth continues, as few GCDs require water metering or voluntary reporting for exempt use wells. People may not accurately estimate domestic or household use when reporting withdrawals without metering. Other modeling issues included sparse or incomplete data to develop estimates in non-modeled areas or untapped aquifer subdivisions. Weather extremes predicted to be more prevalent in the ensuing decades could cause the value of these current modeling efforts to decrease unless they are included in the models. Including predicted climate changes in GAMs could reduce some uncertainty in predicted MAG values due to potential climate changes. For example, GAM run

10-005 in GMA 9 and runs in several other GMAs included more severe droughts than the previous regional groundwater modeling efforts.

This chapter describes the regional planning groundwater data applicable to GMA 9, characterizes the local GCDs, and discusses groundwater modeling results for the GMA 9 DFC process. GMA 9 decision makers considered the regional water planning efforts, climate fluctuation, and population increases when planning for the DFCs. The GMA 9 simulations used the available groundwater models. However, even with the best models and data the decision makers articulated mistrust of both during the decision-making process and in surveys. It is clear that stakeholders and decision makers may prefer to use their own preferences to consider the implications of models on possible aquifer simulations. Chapters 6 and 7 present the results of surveying the GMA 9 stakeholders, regarding their valuation of groundwater and their preferences for policy choices, GMA 9 decision makers, and statewide decision makers.

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Chapter 6: Contingent Valuation in GMA 9

As groundwater in Texas is not a commonly traded commodity that citizens buy or sell, neither groundwater managers nor landowners know how to price or value groundwater. Water from the ground is not ‘priced’ in an organized Texas market. This means that users have a difficult time knowing what to pay for groundwater (if it could be obtained) or value how much landowners expect to be compensated to sell. This means that the decision makers responsible for considering socio-economic impacts of the DFC process have little information to evaluate their choices. These questions can be addressed through a contingent valuation (CV), where stakeholders are asked to value groundwater directly.

This chapter describes three questions in a landowner survey used to value groundwater resources in GMA 9 and seven questions in focus groups surveys comparing stakeholder and decision maker responses. One section reports on the landowner survey responses where each question sought to estimate the value of future financial losses due to water level declines. This survey captures stakeholders CV as an action on questions of “willingness to pay” (WTP) or “willingness to accept payment” (WTAP) for groundwater. By asking landowners the value of securing alternative water sources versus leasing groundwater, or WTP, help an analyst estimate the CV. A second question asks landowners what price they would accept to sell unused groundwater to a neighbor in need, or WTAP, help an analyst estimate the CV. A second section reports on focus group responses to identical questions which sought to characterize the stakeholders and decision makers through comparing survey-taker’s responses and opinions illustrated by comments provided by some after each question.

WTAP and WTP studies show that people value non-marketed goods differently depending on whether they are paying or being paid for a good, service, or outcome.[1] Some studies show that people consistently are willing to pay significantly less for something than to sell the same good, service, or outcome, contrary to economic theory predicting little or no difference.[1; 2] In 1976, research indicated that if the payment amount is a small part of personal income, then WTAP should approximately equal WTP.[2] In 1991, research suggested plentiful substitution availability could also support WTAP or WTP as proxies.[3] Other researchers have several explanations of why respondent's estimates could differ including: (a) people may not have formed clear preferences of wealth, risk, and safety[4]; (b) seller's inexperience could cause an underestimated value[1]; (c) moral judgment or influences [5]; (d) intangibles such as intrinsic or existence worth [6]; and (e) personal income effects.[7] A variable WTAP-WTP ratio may reveal flawed test methods or questions as not accurately testing people's preferences or CV.[7] Other critiques include the use of hypothetical scenarios, student subjects, and questions incompatible with rewards.[8] In a meta-analysis of WTAP-WTP studies, results indicated that people may inflate hypothetical values compared to actual values at a greater difference in WTAP compared to WTP scenarios.[9] Psychological studies indicate that a possible explanation is that "loss aversion" causes people to be less likely to want to sell something once they possess or have purchased it because of perceived risk.[10] Many experimental ratios for non-marketed items are above 2 (see Table 6.1). One marketed goods study cited people's moral concerns as an explanation of no payment differences for buying or selling conventionally produced eggs and a 1.5 WTAP-WTP ratio for organically produced eggs.[5] These studies provide a gauge for the GMA 9 stakeholder responses as the 2002 study in France showed that few respondents wanted to participate, similar to the majority of GMA 9 landowners not wanting to sell their groundwater at any price. This lack of participation should be reflected, possibly as a higher valuation, in the

DFC decision makers' consideration of groundwater valuation in their choice of aquifer conditions.

Groundwater in the Trinity Aquifer, a non-marketed item critical for most landowners living in the Texas Hill Country, may or may not have readily available substitutes. GMA 9 landowners responded to two survey questions gauging WTAP and WTP for groundwater. These answers reveal seller or buyer preferences. In the first question landowners had four choices for buying alternative water resources given that their only water source, a groundwater well, had gone dry. Conversely, the second question asked how much a landowner would be willing to sell their groundwater if the landowner had excess groundwater available after providing for current household and outdoor needs. A WTAP-WTP ratio for groundwater in GMA 9 was about 1.4, calculated from landowners indicating that they had a groundwater well and chose among four alternatives and landowners that would consider selling their groundwater. Landowners were reluctant to sell excess groundwater, 510 out of 767, if their neighbor's well were dry, reflecting study results showing people's tendency for "loss aversion." The Trinity Aquifer groundwater WTAP-WTP ratio was similar to studies of marketed goods with substitutes and real cash experiments, possibly indicating groundwater behaves closer to a marketed good and GMA 9 landowners have an intrinsic understanding of the value of groundwater that reflects a real water market nearby such as the Edwards Aquifer.

People in GMA 9 willing to sell their groundwater valued the selling price higher versus what they would pay securing groundwater for themselves. Landowners selling groundwater value it higher than the price of their own resource access. Is there a reluctance to pay too much for access to a scarce resource, but no shame in charging others more?

Table 6.1 Studies Comparing WTAP:WTP Ratios

Year	Topic	WTAP:WTP Ratio	Explanation
1986 [11]	Measured economic loss through CV surveys	Implied WTAP exceeded WTP	Disparities both real and psychological are best measured in terms of gains and losses from a neutral reference point
1987 [12]	Measured tasting a bitter compound	~ 3.33	Increased market/good experience can decrease disparity of WTA-WTAP ratio
1991 [3]	Compared perfect and zero substitution for public/private goods	WTAP should exceed WTP	Income and substitution availability where substitution far exceeds income for affecting the WTAP:WTP ratio
1992 [6]	Buying to preserve or selling back/killing a rare tree seedling	1.66 to 2.36	Moral values may influence WTAP value if the WTP is small or zero; buying seedling might be proxy for property rights
1994 [4]	Assess adding safety feature to car to value risk of nonfatal injuries	2.4 to 4.13/ 4.43 to 6.16	Imprecise or unformed preferences among wealth, risk, and safety
1998 [13]	Buying or selling a signed art print	2.11	Study resulted in paired comparison close to what real cash experiments show, a lower WTAP/WTP ratio.
2000 [5]	Tests conventionally or organically produced eggs	Negligible to 1.5	Organically–produced eggs produced the higher ratio, representing a measure of moral responsibility
2002 [14]	Creating riparian habitat reserve near Toulouse, France	Positive, no value possible due to few responses	Half wanted to participate yet few were interested in accepting money, particularly if they already created a riparian habitat without compensation.
2002 [8]	Compiled and reviewed other experiments	7	If the good is not traded in a normal market the ratio increases
2003 [7]	Compiled 46 studies of public or non-market good	10.41	Meta-analysis showing WTAP/WTP ratio results support psychological preference theories
2007 [15]	Assessed hearing care operation to value procedure's benefit	4	One-third of participants provided WTAP feedback due to complexity of available substitutes for medical procedure.
2013	Central Texas landowners with Trinity Aquifer groundwater wells	1.4	Of the landowners indicating they had a well for domestic or livestock uses, few were interested in selling their groundwater, but at a greater rate than buying

Source: Rima Petrossian, 2013

The CV value (see Table 6.2) is about 40 percent higher for WTAP when compared to the stakeholder's WTP response, with stakeholders being given an example of the Edwards Aquifer market rate with a range from $1,100 to $5,500 in the framing of the question.

Table 6.2: CV Landowner Survey Results

	WTP: Landowner buys groundwater	**WTAP: Landowner sells groundwater**	**WTAP:WTP Ratio**
Calculated Value	$2,855	$4,069	1.4

Source: Rima Petrossian, 2012

While revealed non-market water price valuations may not mimic actual groundwater production transactions,[16] this research provides evidence for calculating groundwater values for each GMA 9 county to illustrate differences within the GMA. For example, one question's four alternatives set upper and lower bounds on the values: buying or receiving surface water; leasing groundwater; deepening or drilling a new well; or rainwater harvesting as substitutes for a dry well. The majority of those surveyed, 510 landowners or 66.5 percent, indicated they would not want to sell groundwater at any price. Survey responses indicate that landowners appear reluctant to value a resource that is simultaneously both 'priceless' and 'free.'

QUALITATIVE SURVEY INSTRUMENTS

This study used four surveys, one delivered by mail, one electronic, and two hand-delivered in focus groups. Surveys sought to record the opinions and preferences of GMA 9 stakeholders as well as statewide-based decision makers. Table 6.2 describes distribution of the surveys; copies are located in Appendix A.

Table 6.3: Distribution of Four Surveys

Distribution of Surveys	Decision Makers	Decision Maker Focus Group	Landowners in Five GMA 9 Counties (Hays County surveyed separately)	Stakeholder Focus Group
Number of Questions	45	14	6 (6)	11
Year Sent	2008	2011	2008 (2009)	2011
Number Sent	90	9	4,309 (523)	64
Distribution Process	Electronic Mail	Hand-delivered	Mail (Mail)	Hand-delivered

Source: Rima Petrossian, 2011

Likert Scale

The decision maker survey used a modified Likert Scale (LS) with six choices and a comment box for written statements to elicit preferences. Choices included strongly agree, agree, neutral, disagree, strongly disagree, and no comment. This LS style was selected over LSs that include “not sure” or “undecided” for a “neutral” response, which both the researcher and the respondent could interpret as being a different than being neutral about the statement. Specifically, in this dissertation, the Likert Scale is used in order to highlight the differences and similarities between the responses and preferences of stakeholders (or landowners) and decision makers. Additional Likert scale history and description of the development of this level-of-agreement survey method used in 62 questions in three surveys is included in Appendix A.

Software

Four different kinds of software were used to process these data: QSR NVIVO 9 language software to code focus group verbal responses; Microsoft Access database for storing and querying survey data; Microsoft Excel spreadsheets (to organize, count, and code individual stakeholder’s addresses and comments); and SPSS statistical software for survey data processing.

Landowner Survey

A six-question survey instrument was mailed in December 2008 (see Table 6.3) to 4,309 GMA 9 households in five counties identified through county tax rolls or GCD databases. Responses totaled 665, or a 15.4 percent response rate, with 295 surveys returned as undeliverable. Hays-Trinity GCD residents received a modified survey in July 2009. There were 102 households in western Hays County that responded from a total of 384 households, or a 26.6 percent response rate, with 139 surveys returned as undeliverable. The second landowner survey, sent out later due to receiving the landowner database later, contained the same questions as the 2008 survey with wording and formats modified slightly based on suggestions from respondents and observations about the earlier survey responses.

The list of addresses for the landowner survey was developed using five electronic address lists and an Excel pseudo-random number generator method was used to select a random sample of persons to receive the surveys.

Decision Maker Survey

An electronic 45-question qualitative survey was sent in December 2008 to all GCD GMs with an electronic mail address, a total of 640 decision makers, including 81 GMs (see Table 6.3). The survey sought to elicit how all GCD board members and GMs view groundwater. GMs were directed to print out a version and deliver it to any board member without internet access or for those who preferred a paper version. Survey questions asked each GM and GCD board member regarding DFC policy and its implications with respect to four issues: (a) groundwater management and financial consequences; (b) the desired future conditions decision process; (c) the information supporting the decision process; and (d) the responsible parties for managing groundwater, supporting groundwater conservation districts, or making decisions. Electronic responses totaled 94 and printed responses totaled 10 out of a possible 640 statewide decision makers. Twenty-one starting the electronic survey failed to complete it, resulting in 79 useable surveys or a 12.3 response rate and a 24 percent failure to complete.

GMA 9 Decision Maker Focus Group Survey

A 14-question decision maker survey instrument was distributed in one focus group in December 2011 to nine GCD GMs, GCD staff, or Board Presidents representing six of the nine GMA 9 counties (see Table 6.3). This survey, administered prior to the discussion, set the stage for decision makers to contribute to discussion of one question, "*tell me about the desired future condition process*." These responses were recorded electronically, entered into a database, and categorized.

Stakeholder Focus Group Survey

An 11-question stakeholder survey instrument was distributed to 14 focus groups from January through June 2011 to self-selecting stakeholders identified through GCD GMs or by other stakeholders referrals (see Table 6.3). A total of 64 stakeholders completed the survey in eight of the nine GMA 9 counties. This survey, administered prior to discussions, set the stage for stakeholders to contribute to focus group discussions of three additional questions, with 62 people attending 14 focus groups. Two stakeholders declined to participate in a focus group discussion. All responses were recorded electronically, entered into a database, and categorized.

Landowner Mailed Survey Results

Landowners in GMA 9 responded to a six-question mail CV survey to gauge groundwater valuation without markets.[17] Out of 665 respondents completing the survey in five counties (Bandera, Bexar, Blanco, Kerr, Kendall), 360 (or 54.1 percent) completed all CV-related questions. Landowners were asked to identify a specific range in dollars for buying or selling water resources as an implicit valuation, in the absence of an easily accessible market.

This exercise requires a landowner to indicate the value (or dollars) where her or his behavior would change in response to a specific financial offer for leasing groundwater. Based on the set of responses for the CV survey an analyst can calculate the DFCs financial implications. Such calculations are beyond the scope of this dissertation.

Tables 6.4 and 6.5 present specific landowner survey quantitative details and response rate data. Table 6.4 lists the number of addresses used to generate the random sampling. The random sampling process is discussed in Appendix B. The Bandera and Blanco County tax appraisal databases provided names and addresses of all landowners. The GMs from northern Bexar, western Hays, Kendall, and Kerr Counties provided electronic databases of groundwater well owners for their respective districts. Comal County does not have a district and was not surveyed. Travis County and Medina County have small areas in GMA 9 and were not surveyed.

Table 6.4: Landowners Response from December 2008 Groundwater Survey

District/County Name	Original and Duplicate Records	Non-Duplicate Records	Records Sampled	Undeliverable Surveys	Surveys Returned	Percent Response Rate
Bandera County River Authority & GW District/Bandera County	32,594	16,544	1,033	26	142	14.1
Blanco-Pedernales GCD/Blanco County	7,556	7,556	1,080	15	205	19.3
Cow Creek GCD/Kendall County	5,456	4,986	998	135	146	16.9
Headwaters GCD/Kerr County	2,414	2,030	1,014	133	136	15.5
Trinity Glen Rose GCD/northern Bexar County	479	479	479	86	34	8.7

Source: Rima Petrossian, 2010

The survey document was printed double-sided on two sheets with a cover letter and postage-paid response envelope enclosed. It included a SurveyMonkey.com-based web address in case the respondents wished to enter responses online. This response method eliminated the ability to skip questions, write in comments, choose multiple answers, or respond incorrectly in the matrix question. Ten respondents total from Blanco, Bandera, Kendall and Kerr Counties finished the survey online. Table 6.5 lists the response results from the second landowner survey sent to Hays County residents of Hays-Trinity GCD.

Table 6.5: Landowners Response from June 2009 Groundwater Survey

District/County Name	**Original and Duplicate Records**	**Non-Duplicate Records**	**Records Sampled**	**Undeliverable Surveys**	**Surveys Returned**	**Percent Response Rate**
Hays-Trinity GCD	523	523	523	139	102	26.6

Source: Rima Petrossian, 2010

Landowner Survey Questions One and Two

The first question of every district-specific survey established whether the landowner owned, did not own or was unsure about a groundwater well on their land. Question 2 asked each landowner how they used groundwater, for domestic use, livestock, or no use. Out of the 767 total surveys returned, 606 (79 percent) reported a well. Table 6.6 shows information categorized by the county where a GCD exists with well-ownership responses summarized. Column one, labeled Respondents, captures the overall response rate in rows one through three, and categorizes the range of choices for how respondents could answer the first two multiple choice questions in rows four through ten. For example, in Bandera County, 142 responded out of 1007 surveys received. Over half or 59.2 percent had a well, and 54.9 percent indicated the well was for domestic use. The highest percent of all the counties surveyed, over one third or 35.2 percent, indicated they did not have a well and either indicated it was not domestic or did not specify the use. The highest percent of all the counties surveyed, at less than three percent, did not know if there was a well on the property. Just over one percent chose not to answer the question and left a comment.

Table 6.6: GMA 9 Landowner Response to Survey Question about Well Ownership

Respondents	**Bandera**	**Bexar**	**Blanco**	**Kendall**	**Kerr**	**Hays**
Total Responses	142	34	205	146	138	102
Total Sent	1,033	479	1,080	998	1,014	523
Returned Undeliverable	26	86	15	135	133	139
Yes to well	59.2%	94.1%	68.3%	97.9%	89.7%	83%
Yes to well, yes to domestic	54.9%	85.3%	64.9%	95.9%	88.2%	75%
Yes to well, no to domestic	3.5%	8.8%	2.9%	2.1%	6.6%	7%
Yes to well, blank to domestic	0%	2.9%	0.5%	0%	0%	0%
Yes to well, NA to domestic	0%	0%	0%	0%	0%	0%
No well, no to domestic	20.4%	2.9%	17.60%	1.4%	1.5%	0.01%
No well, blank or NA to domestic	14.8%	0%	5.90%	0%	5.1%	0.1%
Do not know if there is a well	2.8%	0%	1.50%	0%	1.5%	0%
Left well choices blank	3.5%	2.9%	9.30%	0%	2.9%	0%
Left comment, no answer filled in	1.4%	0%	3.40%	0.7%	1.5%	0%

Source: Rima Petrossian, 2010

Although more than half of the residents in the five counties surveyed had wells, Kendall County residents rely almost totally on groundwater for domestic uses. Only slightly above half relied on a well for domestic water in Kerr County, western Hays County, and Bexar County, trailed by Blanco County, and lastly in Bandera County.

Landowner Survey Question Three

Question 3 asks respondents how much they wish to pay for the GCD to manage their groundwater resources, as compared to the established fee structure described, as a range or percentage change of current taxes or fees. Table 6.7 shows each GCD’s 2005 tax or fee schedule, budget, and funding source.

Table 6.7: GMA 9 GCD Budget and Permitting Costs

District	Annual Budget	Funding Source	Tax Rate/Permitting Cost
Bandera County River Authority & Ground Water District	$394,152	Ad Valorem and Permitting/Registration Fees	$0.03/ $125 registration fee; $400 permitting fee
Barton Springs/Edwards Aquifer Conservation District	$1,482,000 + $193,000 of grant money in current fiscal year	Water Use Fee	$0.17/1,000 gallons
Blanco Pedernales GCD	$194,500	Ad Valorem	$0.03
Cow Creek GCD	$280,000	Ad Valorem, production fees, and new well drilling fees	1/2 of 1¢ or $0.005
Edwards Aquifer Authority	$10,592,000	Water Use Fee	$37/acre-foot (Mun. & Ind.) $2/acre-foot (Irr.)
Hays Trinity GCD	$90,000	Well Registration Fee	n/a
Headwaters GCD	$552,501	Ad Valorem, Well application fees,	$0.01
Medina Co. GCD	$145,500	Ad Valorem	$0.0087
Trinity Glen Rose GCD	$110,000	Water Use Fee	$10/acre-foot Mun. & Ind. $1acre-foot ag.
*Data collected by Rima Petrossian from each GCD in 2005 and Texas Commission on Environmental Quality report[18] Note: Mun is Municipal, Ind is Industrial, Irr is Irrigation			

Source: Rima Petrossian, 2010

Question 3 asks each respondent to vote in a hypothetical referendum with choices that range from no cost increase to about a 300 percent increase, depending upon a GCDs 2005 tax or fee rate. The referendum question includes the maximum tax rate allowed by law or specific fees detailed by each GCDs enabling legislation depending on how close the current rate was to the legislative cap. Proposed rate increases varied by county depending in part upon the current rate compared to the maximum allowable rate under Section 36.020 rules[19] of 50 cents per $100 property valuation. Tax increase choices for Bandera, Bexar, and Blanco Counties are the same (see Table 6.8, column one). Tax increase choices for Kendall and Kerr Counties are different from each other and the others (see Tables 6.9 and 6.10, column one). A Blanco-Pedernales GCD referendum provided the question 3 template for each of the five surveys (see Appendix A Blanco County Survey Question 3).

Each survey answer choice provided respondents with a "percent increase" category, whether the choices were tax or fee increases (see Table 6.8, column one). Bandera, Blanco, and northern Bexar counties had six "percent increase" choices, Kendall and Hays counties had seven "percent increase" choices, and Kerr County had nine "percent increase" choices. Question 3 for Bandera, Blanco, and Kendall counties followed the same wording except for the particular tax rates. When asked about tax rate increases in Bandera, Bexar, and Blanco Counties, 70.6 percent of Bexar County residents did not want taxes raised, the second highest percentage of landowners relying on wells by county (see Table 6.8). Bexar County landowners in the GCD were the most opposed to increased taxes and had the most comments to offer on this question. Bandera landowners were the least reliant on groundwater wells for domestic use and the least opposed to increased taxes to support GCD activities. Tables 6.8 through 6.10 reflect that for landowners reliant on groundwater over half chose not to support tax increases to support GCD activities.

Table 6.8: Respondents' Reaction to Increasing Taxes in Three GMA 9 Counties

Tax Increase Choices	Bandera	Bexar	Blanco
No tax increase	47.2%	70.6%	60.5%
0-20 % tax increase	22.5%	5.9%	19.5%
20-40 % tax increase	5.6%	0%	4.4%
40-60 % tax increase	4.2%	0%	2.4%
60-80 % tax increase	0%	0%	0.5%
80-100 % tax increase	4.9%	2.9%	5.4%
Left Blank	12.7%	5.9%	4.9%
Left Comment	2.8%	14.7%	2.4%

Source: Rima Petrossian, 2012

Kendall County landowners, the most responsive group on this question and the most reliant on groundwater in GMA 9, were not supportive of a tax increase (see Table 6.9). Over half, or 50.7 percent did not want to increase taxes. Almost 7 percent of landowners supported up to a 300 percent tax increase, the most support for the highest tax increase.

Table 6.9: Respondents' Reaction to Increasing Taxes in Kendall County

Tax Increase Choices	Kendall
No tax increase	50.7%
50 % tax increase	21.9%
100 % tax increase	11.0%
150 % tax increase	4.1%
200 % tax increase	1.4%
250 % tax increase	0.7%
300 % tax increase	6.8%
Left Blank	2.1%
Left Comment	1.4%

Source: Rima Petrossian, 2012

Kerr County landowners (see Table 6.10), were just behind Bexar County as the most opposed to increasing taxes to support GCD activities. Kerr County landowners' survey comments included,

- "Note: I should not have to pay taxes on something that I spent $20,000 to install, pay electricity to pump it, and pay to maintain the well, pumps, etc…!"

- People will fight this. Are you going to pay each & every individual for their cost to drill their wells? Hell NO.
- It's my water why should I pay taxes on it?
- I would like to see well water education programs as well. Smart Usage, water quality, etc.
- This proposed tax is CRAZY!
- I disagree to the method of taxing ground water as a percentage of our total property value, not the concept of paying more for water.
- No new taxes!!! No tax increase!!!

Table 6.10: Respondents' Reaction to Increasing Taxes in Kerr County

Tax Increase Choices	Kerr
No tax increase	64.7%
20 % tax increase	13.2%
40 % tax increase	2.2%
60 % tax increase	2.2%
80 % tax increase	0%
100 % tax increase	2.9%
100-200 % tax increase	0.7%
200-300 % tax increase	0.7%
300-400 % tax increase	2.9%
Left Blank	5.9%
Left Comment	4.4%

Source: Rima Petrossian, 2012

More than half of those who responded in all five counties (436 respondents) did not want to pay more than current rates for the GCD services. In all the counties surveyed, 141 respondents (or 18 percent) chose the second lowest rate increase as the next most popular choice, ranging from a 20 to 50 percent increase depending on where the landowner lived.

Landowner Survey Question Four

Question 4 asked each landowner for a preference about the Trinity aquifer condition. The choices included the aquifer staying at the same depth or elevation or declining depending on the GCD permit policy for the Trinity Aquifer. This question indirectly elicits the preferred DCF of the Trinity Aquifer in GMA 9 through illustrating the permitting consequences associated with reaching the DFCs. Each county received the same survey question.

Table 6.11.1 through Table 6.11.10 reports response results for each possible answer. Although the survey asked respondents to select only one answer, out of the 653 respondents who provided an answer, 39 respondents chose more than one response. The majority of those who responded chose the aquifer condition to remain the same, allowing no new users in their GCD. The next most popular choice a 0-5 foot drawdown range as an acceptable DFC in all districts, and chose permit cutbacks for all permittees as the third most popular DFC. Possible survey question "Choices A through J" (see titles of Tables 6.11.1 through 6.11.10) include all the scenarios the decision makers considered in the DFC process. For example, in Table 6.11.3, respondents considered second choice to be, "Current Water Levels may Decrease 0-5 feet over the next 50 years." No more than 10 percent of landowners chose the seven choices of greater than zero to five foot drawdown as a DFC, (see Tables 6.11.4 through 6.11.9), except for 11 percent of Kerr County landowners choosing a 0-15 foot drawdown as acceptable (see Table 6.11.4). Tables 6.11.1 and 6.11.2 list multiple options stakeholders chose for combining choices A and B with other choices.

Table 6.11.1: Choice A: No New Users Issued Permits so Water Levels Do Not Drop

Response*	**Bandera**	**Bexar**	**Blanco**	**Kendall**	**Kerr**	**Hays**
A	33.10%	38.20%	42.90%	43.80%	32.40%	48.00%
A/B	0.70%	0.00%	0.50%	0.00%	0.00%	0.00%
A/B/C	0.00%	2.90%	0.00%	0.00%	0.00%	0.00%
A/C	0.00%	2.90%	0.50%	0.70%	0.00%	0.00%
A/H	0.70%	0.00%	0.00%	0.00%	0.00%	0.00%
A/D	0.70%	0.00%	0.50%	0.00%	0.00%	0.00%
A/J	0.00%	0.00%	0.00%	0.70%	0.00%	0.00%

Source: Rima Petrossian, 2012; * Some respondents chose more than one option

Landowners in western Hays County chose cutting back current users to allow new users (see Table 6.11.2) as the second behind "no new users," to maintain aquifer levels. The rest of the counties chose this as third best choice.

Table 6.11.2 Choice B: Current Permitted Amounts will Drop to Allow New Users

Response*	**Bandera**	**Bexar**	**Blanco**	**Kendall**	**Kerr**	**Hays**
B	16.90%	8.80%	14.60%	15.10%	14.00%	19.60%
B/C	0.70%	0.00%	0.50%	0.00%	0.00%	1.00%
B/D	0.00%	0.00%	0.00%	0.70%	0.00%	0.00%

Source: Rima Petrossian, 2012;* Some respondents chose more than one option

Landowners is all counties except for western Hays County chose allowing aquifer levels to drop up to 5 feet over 50 years (see Table 6.11.3) as second behind "no new users."

Table 6.11.3 Choice C: Current Water Levels May Decrease 0-5 Feet over 50 Years

Response	**Bandera**	**Bexar**	**Blanco**	**Kendall**	**Kerr**	**Hays**
C	19.70%	14.70%	18.50%	15.80%	22.10%	3.90%

Source: Rima Petrossian, 2012

Kerr County landowners were most supportive of allowing aquifer levels to drop up to 15 feet over 50 years (see Table 6.11.4). No western Hays County landowners chose to allow the aquifer to drop more than 15 feet over 50 years.

Table 6.11.4: Choice D: Current Water Levels May Decrease 0-15 Feet over 50 Years

Response	Bandera	Bexar	Blanco	Kendall	Kerr	Hays
D	4.20%	2.90%	7.80%	4.80%	11.00%	2.00%

Source: Rima Petrossian, 2012

Northern Bexar County landowners were most supportive of allowing aquifer levels to drop up to 25 feet over 50 years (see Table 6.11.5).

Table 6.11.5: Choice E: Current Water Levels May Decrease 0-25 Feet over 50 Years

Response	Bandera	Bexar	Blanco	Kendall	Kerr	Hays
E	2.80%	8.80%	2.40%	7.50%	3.70%	2.00%

Source: Rima Petrossian, 2012

Landowners showed little or no support for the DFC closest to the one decision makers chose supporting of allowing aquifer levels to drop up to 35 feet over 50 years (see Table 6.11.6).

Table 6.11.6: Choice F: Current Water Levels May Decrease 0-35 Feet over 50 Years

Response	Bandera	Bexar	Blanco	Kendall	Kerr	Hays
F	1.40%	0.00%	1.00%	0.00%	0.00%	0.00%

Source: Rima Petrossian, 2012

Landowners showed no support for allowing aquifer levels to drop up to 45 feet over 50 years (see Table 6.11.7).

Table 6.11.7: Choice G: Current Water Levels May Decrease 0-45 Feet over 50 Years

Response	Bandera	Bexar	Blanco	Kendall	Kerr	Hays
G	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Source: Rima Petrossian, 2012

Northern Bexar County landowners were most supportive of allowing aquifer levels to drop up to 55 feet over 50 years (see Table 6.11.8).

Table 6.11.8: Choice H: Current Water Levels May Decrease 0-55 Feet over 50 Years

Response	Bandera	Bexar	Blanco	Kendall	Kerr	Hays
H	0.70%	2.90%	1.00%	2.10%	1.50%	0.00%

Source: Rima Petrossian, 2012

Kerr County landowners were most supportive of allowing aquifer levels to drop up to 55 to 125 feet over 50 years (see Table 6.11.9).

Table 6.11.9: Choice I: Current Water Levels May Decrease 55-125 Feet over 50 Years

Response	Bandera	Bexar	Blanco	Kendall	Kerr	Hays
I	0.00%	0.00%	0.50%	1.40%	1.50%	0.00%

Source: Rima Petrossian, 2012

Northern Bexar County and Kerr County landowners were most supportive of allowing aquifer levels to drop over 125 feet over 50 years (see Table 6.11.10).

Table 6.11.10: Choice J: Current Water Levels May Decrease 125 Feet+ over 50 Years

Response	Bandera	Bexar	Blanco	Kendall	Kerr	Hays
J	1.40%	2.90%	0.00%	0.00%	2.90%	0.00%

Source: Rima Petrossian, 2012

Bandera County and Bexar County landowners chose not to answer this question at the highest rates (both greater than 10 percent), indicating the question was likely too complicated. Table 6.11.11 lists the percent of respondents choosing to include a comment or to not respond. Bandera County respondents chose not to respond at the highest rate and tied for providing the least comments while Hays County respondents provided the most comments and left the least blanks.

Table 6.11.11: Respondents' Choosing Not to Answer or Provided a Comment

Response	Bandera	Bexar	Blanco	Kendall	Kerr	Hays
Blank	16.20%	11.80%	6.80%	6.80%	7.40%	4.90%
Comment	0.70%	2.90%	2.40%	0.70%	3.70%	10.80%

Source: Rima Petrossian, 2012

Landowner Survey Questions Five and Six

Questions 5 and 6 asked each landowner to assess financial consequences of a potential DFC decision through asking about the value of buying, selling, or replacing the water source. Question 5 asked how much money the respondent would be willing to spend or WTP if she or he needed another source of water and if groundwater was not readily available, such as if the landowner had a newly dry well. Respondents who indicated they did not have a well, did not know whether they had a well or not, or did not completely fill in all ten groundwater leasing costs were not included in this measure. Question 5 offered four choices (rainwater harvesting, drilling a deeper well, leasing or buying groundwater, or obtaining surface water) for securing water, assuming their well went dry. These options were compared with ten hypothetical costs for leasing groundwater, with prices expressed in dollars per-acre-foot of groundwater. If respondents chose "leasing" groundwater as a preferred alternative, that choice led to a direct way to value WTP. When respondents changed their source of water, based on the price of groundwater, this change was the trigger point for calculating their CV. The structure of the question allowed respondents to change preferences at least nine times among the four alternatives.

Almost half or 181 respondents changed from one water resource choice to purchase or get water to another choice at least once, depending upon the groundwater lease price. These responses were the basis for the CV calculation to capture respondents' views that completed the survey question. Incomplete responses were recorded and included on the figures below to use the most results available and provide more complete representation. Twenty-six respondents from the five-county landowner survey were willing to lease groundwater at $1,000-1,500 per acre-foot and did not complete the question by changing their approach to securing a water source as the price increased; these responses were not included in the calculations because these respondents seemed to value groundwater the same across all pricing schemes.

Table 6.12 indicates the responses of people who chose leasing or buying groundwater and buying surface water, when compared to groundwater lease or purchase prices, with prices ranging from $1,000 to $5,500 in $500 increments. For example, when the price of leasing groundwater is $1000 to $2000 shown in rows 1 and 2 below, most respondents choose to buy surface water. When leasing groundwater is at a $1,000 to $1,500 and $1,500 to $2,000 lease price, 40 or less choose to lease groundwater at each price; when the groundwater lease price exceeded $3,000, those choosing to lease groundwater drops in half to less than 20 for each $500 increment increase (see Table 6.12, column 4).

Table 6.12: Respondents Choosing to Buy Surface Water or Lease Groundwater

Groundwater Lease Cost per Acre-foot	Buy Surface Water	Buy Surface Water with Other Options	Lease Groundwater	Lease Groundwater with Other Options
$1000-1500	170	10	39	6
$1500-2000	112	2	40	2
$2000-2500	88	1	37	1
$2500-3000	74	2	28	2
$3000-3500	61	0	19	0
$3500-4000	53	0	17	0
$4000-4500	50	0	13	0
$4500-5000	46	1	10	1
$5000-5500	47	1	9	1
$5500+	43	2	11	2

Source: Rima Petrossian, 2012

Buying surface water, initially an attractive choice quickly became less popular as the price of leasing groundwater increased (see Figure 6.1). The *buying surface water* curve is described by a power function:

$$y = 169.38\,x^{-0.613} \qquad \text{Equation 6.1}$$

where y is number of respondents, and x is groundwater lease price.

The R squared value of 0.9926 indicates Equation 6.1 closely characterizes the number of respondents who choose to buy surface water

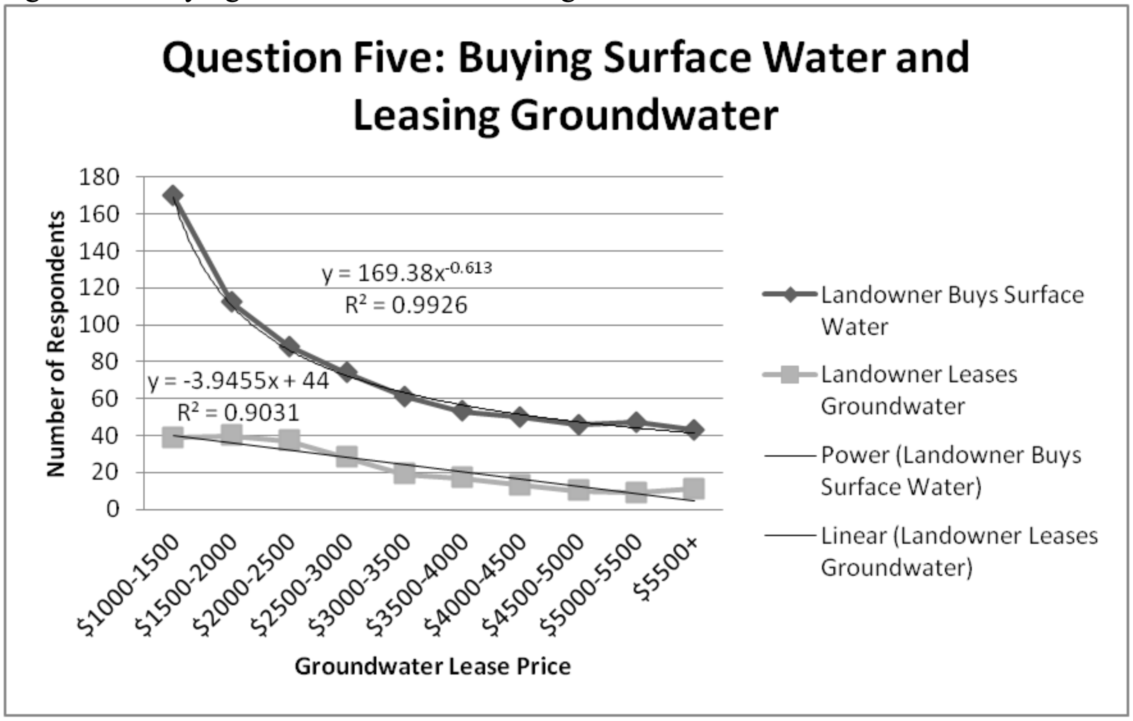
Buying groundwater, the least attractive of the four choices, became less attractive as the price of groundwater increases, shown on the bottom curve. Most chose to lease groundwater at the lower prices starting at $1,000 per acre-foot (or $0.003 per gallon). Only 11 out of 664 (1.7 percent) choose buying groundwater at over $5,500 an acre-foot. The *leasing groundwater* curve is described by a linear function:

$$y = -3.9455\,x + 44 \qquad \text{Equation 6.2}$$

where y is number of respondents, and x is groundwater lease price

The R squared value of 0.9031 indicates Equation 6.2 closely characterizes the number of respondents who choose to lease groundwater.

Figure 6.1: Buying Surface Water or Leasing Groundwater Versus Lease Price/Acre-Foot



Source: Rima Petrossian, 2012

Table 6.13 indicates the responses of people who chose deepening or drilling a new well and rainwater harvesting, compared to groundwater lease or purchase, with prices ranging from $1,000 to $5,500 in $500 increments. For example, when the price of leasing groundwater is $1,000 to $2,000, shown in rows 1 and 2 below, most respondents choose to deepen or drill a new well. When leasing groundwater is above $4,000 to $4,500 more choose rainwater harvesting at each subsequently higher price; when the groundwater lease price exceeded $4,000, those choosing to have their own well remained fairly steady dropping by only a few percent at each $500 increment increase (see Table 6.13, column 2).

Table 6.13: Deepen/Drill Well or Rainwater Harvesting Versus Lease Price/Acre-Foot

Groundwater Lease Cost per Acre-foot	Choice Three: Landowner Deepens or Drills New Well	Choice Four: Landowner Harvests Rainwater
$1000-1500	210	112
$1500-2000	190	105
$2000-2500	191	129
$2500-3000	195	144
$3000-3500	202	152
$3500-4000	189	173
$4000-4500	181	190
$4500-5000	174	202
$5000-5500	170	206
$5500+	172	210

Source: Rima Petrossian, 2012

Initially deepening or drilling a new well was an attractive choice; it became less popular as the price of leasing groundwater increased (see Figure 6.2). Harvesting rainwater, the third most attractive of the four choices, became more attractive as the price of groundwater increases, and became the most attractive option of the four choices when leasing groundwater exceeded $4,000.

Deepening or drilling a new well, an initially attractive choice became slightly less so as the price of leasing groundwater increased (see Figure 6.2). Most landowners chose to deepen or drill a well at the lower prices starting at $1,000 per acre-foot. The landowner deepening or drilling a well (see Figure 6.2), is described by a linear function:

$$y = -3.7697x + 208.13 \qquad \text{Equation 6.3}$$

where y is number of respondents, and x is groundwater lease price

The R squared value of 0.7494 indicates Equation 6.3 somewhat characterizes respondents who choose to deepen or drill a new well.

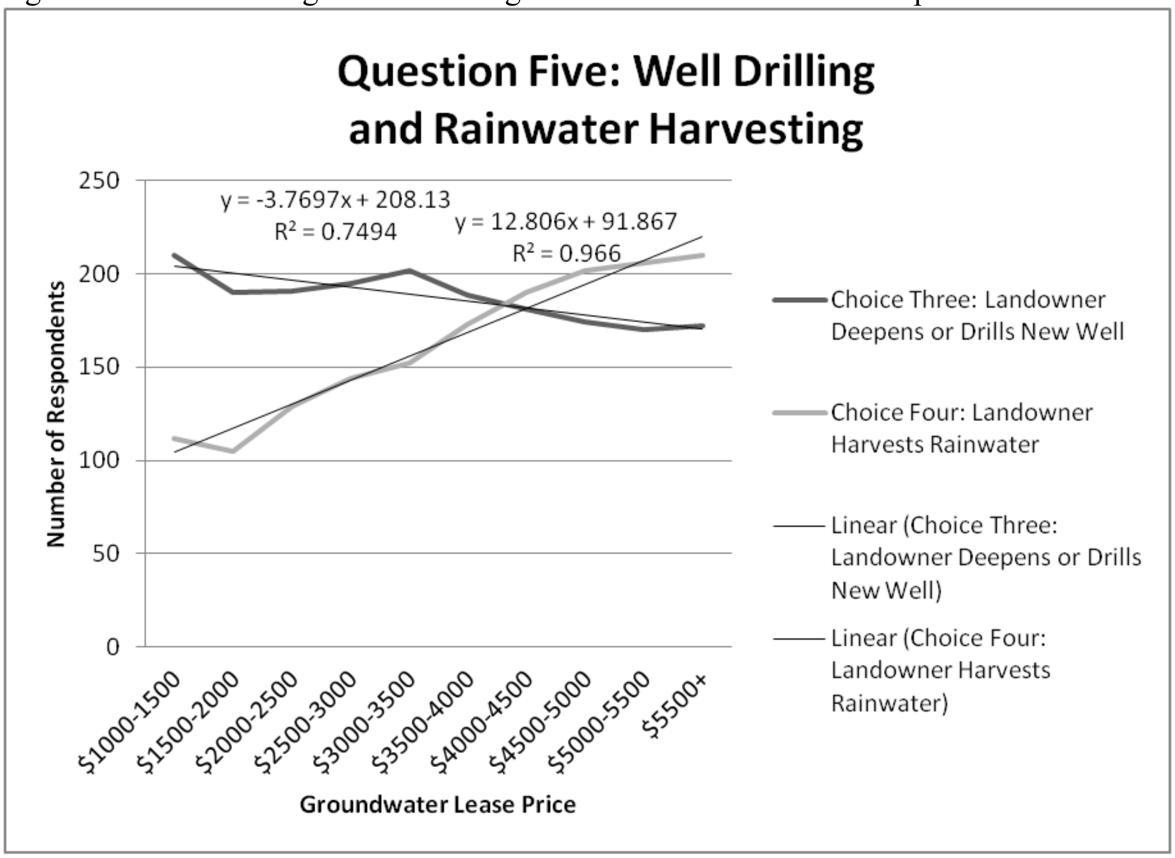
Deepening or drilling a well became less popular when leasing groundwater exceeded $3,500 an acre-foot. The *rainwater harvesting* curve (see Figure 6.2) is described by a linear function:

$$y = 12.806\,x + 91.867 \qquad \text{Equation 6.4}$$

where y is number of respondents, and x is groundwater lease price.

The R squared value of 0.966 indicates Equation 6.4 closely characterizes respondents who choose to lease groundwater.

Figure 6.2: Well Drilling and Harvesting Rainwater versus Lease Price per Acre-Foot

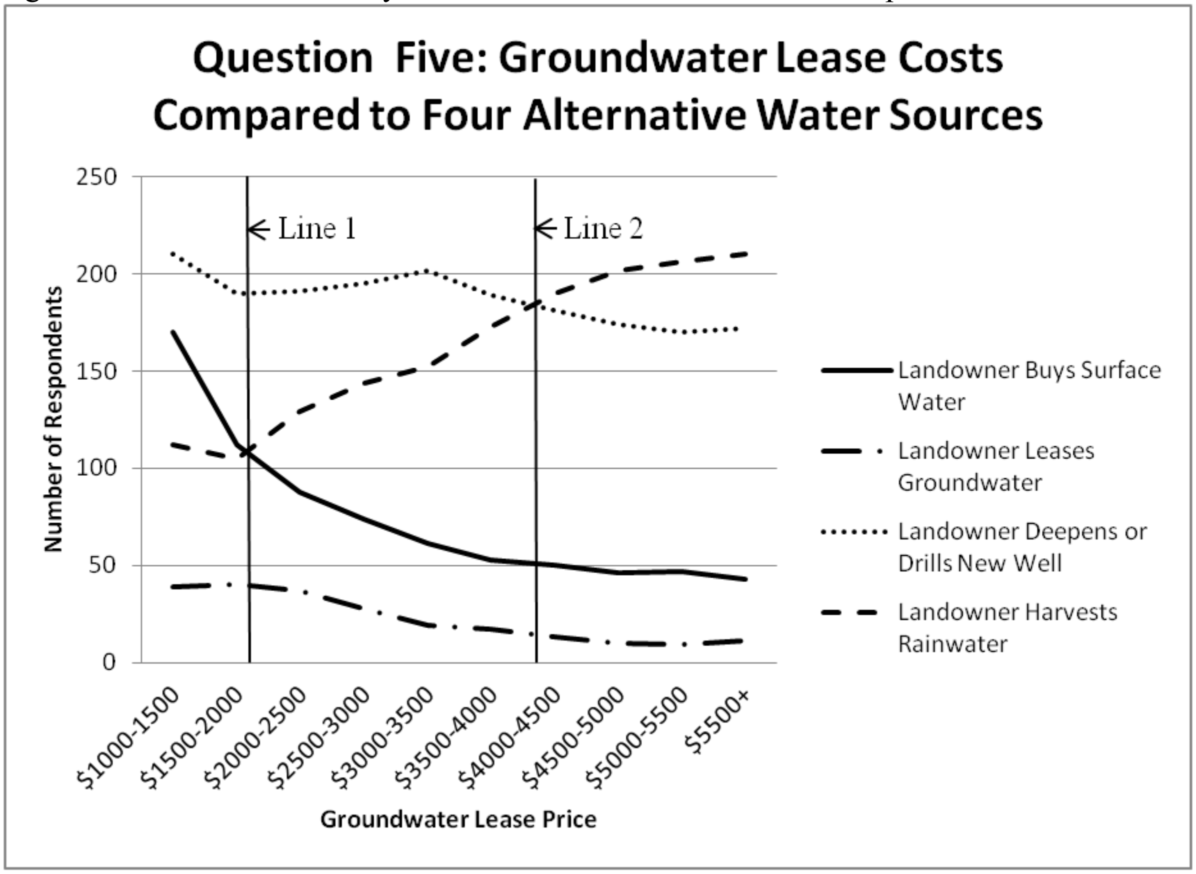


Source: Rima Petrossian, 2012

Deepening a well or drilling a new well (estimated to cost $100 per linear foot) is an attractive alternative to increasing groundwater prices. People would rather spend a potentially large sum of money to install a new well, buy surface water or harvest rainwater rather than buy from a neighbor who has groundwater to sell. Purchasing groundwater from others was the least popular choice. Purchasing surface water or joining a surface water distribution system is a strong alternative at the initial pricing, but quickly becomes the third choice. Rainwater harvesting is the only alternative of the four that becomes more popular as the price of buying groundwater increases, listed on the survey as having an average cost of $9,000 for a system.

Figure 6.3, illustrates all water source choices depicted in Figures 6.1 and 6.2 shows the trends over the range of groundwater prices. The landowner buying surface water starts as the most popular choice at the lowest groundwater lease price, followed by deepening or drilling a new well, harvesting rainwater, and lastly leasing groundwater. Line 1 shows the inflection point, where: (a) leasing groundwater costs about $1,500 to $2,000; (b) an equal number of landowners are buying surface water and harvesting rainwater as alternatives to leasing groundwater; and (c) above this groundwater lease price harvesting rainwater becomes the only increasing trend among landowners. Line 2 shows the inflection point where: (a) leasing groundwater costs about $4,000 to $4,500; (b) rainwater harvesting surpasses the three other water resource choices.

Figure 6.3: Stakeholder Survey Water Sources: All Alternatives Comparison

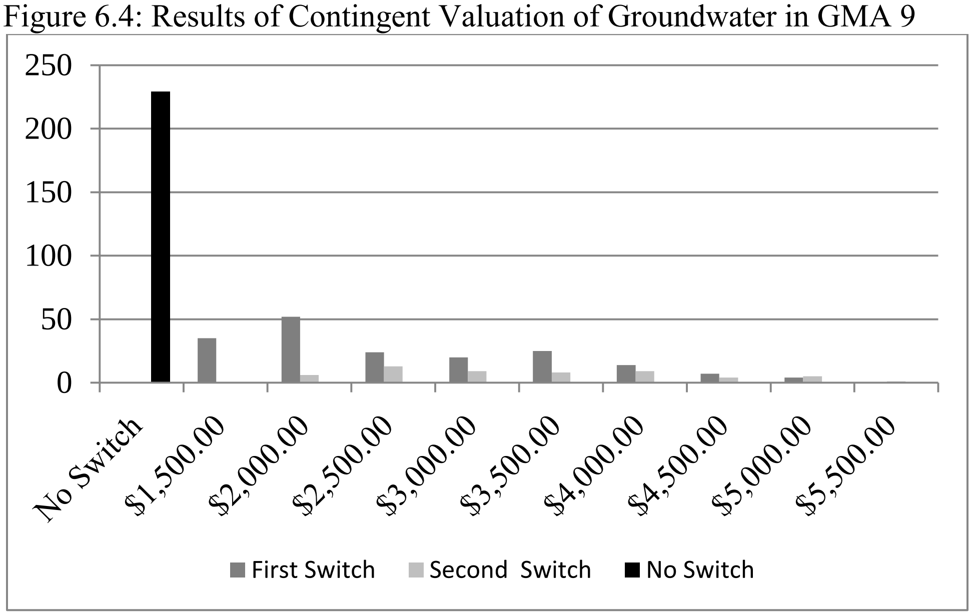


Source: Rima Petrossian, 2012

Calculations, based on 181 stakeholders changing from one preference to another, used a weighted averaging method to calculate a single value for each respondent because there was no relevant method available from other CV studies. The weighted average was calculated by adding up the number respondents who switched from one preference to another, categorizing those, and multiplying that number by the average of the range of groundwater prices. For example, if 20 respondents switched from surface water to leasing groundwater at a lease price of $1,500 to $2,000, 20 would be multiplied by the average of $2000 minus $1500, or $1750, resulting in a weighted average, and so on. Then all the weighted averages were added and divided by the total for a single monetary value. The calculated value with Hays-Trinity GCD responses counted equals $2,871.55 and without Hays-Trinity GCD responses, approximately the same at $2,973.46. Calculations are shown in Appendix B.

Figure 6.4 shows three different response-types to the lease price of groundwater on the x-axis versus the number of respondents choosing to switch a preference at each price on the y-axis. At the first lease price, the dark bar shown represents those who did not change their preference for procuring a water source to another source at any price. The grey bars represent those who changed once to a different water source at lease prices $1,500 and above. The light grey bar shows those who changed a preference twice, either to a new source or back to their previous choice. Most respondents (229 or 56 percent), shown as No Switch in Figure 6.4 chose the same water source at all groundwater lease prices: 20 chose surface water, one chose to lease groundwater, 116 chose to drill a new well or deepen a well, 74 chose rainwater harvesting, and 24 chose a combination of drilling deeper and rainwater harvesting. These people preferring not to switch at any of the groundwater lease prices were not included in the valuation because this method relied on a switch to a new source to calculate the groundwater value.

Figure 6.4: Results of Contingent Valuation of Groundwater in GMA 9



Source: Rima Petrossian, 2012

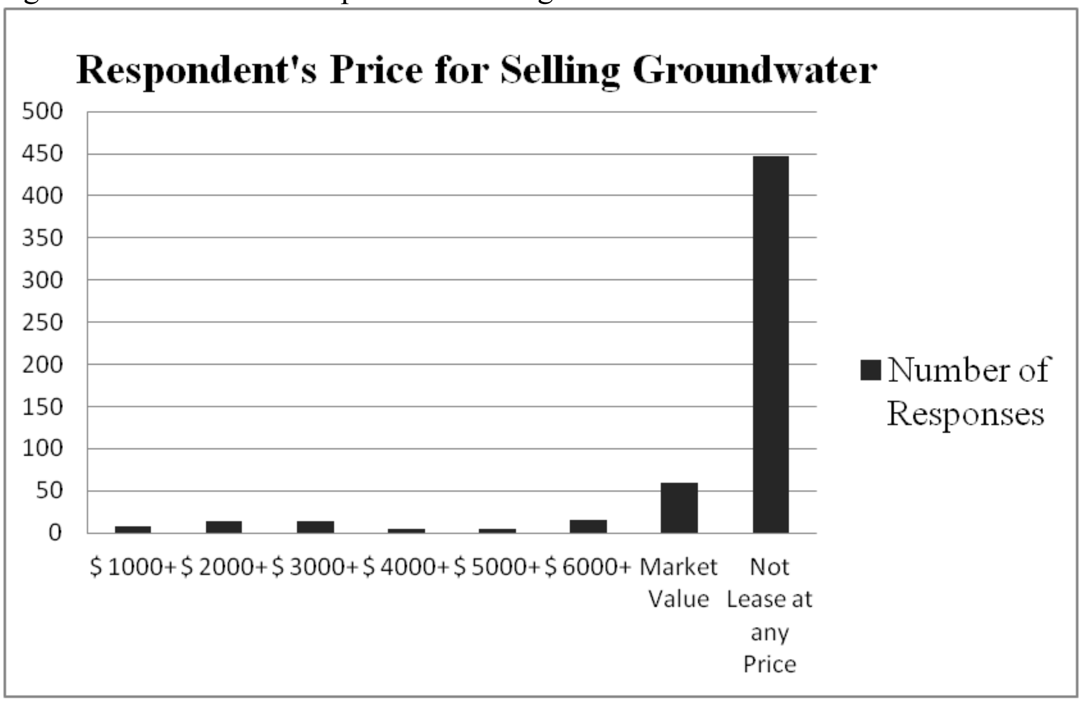
Landowner Survey Question Six

Question 6 asked for how much the landowner would be willing to "sell" excess groundwater, WTAP, assuming that they have enough, with prices shifting in increments of $500. This "sell" question approaches groundwater valuation from the opposite direction of the "buy" question, WTP, by trying to determine how much the landowner would sell extra groundwater for, given an opportunity. Question 6, intended as the inverse of question 5 offered eight choices with similar values, as an attempt to determine the CV should the landowner try to lease groundwater assuming she/he has plenty of groundwater for their own use. An assumption was that how much a landowner would want to sell her/his groundwater would be similar to how much landowners would be willing to pay, creating a bracket for groundwater valuation in GMA 9.

Leasing groundwater to others at prices ranging from $1,000 to $6,000+ per acre-foot in $1,000 increments was not popular: from a low of 0.1 to a high of 2.6 percent of respondents chose one of six dollar amounts. Another choice, to not lease groundwater to others at any price, appealed to 74.3 percent or 450 of the 606 survey respondents who reported they had a well or did not know. Another choice, called a "market rate," did not designate a specific dollar amount; it appealed to 10.2 percent or 62 of the 606 survey respondents. Questions left blank or listing only comments are not counted, so out of the 95 percent who answered this question more than 78 percent refused to choose to sell or lease their groundwater for any price. Only 9.9 percent or 60 respondents chose prices from $1000 to greater than $6000. Lease benchmark values and response values provided in the question are taken from published lease values in the nearby Edwards Aquifer.[20; 21] The survey question gave examples of lease values $1100 through $5500.

Some responses included more than one answer to this question. These answers are used in the CV calculation by choosing the lowest value choice of multi-response answers to include in the calculation. The CV for leasing or selling groundwater to others, at $4,068.97 for 58 respondents, is 41.7 percent higher than the CV calculated from the question 5. Sixty persons reported they would accept the market price and 447 stated they would not sell under any circumstances.

Figure 6.5: Results for Respondent Leasing their Groundwater to Others in GMA 9



Source: Rima Petrossian, 2011

DECISION MAKER ELECTRONIC SURVEY RESULTS

Decision makers from about 81 GCDs and 14 GMAs statewide answered 45 questions in a survey of opinions and preferences. Table 6.14 lists the questions in five categories in the decision maker's survey. Similar questions were worded in different ways to test for a respondent's internal consistency. Questions in effect asked: (a) who should determine the DFC; (b) what knowledge or groundwater science is needed to make a DFC decision; (c) how well-conceived is the DFC process; (d) what groundwater information is available; and (e) how Texas' should approach groundwater management, through a legislative or legal framework?

Questions focused on the decision maker's understanding and opinion about the 2005 DFC process. The questions gauged decision makers' level of agreement with the survey statements using a LS style scale or multiple-choice responses. These results were coded using descriptive statistics and evaluated using chi-squared tests to assess where there were differences between decision makers and stakeholders. Appendix A contains a copy of the 2008 decision maker survey, frequency response and counts to the 45 questions, reported by individual GMA.

To interpret the internal consistency among question responses, two sets of questions were tested to see if similar or parallel questions result in similar responses. The survey questions have LS-style responses and the chi-squared statistic can be used to assess multinomial experiments counting outcomes as falling into pre-defined groups, appropriate for the LS.[22; 23] Similarly worded or parallel questions such as those listed in Table 6.14 can reveal response consistency.

Table 6.14: Questions Topics from the Decision Makers Survey and Correlated Questions

Question Topics	**Question Numbers**
Who should determine the desired future condition decision?	Directly Asked: 5, 16, 42, 43, 44 Indirectly Asked: 2, 3, 4, 25, 34
What knowledge or science is necessary to make the decision?	7, 8, 9, 10, 11, 37, 45
How well-conceived is the DFC process?	1, 12, 14, 15, 17, 18, 19, 32, 38, 39, 41
What groundwater information is available?	13, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30,
What is the legislative or legal framework?	6, 31, 33, 36, 40

Source: Rima Petrossian, 2011

Table 6.15 shows which GMA the respondents identified as their location, the number of possible respondents based on the number of board members and general managers, how many responded, and the percent response rate based on the 640 possible decision makers. GMA 9 had the highest response rate at 34.7 percent and GMA 3, composed of one GCD, had no responses. GMA 5 does not have GCDs to survey.

Table 6.15: Decision Makers Response from Groundwater Survey December 2008

GMA	Number of Possible Respondents	Number Responded	Percent Response
1	24	7	12.5
2	41	9	9.8
3	12	0	0
4	33	4	9.1
5	0	0	NA
6	36	3	5.6
7	104	10	4.5
8	50	11	14.0
9	46	22	34.7
10	32	5	9.4
11	44	5	12.8
12	41	2	2.4
13	38	8	18.4
14	48	6	10.4
15	49	10	18.4
16	31	2	6.5
Total	640	79	12.3

Source: Rima Petrossian, 2010
NA – Not Applicable, No Districts Present

Pairwise Question Comparisons

Further analysis of other responses showed that slightly rewording a question could result in a different response. Several questions were worded differently with slightly different word choices to convey a similar understanding. Table 6.16 lists the questions 5, 17, 35, 43, and 44, used to indirectly test whether or not the respondent is consistent on their responses about who should be making the DFC decision. These four questions are worded in two ways, Questions 5 and 45 as multiple choice and Questions 35, 43, and 44, using the LS.

Table 6.16: Multiple Choice Questions Testing the Best Entity to Decide on DFCs

Question 5	Groundwater decisions are best made by the: Individual landowner or corporation; Groundwater Conservation District or county; Groundwater Management Area; Regional Water Planning Group; Texas Commission on Environmental Quality; Texas Water Development Board; Environmental Protection Agency; United States Geological Survey; No Comment.
Question 45	The development of groundwater supplies is best planned by the: Municipalities, Industry, Groundwater Conservation Districts, Groundwater Management Areas, Regional Water Planning Groups, Texas Water Development Board, Texas Commission on Environmental Quality, Environmental Protection Agency, United States Geological Survey, No Comment

Source: Rima Petrossian, 2012

Reponses to question 5, one of the first questions, and question 45, the next to the last question (see Table 6.17) show a change in opinion on who should be making groundwater decisions. Decision makers more strongly supported the GCD or county deciding upon DFCs than a GMA, but dropped their support for groundwater decisions DFCs from 79.7 to 65.8 percent by the end of the survey, increased their support from 8.8 to 13.9 percent for the GMA planning for groundwater and for TWDB from 3.8.to 10.1 percent.

Table 6.17: Decision Maker Responses to Questions 5 and 45

Question 5		**Question 45**	
Entity	**Response Count**	**Entity**	**Response Count**
Individual Landowner or corporation	6	**Municipalities**	1
GCD or county	63	**Industry**	0
GMA	7	**GCDs**	52
RWPG	0	**GMAs**	11
TCEQ	0	**RWPGs**	3
TWDB	3	**TWDB**	8
EPA	0	**TCEQ**	0
USGS	0	**EPA**	0
No Comment	0	**USGS**	0
		No Comment	4
Comments	15	**Other**	10

Source: Rima Petrossian, 2012

Table 6.18 shows the four LS-style questions, reworded slightly for the decision makers to identify who they believed to be the best entity deciding on the DFCs. This question helped to reveal how the decision makers compared to the landowners when viewed from those who lead the decision-making part of the DFC process and those who comply with that decision.

Table 6.18: Likert Scale Choice Questions Testing the Best Entity to Decide DFCs

Question 17	More people should be voting on the desired future conditions of aquifers other than the groundwater conservation district Board president
Question 35	A variety of stakeholders should vote on the desired future condition of aquifers, similar to the regional water planning group process.
Question 43	The groundwater management area is the best collection of entities to make the decision about the future of aquifers.
Question 44	The decision making process about the future of aquifers should be left for to each groundwater conservation district to make on their own.

Source: Rima Petrossian, 2012

Table 6.19 lists all the responses for the four questions about who is the best decision maker. When asked the first time in question 17, decision makers did not support a variety of people deciding on the DFCs. Decision makers indicated more people should be involved in a slightly reworded question. Questions 43 and 44 tried to establish if the GMA was the best decision making entity or the GCD, similar to question 5. Support for the GMAs to make groundwater decisions increased from 8.8 percent in question 5 to 73.4 percent in question 43. Support for the GCD making their own groundwater decisions dropped from 79.7 to 54.4 percent in question 44.

Table 6.19: Decision Maker Responses to Questions 17, 35, 43, and 44.

Scale Response	Question 17	Question 35	Question 43	Question 44
Strongly Agree	8	1	8	18
Agree	8	20	50	25
Neutral or Not Sure	9	15	6	10
Disagree	31	22	8	22
Strongly Disagree	23	21	5	3
No Comment	0	0	2	1
Total	79	79	79	79

Source: Rima Petrossian, 2012

Decision makers' comments on both questions 43 and 44 (see Tables 6.20.1 through 6.20.5) revealed the story behind the tension presented by having GCDs working together in GMAs. Some decision makers saw the GMA as a new pathway to what some call 'state control' as opposed to what is called "local control." Many GCD decision makers and staff may not perceive themselves as being 'state control' over groundwater, even though state law governs many of their processes. Others may perceive the DFC process as a step to improving scientific and groundwater data rather than changing who is tasked with making the decision about groundwater availability. The majority of decision makers believed that GCDs together in a GMA ought to make the DFC decision; a smaller number thought that GCDs ought to make the DFC decision independently of other GCDs, despite their initial reaction preferring that the GMA to make the DFC decision.

Table 6.20.1: Decision Maker Survey Question 42 and 43 Comments

Question 42: The groundwater management area is the best collection of entities to make the decision about the future of aquifers.
"I agree only if science is the deciding factor, not policy."
"For now, when new tools are developed then I could see the use of a science advisory committee."
"As the GMA's currently stand, if added people with little or no knowledge of the process, it would be a disaster."
"The State will ultimately take over and control everything. This exercise is just the start."
Questions 43: The decision making process about the future of aquifers should be left for to each groundwater conservation district to make on their own.
"In some way I agree with this statement but in others I realize that planning needs to cover a larger area."
"Locally elected board are the best avenue for groundwater management as they are responsible to the electorate."
"Some larger, more inclusive entity is needed for this. The GMA is good for now."

Source: Rima Petrossian, 2012

Some decision makers chose an extreme view through strongly agreeing or disagreeing when responding to survey questions. In the three statements below (see Table 6.20.2), no decision makers chose to "strongly agree" and few chose "agree." These statements relate to the pricing or value of groundwater in some way. Decision makers did not want regulatory agencies controlling groundwater pricing; they did not believe that the DFC process would result in giving landowners historically using lower amounts of groundwater an opportunity to profit from future groundwater transaction; or that the DFC would clarify landowner's groundwater rights.

Table 6.20.2: Statements where Decision Maker Did Not Choose Strongly Agree

The following entities should control the price of groundwater: the Public Utilities Commission, Texas Commission on Environmental Quality, or the Railroad Commission.
The desired future condition will result in a fair and reasonable outcome for individual landowners wanting to sell or lease their groundwater rights at some point in the future but currently are not producing high volumes of groundwater.
The desired future condition will clarify groundwater rights for non-exempt well owners.

Source: Rima Petrossian, 2012

The highest percent of decision makers chose “strongly agree” on two questions from the decision maker survey (see Table 6.20.3). These statements relate to changing or improving the DFC decision, where decision makers believed that the DFC process should have a chance to remain static through implementation, yet they expressed a need to better understand the groundwater models to decide on DFCs. Although in other comments the decision makers might have called the process an “unfunded mandate,” many supported leaving the DFC process as is.

Table 6.20.3: Highest Number of Decision Makers “Strongly Agree” in Survey Questions

Decision makers need a more technical understanding of the models to make their decision.
The legislature should not change the decision process for deciding the desired future condition in groundwater management areas.

Source: Rima Petrossian, 2012

The highest number of decision makers chose to “strongly disagree” in two questions from the decision maker survey (see Table 6.20.4). These questions relate to groundwater levels and pricing. Through the DFC process, a GCD establishes a set amount of groundwater available for permitting to meet their DFC goal over 50 years, potentially affecting groundwater available for export or large uses and costs associated with withdrawals. Decision makers strongly believe that state agencies identified in the survey should not control groundwater pricing. The decision makers recognize that the DFC process adopts a goal for aquifer conditions in the future that may cause aquifer levels to change.

Table 6.20.4: Decision Makers Choose Strongly Disagree in Survey Questions

The aquifer water levels will not change no matter what we have chosen as a desired future condition.
The Railroad Commission should control the price of groundwater.
The Texas Water Development Board should control the price of groundwater.
The Public Utilities Commission should control the price of groundwater.
The Texas Commission on Environmental Quality should control the price of groundwater.

Source: Rima Petrossian, 2012

Decision makers are divided on how well the DFC process was conceived in several aspects (see Table 6.20.5). In these four questions almost an equal number agreed and disagreed.

Table 6.20.5: Equal Number of Decision Makers "Agree" and "Disagree" in Statements

The Texas Supreme Count need to resolve the rule of capture and establish groundwater rights.
DFCs will benefit landowners who already produce a lot of groundwater.
The DFC process will help to establish groundwater rights and how much groundwater is available legally for property owners.
Groundwater cost will increase in a GCD because of the desired future condition.

Source: Rima Petrossian, 2012

Decision Maker Electronic Survey Additional Comments

The survey form provided space at the end of many questions for a respondent to add clarification. Many decision makers wrote about whether the current DFC process would be a preferable way to meeting their expectations or another process could better determine groundwater availability. These comments are presented to reveal how the decision makers view the DFC process in their own words, allowing them to voice their concerns anonymously without constraints of specific answers and scales. All comments are listed in Appendix B with the corresponding questions and some interesting results are discussed below.

Several questions address concerns about the current DFC decision-making process, such as whether the DFC process worked for the respondent's GMA, with the choices of *it works*, *it works but needs improvement*, and *it does not work*. These options seemed to confuse as some chose more than one response resulting in no clear response to this question, and no clear majority opinion. Additional comments (see Table 6.21) included three commonly voiced issues through the public meetings: flawed groundwater modeling effort, flawed process, and conflict in the process between the two types of districts, tax- and fee-based

Table 6.21: Decision Makers Survey Comments from Question One

Question One: What do you think about the process used in Groundwater Management Areas for determining your desired future condition?
Continuous improvement process.
Process is not equitable.
Without data it is hard to say if it is going to work.
The process is dependent on GAMs that even the TWDB admits have problems
Problem is conflict between tax based districts and fee based districts
Process still in progress.
Getting our GAM runs is/was slow. I think we were promised to have the report within a week or two.
Relies too heavily on faulty modeling
Our GMA has done a good job trying to implement a very seriously flawed process the legislature handed us.

Source: Rima Petrossian, 2012

Comments addressing stakeholder representation (see Table 6.22), support the GCD providing legitimate representation of all stakeholders. Some viewed the current process as effectively representing all stakeholders. Only a few indicated the necessity of more public participation due to the low level of current participation and lack of collaboration between stakeholders and decision makers.

Table 6.22: Decision Makers Survey Comments Question Two

Question Two: Note: Originally Senate Bill 3 required participation from a wide variety of stakeholders, but finally resulted in just the Groundwater Conservation District President as the sole vote for a desired future condition of an aquifer. The current groundwater management area process of deciding desired future conditions encourages public participation from different stakeholders other than groundwater districts outside of the public meeting notice requirement.
I agree in concept. However, in reality, though heard during public forums, action on public comment appears to be generally ignored.
A collaboration amongst GMAs and public participation at a minimum.
The public should determine the DFC via a vote.
The process is like Regional Planning - after 10+ years how many of the "public" know about regional planning?
Elected board members of GCDs represent the public and all stakeholders that live within their district.
Every county has been notified both by email and phone
If there has been any outreach attempt, I'm not aware of it. The president's vote determined by his board!!!
I believe that the boards of the WCDs understand the local needs better than "other stakeholders" and therefore are in the best position to address the issue. After all the purpose of a GCD is to provide for local control of the resources within that GCD and thereby within the GMA from those districts.
Revise question, wording unclear. Strongly support public involvement
I take this question to refer to GMA 9's process. I think we have done more than is required.

Source: Rima Petrossian, 2012

Comments addressing public participation (see Table 6.23) show different levels of participation: from little or no participation, to good participation, and of interest group participation. This could reflect participation levels at GMA meetings reflecting aquifers properties, groundwater use, and availability of other water resources.

Table 6.23: Decision Makers Survey Comments Decision Makers Question Three

Question Three: The public is participating in my groundwater management area by attending the groundwater management area meetings.
I have not seen much public participation in GMA 8.
Yes - and at community Workshops.
We have had only a few public attend any of our GMA meetings.
Including CAFO, Public Utility, Local Producers.
The public could care less and do not attend.
Have a room full at every meeting.
Limited agreement; there has been little or no attempt in our district to encourage public attendance.
Many seem to represent identifiable interest groups rather than the general public.

Source: Rima Petrossian, 2012

Comments addressing stakeholder participation at GCD meetings (see Table 6.24) showed a balance of full and limited participation. This is, as one decision maker observed, possibly a reflection of the level of local "hot-button" issues.

Table 6.24: Decision Makers Survey Comments Question Four

Question Four: The public is participating in my groundwater conservation district by attending our district board meetings.
Notwithstanding "hot button issues", public attendance is minimal and generally limited to a very small, but regular group of participants.
Sometimes
We never have anyone come to the Board Meetings
Do not attend
Have a room full at every meeting.

Source: Rima Petrossian, 2012

Comments about identifying the best groundwater decision makers (see Table 6.25) suggest that decision makers have widely varying opinions on who should make decisions about groundwater and what decisions those decision makers should make. There was no clear direction about who should make groundwater decisions.

Table 6.25: Decision Makers Survey Comments Question Five

Question Five: Groundwater decisions are best made by the: Individual landowner or corporation; Groundwater Conservation District or county; Groundwater Management Area; Regional Water Planning Group; Texas Commission on Environmental Quality; Texas Water Development Board; Environmental Protection Agency; United States Geological Survey; No Comment.
Until true consensual management can be applied over a common aquifer, I would much rather apply rules of a District that is too conservative in managing available groundwater over a neighboring District that issues permits with little concern for the future.
A consensus at the GMA level is beneficial. We should have a standard of operations at that level.
A cooperative effort between the GCD and individuals within the District is vital for good decision making.
Both the individual and the Groundwater Conservation District.
Note that a GCD and a county are not the same. Groundwater decisions [cannot] be made by a county nor county decisions by a GCD.
I am not sure what groundwater decision you are referring. Is it the type of pump or the amount needed to perform business, groundwater conservation districts are the second best decision maker after the individual.
These boards should be made up of landowner and business people from that area who know there conditions.
Actually various entities listed above should participate: District, GMA, TWDB, USGS.
With landowner, and public involvement
A consensus of GMA representatives would certainly be helpful.
Provided the groundwater district has fully shared the consequences of DFC and mismanaging resources
The GCD represents those individuals within its district therefore the landowners are represented by them. The less government we have the better (although the GCD is a government entity)
With landowner input
Groundwater Boards are elected officials responsible for the management and protection of groundwater
The scientific bases for decision-making are very limited even on a local basis, much less a regional one.

Source: Rima Petrossian, 2012

Comments on the legislature changing the DFC process (see Table 6.26) indicated it was too soon to consider changes other than voting requirements. One other change suggested solving the perceived contradiction of district funding driving opposing withdrawal approaches.

Table 6.26: Decision Makers Survey Comments Question Six

Question Six: The legislature should not change the decision process for deciding the desired future condition in groundwater management areas.
The Legislature should not change the process by law. Rather, the TWDB by policy should insist putting science before policy.
Not if the DFC can be decided by one person for an area.
There are some needed changes to the process but not the time period for the first settings in 09-10.
Not at this time, give the current process time to work and then we can work to improve the areas that are weak.
Problem with fee based vs tax based districts, one wants to conserve, the other sell water
All agencies charged with groundwater management like the Subsidence Districts should be included with voice and vote
Give the GMA's a chance to complete their task.
Not at this time! We haven't given it a chance yet! The idea seems to be plausible but more information and time are needed. We CANNOT start jumping from one thing to another just because it’s complicated and someone is doubtful.
What's the point of groundwater management areas if the legislature can willynilly override their decisions

Source: Rima Petrossian, 2012

DECISION MAKER AND STAKEHOLDER DFC FOCUS GROUP SURVEY RESULTS

Nine decision makers and 64 stakeholders responded to the same seven question survey in focus groups. It is possible that decision makers and stakeholders may have similar or different opinions. Statistical tests can evaluate whether GMA decision makers and stakeholders follow similar distribution patterns, agree on how groundwater availability should be decided and what factors are important in making such a decision or if the two groups’ response are different. Survey results were interpreted using a chi-square, goodness-of-fit test that is useful for evaluating LS data. Table 6.27 compares stakeholders to decision makers’ responses to questions of well ownership which resembled each other when asked about well ownership and water use type. Most stakeholders (68.8 percent) indicated they had a well and 60.9 percent used groundwater wells for domestic or livestock purposes. Eight stakeholders (12.5 percent) did not indicate how they used their well. Six out of nine (66.7 percent) decision makers indicated that they had a well. Five (55.6 percent) indicated they used their well for domestic or livestock use and four decision makers (44.4 percent) indicated this was not applicable.

Table 6.27: Stakeholder and Decision Maker Focus Group Identical Survey Questions

Question	Stakeholders			Decision Maker		
	Yes	No	Blank	Yes	No	NA
Do you have a groundwater well?	68.8%	31.3 %	NA	66.7%	33.3 %	0
If you have a well, do you use your well for household use and/or livestock watering?	60.9%	7.8 %	12.5%	55.6	22.2 %	22.2%

Source: Rima Petrossian, 2012

Table 6.28 lists seven questions, the percentage of stakeholders' and decision makers' LS responses as the data source for a chi-square test of independence, discussed later. Table 6.28 lists people's responses to whether TWC Section 36.108 guidelines were specific enough for developing reasonable DFCs. Decision makers agreed (66.7 percent) that the guidelines sufficed for developing reasonable DFCs, were not sure (22.2 percent) or disagreed (11.1 percent). Stakeholders disagreed (37.5 percent), were not sure (25 percent), or agreed (28.1 percent).

Table 6.28 lists people's responses to whether currently available models, data, and information were good enough to develop reasonable DFCs. Decision makers agreed (66.7 percent) that the guidelines sufficed for developing reasonable DFCs, were not sure (33.3 percent), and none disagreed. Stakeholders disagreed (37.5 percent) or were not sure (39.1 percent) with 17.3 percent agreeing.

Table 6.28: DFC Focus Group Survey Questions Three through Nine Responses

Question 3: Are the guidelines from Texas Water Code (TWC) Section 36.108 specific enough to develop a reasonable desired future condition of an aquifer?						
	Strongly Agree	Agree	Neutral or Not Sure	Disagree	Strongly Disagree	No Response
Stakeholder	0	28.1%	25%	25%	12.5%	9.4%
Decision Maker	0	66.7%	22.2%	11.1%	0	0
Question 4: Can the decision makers make a reasonable decision about desired future conditions using the currently available models, data, and information?						
	Strongly Agree	Agree	Neutral or Not Sure	Disagree	Strongly Disagree	No Response
Stakeholder	3.2%	14.1%	39.1%	25%	12.5%	6.3%
Decision Maker	11.1%	55.6%	33.3%	0	0	0
Question 5: Would stakeholders articulating their desired future condition through a filmed or recorded interview or anonymous survey help the decision makers?						
	Strongly Agree	Agree	Neutral or Not Sure	Disagree	Strongly Disagree	No Response
Stakeholder	7.8	42.2%	26.6%	15.6%	3.1%	9.4%
Decision Maker	0	11.1%	44.4%	33.3%	11.1%0	0
Question 6: If the decision makers were able to run groundwater models and test out pumping scenarios in a short time could they develop more reasonable desired future conditions?						
	Strongly Agree	Agree	Neutral or Not Sure	Disagree	Strongly Disagree	No Response
Stakeholder	10.9%	42.2%	17.2%	21.9%	6.3%	1.6%
Decision Maker	33.3%	33.3%	11.1%	22.2%	0	0
Question 7: If the decision makers knew about potential financial implications associated with decisions about DFCs they would develop a better or more reasonable DFCs?						
	Strongly Agree	Agree	Neutral or Not Sure	Disagree	Strongly Disagree	No Response
Stakeholder	12.5%	51.6%	20.3%	12.5%	1.6%	1.6%
Decision Maker	11.1%0	44.4%	11.1%	33.3%	0	0
Question 8: If decision makers analyzed past conditions of the aquifer, groundwater use patterns, trends, and elevation changes, they could develop more reasonable DFCs?						
	Strongly Agree	Agree	Neutral or Not Sure	Disagree	Strongly Disagree	No Response
Stakeholder	18.8%	59.4%	15.6%	4.7%	1.6%	0
Decision Maker	33.3%	66.7%	0%	0%	0	0
Question 9: Do you believe that the decision makers could develop a better or more reasonable desired future condition if they considered possible climate change (rainfall and temperature) implications for groundwater resources?						
	Strongly Agree	Agree	Neutral or Not Sure	Disagree	Strongly Disagree	No Response
Stakeholder	9.4	67.2%	20.3%	3.1%	0	9.4%
Decision Maker	0	33.3%	44.4%	11.1%	11.1%	0

Source: Rima Petrossian, 2012

Table 6.28 lists that many stakeholders agreed or strongly agreed (50.0 percent) that a filmed or recorded interview or an anonymous survey of stakeholder advice articulating their DFC would help the decision makers. Most decision makers were either not sure (44.4 percent), disagreed or strongly disagreed (44.4 percent) that stakeholder advice would help their decision making.

In the early part of the five-year DFC process GMA 9 stakeholders were able to run the Trinity Aquifer GAM model due to UT student assistance. Table 6.28 lists that most decision makers agreed or strongly agreed (66.6 percent) that decision makers running models improved the process for developing a better or more reasonable DFC. Stakeholders agreed (53.1 percent) with the decision makers on the value to decision makers on being able to run the models.

Table 6.28 lists that stakeholders felt slightly more positive (64.1 percent) about the value of decision makers knowing the financial implication for ensuring better or more reasonable DFCs. More decision makers saw this as useful (55.5 percent) versus not useful (33.3 percent). After September 1, 2011, financial implications are a required consideration in the DFC decision making process.

Table 6.28 lists that 100 percent of the decision makers agree that if they reviewed and analyzed past conditions of the aquifer, groundwater use patterns, trends, and changes, they could develop more reasonable DFCs. Stakeholders were less sure yet agreed (78.2 percent), were not sure (15.6 percent), and some disagreed (6.3 percent).

Table 6.28 lists that decision makers had no strong opinion that considering alternate future climate assumptions in the models to account for future changes could lead to better or more reasonable DFCs; most were neutral or not sure (44.4 percent), some agreed (33.3 percent) and some disagreed (22.2 percent). Most stakeholders agreed (76.6 percent) some were not sure or neutral (20.3 percent) and few disagreed (3.1 percent) that considering alternate future climate assumptions could improve the DFC choice. Climate inputs, primarily rainfall, are present in the TWDB GAM models.

Ranking of Information Informing the DFC Process

Table 6.29 lists key findings about decision maker and stakeholder rankings of possible DFC process data inputs posed in one of the survey questions. Decision makers and stakeholders ranked similarly information inputs that decision makers could use in deciding the DFC. Stakeholders and decision makers chose the same three types of information to use as the least important when deciding about DFCs.

Table 6.29: Comparison of Focus Groups Ranking Importance of Information Inputs

Stakeholders	Decision Makers
Historical Groundwater Data/Current Aquifer Conditions	Historical Groundwater Data/Current Aquifer Conditions
No majority winner, distributed over all choices.	Decision makers running groundwater models/testing scenarios
Rainfall and temperature variation and changes	Technical presentations and assistance
Tied: • Decision makers running groundwater models/testing scenarios • Technical presentations and assistance	Rainfall and temperature variation and changes
Future financial implications for entire local economy	Probability/likelihood desired future condition will happen
Landowner's/Well Owner's stated preferences	Future financial implications for entire local economy
Probability/likelihood desired future condition will happen	Landowner's/Well Owner's stated preferences

Source: Rima Petrossian, 2012

Stakeholders and decision makers did not share a vision (see Table 6.30) of who the best individuals are to decide about future groundwater policy. Stakeholders indicated that the best individuals to decide about groundwater availability were stakeholders or well owners. When asked about the best decision makers for the DFCs, 10 out of 39 stakeholders (25.6 percent) chose the GCD Board presidents as the people who ought to decide on DFCs. Nine stakeholders chose stakeholders and GCD president, four out of those nine modified their response to select stakeholders, RWPG, and TWDB, and one of the nine modified their response to add “every group [listed] and true statesmen.”

Decision makers chose GCD board presidents as the best individuals to decide on DFCs, with over 83 percent adding a comment which supported input from many other stakeholders. When asked about the best decision makers for the DFCs, 7 out of 9 decision makers (77.7 percent) chose the GCD Board presidents as the people who ought to vote on DFCs. TWDB and a cross-section of elected citizens tied as second choice.

Table 6.30: DFC Focus Group Survey Responses

Question: The best individuals to decide on the desired future conditions of an aquifer in my area are:	Stakeholders	Decision Makers
Stakeholders/Well Owners	40.6%*	*
Groundwater District Board Presidents	20.3%	77.7 %*
Regional Water Planning Groups	14.1%*	*
Texas Water Development Board	7.8%*	
Texas Commission on Environmental Quality	*	*
Texas Railroad Commission	*	*
A cross-section of appointed citizens in each groundwater management area	3.1%*	*
A cross-section of elected citizens in each groundwater management area	7.8%*	12.5%
No One	0	0
No Comment/Blank	6.25%	0

* Marked as additional in “other” optional choice for input, not for deciding the DFC
** All chose more than one group, including two that chose input from all other groups

One question used forced ranking to evaluate the importance of each decision criteria. Stakeholders and decision makers agreed on historical data being the most important tool, and agreed that stakeholder preferences were among the least important information to use. Table 6.31 reports DFC decision criteria ranking results re-ordered from most to least important.

Table 6.31: DFC Focus Group Survey Responses Ranking Process Tools

Question: Please rank from 1 to 7, from most important to least important, the importance of the following items on developing desired future conditions:	Stakeholders	Decision Makers*
Historical Groundwater Data/Current Aquifer Conditions.	59.4 % ranked #1, 23.4 % ranked #2; ranked in most categories	75 % ranked #1, no one chose lower than #2
Landowner's/Well Owner's stated preferences	29.7% ranked #7, 21.9% ranked #5, ranked in all categories	37.5 % ranked #7, no one chose larger than #3
Technical presentations and assistance	17.2% ranked #4; tied at 15.6% ranked #2 and 6, ranked in all categories	37.5 % ranked #3, no one ranked greater than #2
Future financial implications for entire local economy	25% ranked #5, 18.8% ranked #4; ranked in all categories	37.5 % ranked #6, no one chose higher than #3
Decision makers running groundwater models/testing scenarios	25 % ranked #4, 20.3% ranked #2; also ranked in all categories	Tied: 37.5 % ranked #2; 37.5 ranked #3, also ranked #1
Rainfall and temperature variation and changes	21.9% ranked #3, 18.8 % ranked #4, also ranked in all categories	37.5 % ranked #4, no one chose greater than #4
Probability/likelihood desired future condition will happen	31.25 % ranked #7, 15.6% ranked #6, ranked in all categories	Tied: 25 % ranked #4, 25% ranked #5, also ranked #1

Source: Rima Petrossian, 2012; * Results from 8 out of 9 decision makers surveyed.

CHI-SQUARE TEST RESULTS:GOODNESS OF FIT

Two statements test whether the two populations of stakeholders and decision makers' responses fit a particular probability distribution such as an equal probability of choosing one of the five answer choices. Chi-square tests were used to assess whether the two groups (GMA 9 stakeholders versus GMA 9 decision makers) answered questions in a similar manner. A low χ^2 statistic would indicate 'no difference' and a high χ^2 statistic would indicate 'different' answer patterns. To test these responses two answer categories ("strongly agree" and "agree") were added together to represent a single variable of "agree." The term "neutral" remains a single category. The options "strongly disagree" and "disagree" were added together to represent a single variable of "disagree." If respondents were to answer each of the options with equal likelihood, that frequency output would yield a 40, 20, 40 percent distribution for the three response categories (see Table 6.32). There are two statements which describe the null and alternate hypotheses to test the two population probability distributions:

$H_{o:}$ Stakeholders and Decision Makers have similar answer distributions, versus,

$H_{1:}$ Stakeholders and Decision Makers do not have similar answer distributions.

Table 6.32: Stakeholders and Decision Maker Responses to Six Survey Questions

	Questions						
	3	**4**	**5**	**6**	**7**	**8**	**9**
Stakeholders Responses							
Agree/Strongly Agree	18	11	32	34	41	50	49
Neutral	16	25	17	11	13	10	13
Disagree/Strongly Disagree	24	24	12	18	9	4	2
Decision Makers Responses							
Agree/Strongly Agree	6	6	1	6	5	9	3
Neutral	2	3	4	1	1	0	4
Disagree/Strongly Disagree	1	0	4	2	3	0	2

Source: Rima Petrossian, 2012

The chi-square statistic adds the differences between observed individuals minus expected individuals divided by the expected number of individuals:

$$X^2 i = \frac{\Sigma i(oi - ei)^2}{ei}$$ Equation 1

where i= 1, 2, 3,...n, o = observed frequency; e = expected frequency, and is an index of each person who responds.

Table 6.33 shows the chi-squared statistic results for questions 3-9, compiled from Table 1 in Appendix C. In all questions, the probability of exceeding the critical value of 5.99 is greater than 0.05. The null hypothesis is rejected with 95 percent confidence in all questions. The conclusion is that the stakeholders and the decision makers have different probability distributions for these seven questions and do not responding similarly to DFC-related questions.

Table 6.33: Focus Group Survey Questions 3 through 9 Chi-square Goodness of Fit Test

Questions	X2	Number of Observations	P-value
TWC Section 36.108 guidelines are specific enough to develop reasonable DFCs	10.48	n=67	p< 0.05
Can decision makers make a reasonable decision using currently models, data, and information?	23.5	n=69	p< 0.05
Would stakeholders articulating their DFCs through a filmed or recorded interview or anonymous survey help decision makers?	15.17	n= 70	p< 0.05
If decision makers could run groundwater models themselves and test pumping scenarios could they develop more reasonable DFCs	8.0	n= 72	p< 0.05
If decision makers analyzed past conditions of the aquifer, groundwater use patterns, trends, and groundwater elevation changes, they could develop more reasonable DFCs.	21.03	n=73	p< 0.05
Could decision makers develop more reasonable DFCs if they considered climate change implications?	8.0	n= 72	p< 0.05
More people should vote on DFCs.	21.33	n =72	< 0.05

Source: Rima Petrossian, 2012

SUMMARY

Focus groups and surveys (written or electronic online) were used to ask groundwater stakeholders and decision makers within GMA 9 GCDs to reveal their groundwater preferences. This chapter reports a contingent valuation (CV) assessment of groundwater value based on responses to a widely-distributed stakeholder survey. Benefits include low investment into collecting and interpreting this data, to factor into the decision makers efforts to identify socio-economic factors in the chosen aquifer conditions. Some alternative valuation methods including cost-benefit analysis for projects or policies, revealed preferences through hedonic pricing models. A combination of valuation approaches might be well-considered to derive better estimates. For example specifically for the Ogallala Aquifer, a combination of hedonic pricing, value transfer, and because of the complexity of agricultural activities contributing groundwater conditions, avoided costs for quantifying flooding events, and natural recharge features such as playas.[13]

Focus groups sought stakeholder and decision maker responses for six identical survey questions. Survey results indicated the decision makers did not perceive the DFC process as a multi-stakeholder voting process based on public participation. Some decision makers commented that the current approach relying on GCD leadership to make decisions functioned effectively and changes to the DFC process would not be beneficial. Some decision makers reported that the absence of state funding represent a barrier to maintaining the DFC process or address future disagreements. Some decision makers preferred to delay decisions until better and more complete information became available, although it is unclear how that additional information could effectively be used in the decision making efforts. Some stakeholders preferred to be incorporated effectively and meaningfully into the decision making process Some stakeholders believed that decisions needed to account for climatic changes and better groundwater data to develop reasonable DFCs. Chi-square statistic for goodness of fit for the seven identical stakeholder and decision maker focus group questions indicated that GCD leaders respond differently about the DFC process than do other groundwater stakeholders.

Differences between the stakeholders and decision makers' ideas about what information was valuable to use in the DFC process were collected through a forced ranking of what information was valuable rather than a LS ranking. The forced ranking resulted in the stakeholders and decision makers choosing as their first choice the same information as "Historical Groundwater Data/Current Aquifer Condition," when asked to identify which information might be helpful. Out of the seven choices, both groups ranked the same three items as being least important information. The choice of "Landowner's/Well Owner's stated preferences" being ranked low could indicate that both groups believe that the GCDs will not reasonably consider an individual's preferences as important as the technical and scientific data in the decision making process. These results suggest that the stakeholders and decision makers share preferences about "how" to decide on the DFCs even if they do not share enthusiasm over the resulting DFCs decisions.

The majority of stakeholders identified the best decision makers as stakeholders or well owners; 75 percent of the decision makers preferred the GCD board presidents. This suggests that stakeholders would prefer to be the decision makers rather than being asked for their preferences. It could also mean that stakeholders believe that preferences do not matter as much as technical information, which could mean they trust the process to use the technical information and do not have concerns that the decision makers' preferences are different from their own or are being considered above the technical information, suggested by the responses listed in Table 6.27.

GMA 9 stakeholders differed from GMA 9 decision makers in the ways they think about the DFC process. These differences create an opportunity to improve the process by improving the existing DFC procedures to use those differences to enable GMAs to develop DFCs with all parties participating. Chapter 7 presents stakeholder views gathered though the IQA reporting framework, including a systems analysis and scenario building, and focus group survey narratives.

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Chapter 7: Stakeholder Reactions to Groundwater Management and Decision Makers Definition of the DFC System

This chapter reports on GMA 9 water user and decision makers preferences regarding groundwater management based on focus groups and surveys, as interpreted through Interactive Qualitative Analysis (IQA). One section reports 14 stakeholder focus groups discussions about the desired future conditions (DFC) process and extracts 11 elements from the focus group responses. A second section reports on the decision maker survey results including their identification of the 12 elements of the DFC process system and develops an IQA systems diagram based on the decision makers' focus group. A third section uses the IQA approach to analyze decision makers' perceptions of the DFC system using a so-called a Systems Influence Diagram (SID), included in this section. Final sections discuss the results.

STAKEHOLDER FOCUS GROUPS

Each district manager provided a list identifying local residents who had expressed an interest in groundwater issues and each of those residents were encouraged to identify other stakeholders. Those persons were invited by either by telephone or electronic mail to attend a local uncompensated stakeholders' focus group. GMA 9 decision makers met for a regularly scheduled technical meeting to participate in a focus group discussion.

During the period of January 28 through June 5, 2010 fourteen GMA 9 stakeholder groups met to discuss their opinions of groundwater management practices.

Table 7.1 lists the groups and their respective GCDs. Stakeholder focus group settings varied at each location.

Table 7.1: Fourteen GMA 9 Stakeholder Group Locations and Participants

Location	**Number of Stakeholder Participants**	**Number of Decision Maker Participants***
Bandera County River Authority and Groundwater Conservation District	11	1
Barton Springs/Edward Aquifer Conservation District	0	2*
Blanco-Pedernales Groundwater Conservation District	10	2
Comal County Stakeholders	4	Not Applicable, 0
Cow Creek Groundwater Conservation District	11	1
Hays-Trinity Groundwater Conservation District	8	1*
Headwaters Groundwater Conservation District	10	2*
Medina County Groundwater Conservation District	4	0
Trinity Glen Rose Groundwater Conservation District	7	1*
Total	64	10

Source: Rima Petrossian, 2012; * Six decision makers attended the decision maker focus group, later four additional decision makers gave personal interviews about the conclusions derived from the focus group.

Table 7.2 lists the three questions assessing the DFC process posed to the stakeholders focus groups to spark the discussion. The IQA method sorts the participants own words describing DFC process to identify 12 themes, called elements. Each of the 14 stakeholder focus groups began with a written survey response to 11 questions, then discussed their responses to three questions over 60 minutes, and these responses were recorded, transcribed, and categorized into IQA-style elements. The decision maker focus group, began with a written survey response to 11 questions, then discussed their response to the one question asked (“tell me about the DFC process”), followed by an activity in which decision makers created categories describing the DFC elements. Decision makers individually created a diagram to describing DFC drivers to outcomes by comparing paired elements (see Appendix C). The top 20 percent paired relationships were used to develop a DFC system diagram.

Table 7.2: Focus Group Questions

GMA 9 Stakeholders Focus Groups Asked:	**Number of DFC Elements Derived from Focus Groups**
• If you were to become a decision maker in this process, what would you like your desired future conditions of your aquifer to look like over the next 50 years? • If you were a voting member of the group that makes the decision about the desired future conditions of the aquifer, what information would you like to have in order to make the decision? • To you what are the implications of deciding the desired future condition of the aquifer?	11
GMA 9 Decision Makers (One Focus Group) Asked:	**Number of DFC Elements Focus Group Identified**
• Tell me about the desired future conditions process.	12

Source: Rima Petrossian, 2013

STAKEHOLDER FOCUS GROUP RESULTS

Five stakeholder focus groups met in each of three GCD offices and two groups of Comal County stakeholder met in New Braunfels, where there is no GCD. From two to ten participants gathered to discuss the DFC process for about an hour in each focus group to discuss three questions. Focus groups surveys were administered prior to the open discussion to introduce the DFC process and local groundwater issues. Each focus group occurred in a slightly different manner.

All focus groups had six steps in common: an initial welcome and words of appreciation for attending; an explanation about the session recording; seating around a common table or desk; administration of a short survey (in silence) for about 10 minutes; and an explanation about the process including a 20-minute per question time frame. Participants were advised that the process sought to report each person's reaction to each question.

Stakeholders Elements

Stakeholder's stories, opinions and views as expressed in over 14 hours of recordings, later transcribed, and after analysis organized below into 11 themes or element: Planning, Legal, Governance, Uncertainty, Water Use, Natural Environs, Data/Technology, Political, Cost, Personal Rights, and Human Density. Stakeholder's stories about local water issues, summarized below by element, are excerpted in more detail in Appendix D.

Planning

Stakeholders reported a preference for *planning* and interaction among interest groups to improve groundwater and governance. Groundwater was seen as a controlling force in Hill Country development and Hill Country land development became a re-occurring concern discussed in this and every other element. Landowners articulated fear about not being able to continue to live as they are accustomed to due to local governments' limits on managing, developer or newcomer expectations. Development was characterized as a race to capture the water first through permitting and subdividing. One stakeholder characterized a DFC as being able to turn on the tap and yield water even during "drought of record" conditions. Another stakeholder identified collaboration critical among, "…the county, and the groundwater district, and the state legislature…" as to solve future water supply problems.

Some Hill Country stakeholders indicated that a problem envisioning solutions where no one loses water, all can stay in the Hill Country and preserve investments, and allow future investment. A perceived lack of control of new subdivisions was described as a factor in how GMA 9 has changed over the past few decades and in the way the area will emerge over the next 50 years.

Legal

Participants in each focus group discussed *legal* issues, sometimes expressing frustration and disbelief with the dichotomous and conflicting views of the prevailing legal and administrative approaches to governing groundwater in Texas. Although everyone recognized the existence of the so-called "rule-of-capture" and the GCD authority that modifies that approach (in the majority of Texas), they also realized the management complications of trying to enforce these two approaches at once. One stakeholder accepted how in Texas a private water supplier can exist, but not why a private corporation has ownership rights to profit from groundwater thought of as a common pool resource. Some stakeholders discussed the confusion caused by having two separate and different systems for managing groundwater and surface water in Texas. Stakeholders brought up experiences in other states or with surface water, yet expressed language emphasizing the complexity and secretiveness of groundwater right constraints, for example regarding water "…and that something that can be snuck away from you." Zoning decisions causing lawsuits due to being too restrictive or not restrictive enough are viewed as complex to resolve, such as "…And so I am not sure where I am going with this but it is a matter of there is a lot of competing demands out there, we want the water to be clean, we want folks to want to live here."

Governance

Although GCDs manage groundwater in most of GMA 9, other *governance* such as local zoning influence public responses to the DFC process. Stakeholders recognize issues such as water use, conservation, and lack of controls over larger, wealthier landowners' legitimate water uses. Stakeholders recognized that the people responsible for either providing or controlling water can behave politically when considering how to govern groundwater use. In some areas the GCD director elections are imbued with conflict, for example, "…I think they were just running to pick a fight but they did not get in." Or in an area without a GCD, for example, political will against having groundwater governance is also strong, "There you are talking about politics and how you get things done. You have to take that into account. And I think that when you mix that with facts that is where policial decision making becomes very difficult." Stakeholders express concern about the water volume that will be available in the future and controlling people's practices that waste water, for example, "because they are professional water users…they have got the greenest yards." Stakeholders associated wealth with groundwater uses such as watering lawns or irrigating golf courses. Stakeholders recognized the conflict of having attractive green golf courses in a semi-arid area, for example, "…they built three or four new golf courses that are going to be the most wonderful place to play golf in the world…but you had better find out where the [water is going] to come from." Stakeholders worried about watering livestock perceive golf courses as wasting water. Multiple stakeholders mentioned concerns about golf course development being beyond the control of groundwater regulators in some water-limited areas or "vanity" water uses (such as ponds and fountains), associated with wealthier residents as being unregulated by many GCDs and associated with waste.

Stakeholders identified rainwater harvesting as a solution to water limitations in the Hill Country and reported positively about local ordinances or zoning boards requiring new housing to be built with rainwater harvesting capabilities: "I think the developers ought to be, they should be required to do that when they are developing the property. And it might come to a time when it would be a requirement for builders to put in a rainwater system.I cannot understand, well I can understand very well why it is not done, it is not lucrative to developers and they do not want it but I wish we could require that."

Uncertainty

Despite the unknowns about groundwater planning and population increases *uncertainty* in future groundwater use seems was a common concern. For example, "but if there is a way to figure out how much population can be sustained here and what kind of population and we need to make sure that we do not ever go over that point." Stakeholder uncertainty included the perceived threat to intergenerational persistence of the legacy of land and groundwater to children and grandchildren. Stakeholder's believe that conservation efforts could bring more positive outcomes, such as "…unless you have experienced changes that have been created at Bamberger Ranch, you may not feel that progressive efforts can be very successful, but if you look…the more reason you would find to be optimistic about the good results that you have." Future innovations regarding capturing surface water and storing it underground preventing evaporation and stream flow losses. Uncertainty extends to the hydrogeological setting, such as "I drilled 505 feet I think the driller run out of stem and quit. The driller said it was at the Cow Creek. The more I think about it the more I doubt that" or "If they figure out a way to pump out more water, San Antonio is sitting there just dying to have more water, they would do anything. And we come along and dig for water, we had the equipment that would dig for and now it is getting expensive…" and "they drill so far down they they have ever before, there might be water there, who knows?"

Water Uses

Stakeholders describe conservation as a solution to reducing water use, for example, "This is going to have tremendous implications as far as development, it is going to have implications as far as highways, it is going to have implications as far as water useage, what people can do with water commercially and individually." Stakeholders discussed w*ater uses* as including agriculture, livestock watering, commercial or industrial, municipal and domestic use, recreational and environmental. Stakeholders expressed awareness of water issues such as in-stream flows and losses of fresh water to the Gulf, solutions such as desalination, and impacts of lawn watering and available controls. Having a green lawn in the Hill Country becomes an un-neighborly action when it comes to gauging the best use of groundwater. Stakeholders believe a variety of sources and conservation practices, even on an individual level can make a difference such as, "I would want to encourage more rainwater systems to conserve what falls, educate people how to use a well, and not so much irrigation." In addition, conservation is viewed a future-oriented practice, "…and I would look towards education. In fact I think probably the future of our aquifers in the 9 through12 year olds are going to school today. We need to teach those people conservation. Because quite honestly we are not going to change some of the gray-haired folks around here." Hill Country stakeholder's view water as having special significance, for example, "And those streams and the ability to have water available for recreation, for wildlife, and just for the simple beauty of that stream or creek or whatever it is, is really important, I think, to this area because we are a colony around here first of all that is pretty heavily dependent upon tourism. And that is one of the things that attracts people to this area is that concept of water and the naturalness of the area and so forth." Golf courses tended to be criticized as big water users, for example, "I like to say too, you have got to watch these golf courses, they tell me that 50 percent of the water in San Antonio goes for landscaping and that includes golf courses. Well, no damn wonder there is not any water." Hill Country growth through subdivision development generates conflicting preferences and views. Negative implications include increased groundwater use from growth. For example, "I am not anti-growth, growth is good. What frustrates me is that, and I agree that science, and I also agree that I think that the East case is probably correct where it described groundwater as mysterious and occult."

Natural Environs

When people look at rivers and the *natural environs*, they have a well-developed sense of how much water Texas has each year as we pass through annual rainfall cycles. Groundwater systems are only visible at the surface as spring flow. In one example, a stakeholder indicated, "Now I am only guessing that but if it comes out slow it is going to go in slow." Another stakeholder recognized the connection between springs and groundwater, such as, "there is a certain percentage of the aquifer that is above the point where the streams actually work, you can suck the aquifer down, the creeks will stop flowing the springs will not flow but there will still be water in the aquifer." Legendary droughts and aquifers were not just hyperbole to these stakeholders. Some lived through the famous 1950's drought-of-record and remembered the impacts they and their families experienced and expressed a wish that springs could return to pre-1950's levels. For example, "I am 75 years old, and I well remember the 50's drought and we have had quite a few droughts in the last 10-20 years. And in those days too you put in a windmill and it pumped 2-3 gallons a minute and that was all it would do, as fast as the wind blew." They are also concerned about sustainability and maintaining good water quality. Stakeholders perceive some naturally occurring ecosystem components (such as cedar trees) as water resource threats. One stakeholder indicated, "Yes, I have cleared the cedar several times on my place and in fact I have to go back again. But I noticed, Turkey Creek runs through my place, and I have noticed the difference in the amount of water in that creek because of the cedar clearing I have done." Another stakeholder expressed a complicated request for the future aquifer state, "When I say what I would like to see in my aquifer, I am not sure in 50 years that I should be saying that I would like to see my aquifer full, because you know that is like pie in the sky. I am saying that it would be absolutely unacceptable for the the aquifer to be depleted, or the protected species are not protected or that the springs do not flow, I think that is absolutely unacceptable."

Political

Focus group participants reported that the groundwater management process had not changed over the years and that the *politics* of groundwater remain a part of Texas history. For example, one stakeholder said, "Before Texas became part of the United States it was a huge cattle operatation and I know there were huge fights over the water. I am concerned that same scenario will happen again and we will not be prepared for it." Along the same vein, violence is tied to water shortages, for example, "And then we have not talked about all the conflict that come from when you have a water shortage, you do not have enough water, where people killing each other over water like you have people killing each other over oil." Another stakeholder expressed a view that groundwater planning is like any other political process. "And I think it is the same with politics anywhere, with decision makers anywhere. They do try to affect decisions and I think you have to take those people into account, those industries into account, those kinds of things." Stakeholders expressed concern over the developers responding to opportunities of people interested in retiring in the Hill Country, a relatively dry area, and how that is being encouraged by local ordinances. "We are not one to stop growth, but we do need to channel it. And we need to get over this idea that the ideal is this five or ten acre tract of land with one house on it sitting out in a endless row of subdivisions across the hills." Stakeholders observe what happens when money and control drives a process and are not happy about the outcomes. Some see incentives and control as solutions to water shortages, not interference.

Data/Technology

Stakeholders reported a preference for all available *data and technology* to make decisions about groundwater. For example, one stakeholder indicated "I want all the data I could get" while another stakeholder warned that limitations were important, "Don't have another study, they have studied everything to death." Stakeholders specified information as necessary, such as population projections, hydraulic properties, aquifer levels through well measurements, climate impacts, economics, case studies of effective land management and water management, models, mathematical inputs, hydraulic connectivity, and groundwater availability. Several recognized the need for more hydrogeological information, for example, “But how do you get the money, how do you get this information? Test wells is a step in the right direction, maybe more test wells, more monitoring wells and get a better picture of the aquifer. And it takes the monitoring wells and means to get the scientific information but you cannot make decisions without that scientific information.” or “I think I would like to see the latest scientific data, I do not want something that is years old or hydrogeologist or somebody say, "*well I think this is what we have.*" One of the pieces of information that is really missing in all the modeling is the actual water use of the exempt wells. That it is a big missing number.”

Costs

Stakeholders seemed aware of the *costs* associated with groundwater use, and the implications of the relative health of the economy and socio-economic factors for affecting people’s choices on water use and groundwater management. One stakeholder supported increasing water costs to improve conservation, “So I think you have got to make expensive and I know that is not really a tool per se but it is I think really key to conservation. A few years ago in 2004 the city went to a tiered system to where the more you used the higher you paid a rate and you conserve you pay a lot less, and they did not do as strict of a system as some communities.” Another stakeholder recognized the importance of factoring together scale of use and costs for those on water systems, for example, “I know right now if you use 1-1000 gallons it is a penny a gallon or something and once you go over 1,000-2,000 maybe it is 2 pennies a gallon. Well, once you cross that boundary, all your water should be at that higher rate, not just that portion that went over the 1,000 gallons. So the guys that are really using it, they get socked in the bank." Although no one bills many Hill Country residents once a month for groundwater many people reported that recreation and conservation that might necessitate factoring in the value of groundwater. For example, "to see any ultimate success with any of it is the ability not only to sustain the aquifer you have got to find some way to sustain the economic system that is on top of the ground it is going to help you accomplish things for the aquifer, for the area and what would be good and reasonable and sustainable growth." Harvesting rainwater was seen as an expensive but preferable solution, "A lot of folks are able to go to rainwater collection after the fact and a lot of new homes are being built with rainwater collection but there are a lot of folks that cannot afford to do that." One stakeholder noted another effect of water costs included electricity generation, "I think there are economic implications, we are going to have to do something about electricity, the way we produce electricity there may not be electricity anymore the way we are producing it and we are beginning to look at those kinds of wind generators instead of water generated plants and things like that."

Personal Rights

Some stakeholders believe they have an inherent *personal right* to groundwater even if they are not certain groundwater will be around in their future. Stakeholders expressed concern over neighbors' use of an aquifer and sometimes reported a personal possessiveness toward the resource. For example, "…well she is real protective, she is 86 years old and that is her well and nobody is going to touch it." Another stakeholder indicated, "I am like you where we have to be careful about the amount of straws we put in the ground but I do not want to be overly regulated by the government if it was my own private well." The type of rights stakeholders discussed, although not necessarily supported, varied from private property rights to human rights to constitutional rights, for example, "because your property, whatever it is sitting upon owns all the rights unless the rights have been sold like the oil, the gas, the water," to a sarcastic observation of "…No, it is basically a human right..." that he has a green yard," and the larger picture portrayal of "…it becomes an economic thing of whether they can afford to live here or not but unless you change the constitution that is not going to change."

Human Density

Stakeholders told stories of how the Hill Country once was a semi-arid, sparsely-populated beautiful ranching and farming area different from the rest of the state because of the abundance of rock formations and springs. They related how the Hill Country is becoming a popular retirement and weekend home destination for an increasing population, with increasing *density*.

For example, the story of the 50's drought provides a touchstone for one stakeholder to explain historical differences, "I remember in the seven year drought we had, we did not have the water problem that we had in the last three years because we did not have the people in the 50's that we do now. And we did not have as many homes around like we have now and people did not use as much water back in the 50's." Water conservation is a commonly expressed concern, whether supportive toward or critical of some efforts to get around local drought planning efforts. For example, one stakeholder supported growth and rationing, “You have additional people coming in and you have a limited amount of water so ultimately if your community starts getting too big and you have a limited amount of water, then you are talking about rationing. I would like to be able to support growth in the community anyway.” or “… you get a lot of people from Houston, they have dirt. You drive along the interstate here, we have one inch of dirt on top of rock. These people will bring in dirt and build them a nice yard. And their water bills are real high and it is running down the street. And you say, what are they doing growing rice?

Sustaining

Stakeholders expressed concern for *sustaining* aquifers based on their experience with the water level fluctuations. They related stories about observing nature over time during their residency in the Hill Country. Many made a point of saying that they want to keep the area full of springs and water. According to one stakeholder, supporting human density necessitates, “at some point in time there has got to be a point on the axis where we know more or less how much sustainable water there is going to be here on the long term and then how many people that will support. And then back away from that and maybe your policies or laws or whatever address that particular issue.” One stakeholder tied sustainable definition to science, for example, “And if this [is] an area of Texas that we can only allow so much sustainable growth we must face those facts, but it is scientific information." Stakeholders expressed concern about the timeframe of groundwater use, past wasteful or conservation practices, and intergenerational legacy. One stakeholder talked about sustaining growth, another aspect of sustainability, for example,"So you have got about 300 to 200 acre-feet of water left in the aquifer, how are you going bring in additional growth or how are you going to sustain that growth when it does come into a particular area?"

DECISION MAKERS DFC FOCUS GROUP

Six decision makers, primarily GCD managers, met on December 7, 2011 at the Blanco-Pedernales GCD headquarters in Blanco, Texas. Each of the six attendees completed a survey (Appendix A) and sought to identify relationships among elements. Three additional decision makers not attending the focus group provided survey responses and completed compared element diagrams (see example in Appendix C). As a group they discussed one question, part of the IQA method, "*...tell me about the desired future conditions process.*"

The six decision makers began by describing their impressions of the DFC process. After about 20 minutes to consider this question, the group posted their statements on a wall. They then grouped the statements into similar categories called elements (see Figure 7.1). The written responses were coded and processed using the IQA methodology. Decision Maker Focus Group Results

Participants of the DFC decision-maker focus group named these 12 elements that they agreed describe the DFC process (see Table 7.3). It is interesting that these elements are similar to those listed in the stakeholders' focus groups section above. These elements represent how the decision makers characterize the DFC process or system. Table 7.3 lists the elements in random order and assigns a number to each element. This number identifies the element in the system diagram.

Figure 7.1 Example of Decision-Makers in Interactive Qualitative Analysis Focus Group

Source: Linda Ruiz McCall, 2012

Table 7.3: Twelve DFC Elements

Decision Makers Twelve DFC Process Elements	
1	Collaboration and Planning
2	Metrics & Measurements
3	Controversy
4	Time Frame
5	Education
6	Implementation
7	Unfunded Mandate
8	Political and Interagency
9	Complex Issues
10	Benefits
11	Stakeholder Input
12	Weaknesses

Source: Rima Petrossian, 2012

These 12 elements are the basis for developing a DFC Systems Information Diagram (SID). This diagram illustrates the direction of relationships each element and every other element, or what process drives another process. In this 12-element system, 132 pairs of 66 unique pairwise combinations are possible. This comparison, identifying which element has to happen for another element to happen, is a step for developing a SID. One decision maker explained the choice between the pair 2, 12 as "We think 2 drives 12 because until we get better data and models, how we measure will always be a point of contention. Even something as simple as how to account for unpermitted usage turned out to be a sticking point." [1] Each decision maker filled out a table of pair-wise comparisons while discussing their choices with another decision maker. This exercise provided the source of relationships compiled from 10 decision makers' choices (see Table 7.4). Table 7.4 lists the frequency of decision makers' choices for pair-wise relationships among elements. This approach uses a frequency count to characterize primary system drivers and outcomes, and secondary drivers and outcomes. An arrow originates with the cause (driver) pointing to the effect (outcome) for all possible element pairs. The most often-identified element that the decision makers interpret as driving most pair-wise comparisons becomes the driver of the entire system. Appendix C includes tables representing the steps in the process of identifying the relationships among the elements.

Table 7.4: Decision Makers Focus Group Affinity Pair Occurrence Rate and Relationship

Theoretical Code Occurrence Rate and Relationship Direction Chart							
Affinity Pair	**Rate**	**Affinity Pair**	**Rate**	**Affinity Pair**	**Rate**	**Affinity Pair**	**Rate**
1 → 2	4	2 ← 8	3	4 → 8	2	6 ← 11	5
1 ← 2	6	2 → 9	5	4 ← 8	8	6 → 12	4
1 → 3	6	2 ← 9	4	4 → 9	8	6 ← 12	3
1 ← 3	3	2 → 10	8	4 ← 9	3	7 → 8	5
1 → 4	3	2 ← 10	1	4 → 10	6	7 ← 8	6
1 ← 4	6	2 → 11	6	4 ← 10	0	7 → 9	6
1 → 5	8	2 ← 11	2	4 → 11	7	7 ← 9	4
1 ← 5	2	2 → 12	6	4 ← 11	2	7 → 10	7
1 → 6	9	2 ← 12	5	4 → 12	5	7 ← 10	0
1 ← 6	1	3 → 4	5	4 ← 12	4	7 → 11	7
1 → 7	0	3 ← 4	6	5 → 6	6	7 ← 11	0
1 ← 7	9	3 → 5	8	5 ← 6	5	7 → 12	9
1 → 8	5	3 ← 5	1	5 → 7	1	7 ← 12	1
1 ← 8	6	3 → 6	4	5 ← 7	9	8 → 9	4
1 → 9	7	3 ← 6	5	5 → 8	3	8 ← 9	6
1 ← 9	3	3 → 7	0	5 ← 8	7	8 → 10	7
1 → 10	8	3 ← 7	9	5 → 9	1	8 ← 10	1
1 ← 10	1	3 → 8	2	5 ← 9	8	8 → 11	6
1 → 11	6	3 ← 8	9	5 → 10	8	8 ← 11	5
1 ← 11	4	3 → 9	5	5 ← 10	3	8 → 12	4
1 → 12	3	3 ← 9	6	5 → 11	4	8 ← 12	5
1 ← 12	4	3 → 10	5	5 ← 11	6	9 → 10	7
2 → 3	8	3 ← 10	3	5 → 12	1	9 ← 10	1
2 ← 3	2	3 → 11	4	5 ← 12	7	9 → 11	6
2 → 4	3	3 ← 11	7	6 → 7	2	9 ← 11	4
2 ← 4	7	3 → 12	1	6 ← 7	8	9 → 12	7
2 → 5	5	3 ← 12	6	6 → 8	2	9 ← 12	2
2 ← 5	2	4 → 5	6	6 ← 8	8	10 → 11	2
2 → 6	7	4 ← 5	4	6 → 9	3	10 ← 11	8
2 ← 6	3	4 → 6	8	6 ← 9	9	10 → 12	2
2 → 7	0	4 ← 6	2	6 → 10	5	10 ← 12	3
2 ← 7	9	4 → 7	1	6 ← 10	3	11 → 12	3
2 → 8	5	4 ← 7	7	6 → 11	4	11 ← 12	5

Source: Rima Petrossian, 2012

Table 7.5 lists the most frequently identified pairs and the most frequently identified direction from cause (the driver) to effect (the outcome) that characterize the decision makers interpretation of the DFC system. Decision makers identified the element *Unfunded Mandate* as driving the DFC process with the primary outcome as *Benefits.*

Table 7.5: Decision Makers DFC System Drivers and Outcomes

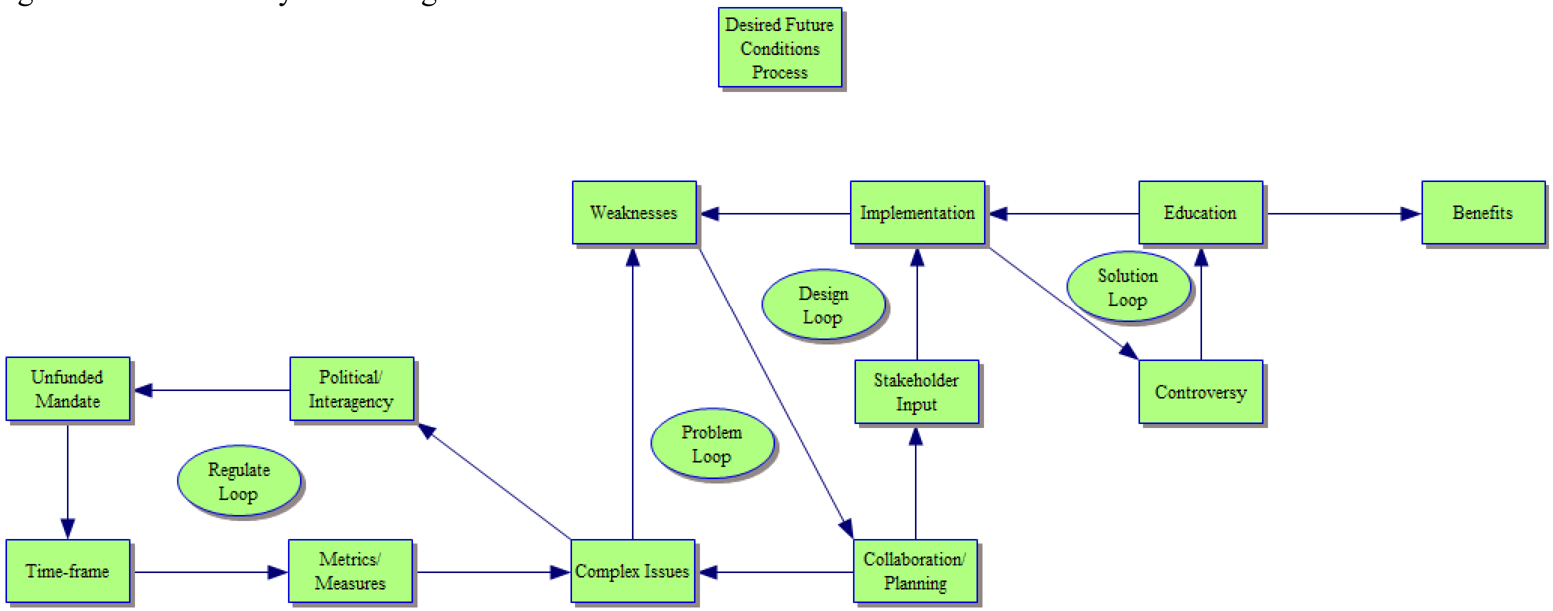
Tentative SID Assignments	
7: Unfunded Mandate	Primary Driver
2: Metrics & Measurements	Secondary Driver
4: Time Frame	Secondary Driver
9: Complex Issues	Secondary Driver
12: Weaknesses	Secondary Driver
8: Political and Interagency	Secondary Driver
1: Collaboration and Planning	Secondary Driver
11: Stakeholder Input	Secondary Outcome
6: Implementation	Secondary Outcome
3: Controversy	Secondary Outcome
5: Education	Secondary Outcome
10: Benefits	Primary Outcome

Source: Rima Petrossian, 2012

Figure 7.2 shows the decision makers DFC systems diagram, a visual and statistical representation of how the decision makers viewed the DFC system they developed in their focus group. The DFC SID element interrelationships are represented with primary driver on the left and primary outcome on the right with the secondary drivers and outcomes making up the rest of the DFC system. Building the SID or a “mindmap” describing the participants’ experiences and interpretation of those relationships requires identifying the fewest relationships that describe at least 80 percent of the system variability using IQA’s Pareto table included in Appendix C.

The SID DFC system diagram can be compared with an electrical diagram providing a map for understanding an electrical system. The SID allows a person to interpret now new issues, such as a petition will resolve, how system components cause different outcomes, or to interpret why changing one system element may not result in desired outcomes.

Figure 7.2 DFC SID Systems Diagram



Source: Rima Petrossian, 2012Using the DFC SID to Build Scenarios

Decision-maker identified elements in the DFC SID (Figure 7.2) represent an interpretation of the DFC system identified through the IQA process. Decision makers can use this system to identify the best places to apply policy changes or exert efforts to improve DFC decision making or management approaches. The DFC process can be tested with scenarios to help identify strengths and weaknesses of the process or to reveal feedback loops to improve the flow of the process and outcomes. The SID, read left to right, is the simplest representation of how the DFC elements interact, with arrows originating at the driving source of influence or cause pointing toward the direction of effect or outcome. All redundant relationships are removed to show the simplest paths through the system. There are four feedback loops in the system (Regulate, Problem, Design, and Solution) representing sets of element that can be recursive steps in the process. For example, when stepping through the system in order the process started at *Unfunded Mandate* as designated by the decision makers, which then leads in one direction to *Time-frame*, then on to *Metrics*, and *Complex Issues*. So far this is the only path the process can follow. At *Complex Issues*, if the group identifies *Weaknesses* in the process, they can go onto the *Problem loop*, and work within *Collaboration* to characterize and address the *Complex Issues*. If not, the loop recurses or the DFC process may return back to *Political/Interagency* for new guidance, enforcement, or process, and starts over again.

An example of DFC system recursion is how the 2011 Legislature provided new guidance, for example requiring an descriptive report about how the group arrived at their choices of DFCs for all aquifers, to address complex issues raised in the 5-year process [2]. Another example could be when the issues involving exempt use and permitting in the initial modeling efforts causing confusion about whether the MAG was a floor or a cap [3]; stakeholders and decision makers went back to the TWDB to ask for guidance [4]. If the group makes it past the *Complex Issues*, identifies the *Weaknesses*, *Collaborates and Plans* for these weaknesses, they may go onto *Stakeholder Input*. If not, they go back to *Complex Issues* to try again. After *Stakeholder Input* and *Implementation*, there are two possible outcomes: *Controversy* moving forward in the process or recursing backward to *Weaknesses* discovered after *Implementation*, which could describe the TWDB Petition process. After DFCs are adopted and there is *Controversy*, the next step is *Education*, by the petitioners to the public and decision makers, by the decision makers to the public, and by the TWDB Board to the petitioners, decision makers, and the public. After *Education*, the DFC process could finish with *Benefits* experienced, or could recurse back to *Implementation* with a new DFC cycle. Depending on the outcome of *Education*, the process could potentially recurse back through all the loops to a new starting point.

A systems diagram can be tested to see how proposed solutions can affect the outcome. For example, if *Implementation* always has to go through *Controversy* to get to *Education*, the solution may be to recurse back through the system to revisit the weaknesses and better resolve them before *Implementation*. Alternatively, if educational steps can the process go through *Controversy* more easily, preventative educational steps prior to implementation might help the process better survive the *Controversy* and minimize *Education* necessary to get to *Benefits*. This system can be scenario-tested to provide decision makers with creative and applicable policy design improvements. Alternatively, the decision makers can collaboratively review the DFC SID, rethink their perceptions of how the DFC process works, and make changes in the steps they follow to stem controversy and streamline the decision process.

STAKEHOLDER AND DECISION MAKER DFC ELEMENTS

It is possible to compare focus group perceptions of the DFC process (see Table 7.6) even though the stakeholder's did not name DFC elements listed above. For example, the comparable decision maker element *Implementation* is the stakeholder element *Legal.* Stakeholders and decision makers identified four common elements and seven different elements. Decision makers developed their elements from responding to the question, "…tell me about the DFC process…," in silence writing their thoughts down on individual sticky notes, as a group arranging sticky notes together with similar content on a wall with the help of a facilitator (see Figure 7.1). Stakeholders responded to questions about desired future conditions in the focus group and their elements were interpreted from their recorded responses.

Table 7.6: Comparison of Stakeholder and Decision Maker Elements

Stakeholder Elements	**Stakeholder Elements Extracted from Dialogue**	**Decision Maker Elements**	**Decision Makers Elements Sample Description**
Political	People who influence or make legislation; governmental entities or GCD board members	Political and interagency	"A politically explosive process to select the aquifer drawdown…with too many possibilities
Legal	Framework of private property rights; legal cases	Implementation	"Lawsuit, DFC Designed For Controversy"
Governance	GCD rules, state agencies processes, legislative framework	Collaboration and Planning	"Cooperative management of the resources; working cooperatively for a regional purpose with local implications"
Water Use	Municipal, golf courses, water parks, existence value	Benefits	"Helping everyone realize the severity of our groundwater situation"
Data/ Technology	Models, water levels, internet, contour maps, aquifer assessments	Education	"Not understood or appreciated by too many of the stakeholders causing much confusion."
Sustainable	Maintaining the aquifer; people and natures' future	Complex Issues	"Tries to cover too large an area."
Personal Rights	Groundwater available for domestic use, for sale by landowner, human right to water.	Stakeholder input	"Not much value in obtaining public opinion, need to use scientific people in the process to determine the DFC."
Human Density	Development, land use, roads, population growth/decline	Weaknesses	"We have no actual data to make the DFC decision, just talk not science…has no real meaning."
Cost	Quantification of groundwater management decisions	Timeframe	"5 year process that will never be done (ever)."
Uncertainty	Risk, chaos, unknowns.	Controversy	"Groundwater wars."
Natural Environs	Climate, geology, hydrology, landforms	Metrics & Measurements	"Aquifer measurements over time and use of groundwater
		Unfunded Mandate	"Monumental task, no state funding; whoever generated the idea could not see the end result."

Source: Rima Petrossian, 2012

DISCUSSION

This chapter presented stakeholder and decision maker evaluations of the DFC process. The data were collected in parallel for the two groups. Both were analyzed using IQA methods and descriptive statistics.

The stakeholders identified DFC system elements that were different from the decision makers; apparently decision makers and stakeholders might not understand the DFC process in the same way. The difference is people's perspective of how the DFC process affects them. Stakeholders identified concerns about the resource, impacts on their land, future population changes, and the process outcome. Even though decision makers also are landowners and process stakeholders, each person's stakeholder or decision maker role in the DFC process affects their preferences.

Decision makers, identifying system elements in a formalized IQA process identified concerns about the mechanics of the process and implementation. For example, decision makers did not explicitly identify an element associated with the environment or human rights. Decision makers had more finely defined descriptions relating to the administrative aspects of the DFC process.

This research addressed mostly the *Design loop* and *Solution loop* of the DFC SID. The DFC SID provides a decision maker or stakeholder tool for scenario-building. Scenario-building using the SID can help identify options by identifying externalities or steps that help move the process along effectively. Chapter 8 will use these results to identify recommendations to reduce controversy, engage stakeholders, and discourage subsequent petitions while honoring the complexity of stakeholder's DFC preferences

Notes

[1] Summerlin, Mary Ellen. 2012. Re: Copy of Interview Process. Austin, Texas, September 18, 2012.

[2] Texas 82nd Legislature. 2011. Groundwater Conservation Districts In *Section 36.108*, edited by Secretary of State of Texas. Austin, Texas: Texas Legislature Online.

[3] Mace, Robert E., Rima Petrossian, Robert Bradley, and William F. Mullican III. 2006. A Streetcar Named Desired Future Conditions: The New Groundwater Availability For Texas. Paper read at 7th Annual The Changing Face of Water Rights in Texas, at San Antonio, Texas.

[4] Garcia, Meredith M. February 7, 2013. *Texas Water Development Board Hearing on Appeal of Groundwater Management Area 13 Desired Future Conditions by Canyon Regional Water Authority and The Hays Caldwell Public Utility Agency* [Hearing Proceedings]. Texas Water Development Board, December 5, 2011 [cited February 7, 2013]. Available from http://www.twdb.state.tx.us/groundwater/petitions/doc/GMA13/2011_Petitions/CRWA/Court_Reporter_Hearing_Transcript_and_Exhibits/TWDB%20HEARING.pdf.

Chapter 8: Recommendations and Conclusions

Texas groundwater ownership and access is characterized by a complex and somewhat contradictory duality: groundwater is a private property right but governed by state-authorized local groundwater conservation district (GCDs) that cover almost 70 percent of the state. Groundwater Management Areas (GMAs) composed of GCD member districts decide about groundwater availability and so govern groundwater access. Texas GCDs can manage groundwater availability decided through the desired future conditions (DFC) process in at least four ways: rule of capture, correlative rights; reasonable use; and prior appropriation [1]. This dissertation has focused on understanding decision makers statewide and in particular on decision makers and stakeholders in GMA 9, which covers parts or all of nine counties in the Texas Hill Country. The goal has been to recommend improved decision-making processes for future groundwater availability in Texas.

KEY FINDINGS

This dissertation presented decision support methods to help improve the desired future conditions process. Results from survey and focus group questions help reveal stakeholder and decision makers preferences. Methods included Interactive Qualitative Analysis, contingent valuation, and descriptive statistics describing decision makers and stakeholder preferences derived from four surveys distributed between 2008 and 2011 and 15 focus groups held in 2011 and 2012. Stakeholders' preferences about desired future conditions revealed that most stakeholders do not want Trinity Aquifer levels to change over the next 50 years, even if such an outcome may not be possible. GMA 9 decision makers decided on no more than an average 30 foot drawdown in the Trinity Aquifer over 50 years through 2060 to account for moderate growth. Stakeholders wanted to keep groundwater levels stable and prefered that the GCDs in GMA 9 restrict access to new users through the mechanism of the GCDs not issuing additional pumping permits. Neither approach guarantees stable or slowly declining aquifer levels because each landowner has the right to pump up to 25,000 gallons per day (gpd), as an exempt use without restriction in most GCDs, and most such exempt use is poorly quantified. In areas where there is no public water service available, if groundwater is not available because it is either deeper than a well or not flowing under a stakeholders land, then a resident will have few options other than rainwater harvesting or trucking in water because there is no requirement for the GCD or the state to provide an individual with water. A landowner survey evaluation of groundwater value (discussed in Chapter 6) disclosed a landowner's strong preference for finding a new water source if wells go dry; stakeholder survey respondents favored rainwater harvesting over other alternatives to groundwater wells as the price to lease or buy groundwater increases. Two question responses revealed how landowners would prefer to be neither a buyer of groundwater nor or a seller. Survey results indicated that most respondents would not want to sell groundwater, and would pay less to buy groundwater (WTP) than what they believe their own groundwater would be worth if sold (WTAP). Out of 568 landowner survey respondents 447 would not sell their groundwater at any price. Of the 58 that would sell, their WTAP CV was $4,069, compared to the WTP CV valuing it at $2,855 per acre-foot, a ratio of 1.4. This ratio is similar to what theory would predict about people’s response and understanding of marketed good or a good with readily available substitutes rather than groundwater. Sixty respondents indicated they would accept payment at the market rates, which had no expressed value.

Stakeholders and decision makers differ in their views about scientific efforts, aquifer properties and hydrogeology, or as one decision maker stated: “Groundwater science meets stakeholder issues.” One way to overcome this disconnect would be to use surveys and focus groups to reveal preferences and support more engaged stakeholders to participate in developing DFCs during years of public meetings and discussion leading to adoption, rather than petitioning afterward.

Recommended Changes to Texas Water Code Section 36.108

Survey results support changing legislation to better incorporate stakeholders in the decision making process. Groundwater management in Texas is in transition from past legislative laissez-faire practices and incremental regulatory requirements to current directives demanding quantitatively-driven permitting and area-wide planning. There are three important areas for improving the decisions made by groundwater management decision makers: resource valuation, ecosystem modeling, and policy evaluation through additional groundwater legislation. This chapter draws upon the previous resources to suggest the following recommendations: enact legislative changes to update Texas Water Code (TWC) Section 36.108 to include stakeholder preferences, financial implications, and an evaluation of the effectiveness of groundwater management through the desired future condition process.

Initially the 79th Texas Legislature required the GMA to hold one public meeting per year. They did not design the DFC process to be a stakeholder or consensus-based process despite landowners' private property rights in groundwater. The 82nd Texas Legislature responded to the DFC process issues they observed with 2011 Legislation suggesting in TWC Section 36.1081 that a GMA could establish an advisory sub-committee for stakeholder input but did not provide requirements. Modifications to Chapter 36 also required additional information to be provided to the public regarding the reasoning and alternatives considered for DFCs. This new legislation, Section 36.108(d) updated the original 2005 DFC process to require the districts to consider the following information during the DFC adoption process:

(1) aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another;

(2) the water supply needs and water management strategies included in the state water plan;

(3) hydrological conditions, including, for each aquifer in the management area, the total estimated recoverable storage as provided by the TWDB, and the average annual recharge, inflows, and discharge;

(4) other environmental impacts, including impacts on spring flow and other interactions between groundwater and surface water;

(5) the impact on subsidence;

(6) socioeconomic impacts reasonably expected to occur;

(7) the impact on the interests and rights in private property, including ownership and the rights of management area landowners and their lessees and assigns in groundwater as recognized under Section 36.002 of the Texas Water Code;

(8) the feasibility of achieving the DFC; and

(9) any other information relevant to the specific DFCs.

Additionally GMAs must submit an explanatory report to the Texas Water Development Board (TWDB), which must address the following details: identify each DFC; provide the policy and technical justifications for each DFC; include documentation that the factors under consideration by the GCDs in the GMA and a discussion of how the adopted DFCs impact each factor; list other DFC options considered, if any, and the reasons why those options were not adopted; and, discuss reasons why recommendations made by advisory committees and relevant public comments received by the GCDs were or were not incorporated into the DFCs.

A new stakeholder-decision maker partnership, proposed here to modify Section 36.108 (d), allows preference-based views to trump previous position-based DFC process views. New code language and actions to describe this new partnership is inserted below in bold and italics into Section 36.108(d):

> (8) the feasibility of achieving the DFC;
> (9***) data gathered and reported annually from joint stakeholder and decision maker focus groups designed to help to achieve this balance and improved understanding of stakeholder preferences and decision making constraints. A component of these focus groups shall include educational materials developed from modeling efforts to address ecosystem planning, financial impacts of desired future conditions, and a review of the permitting processes in each groundwater management area. A majority of decision makers shall attend these focus groups and shall ensure a representative sample of stakeholders are able to participate; and,***
> (10) any other information relevant to the specific DFCs.

Definition of Reasonable Yield

Texas 79th Legislature provided the guidelines for regional decision makers to establish groundwater availability through the DFC process. The Texas 82nd Legislature updated the guidelines specifying that the GMA decision makers provide the reasoning behind their aquifer decisions. This new guidance articulated specific information for the decision makers to consider when establishing DFCs, resulting in a definition for the resulting outcome, the aquifer yield or modeled available groundwater. An additional item, ecosystem services, is proposed for inclusion to tie together the groundwater valuation under socioeconomic and environmental impact components of the existing definition, as follows:

A balanced or reasonable yield finds an equilibrium among the highest level of groundwater production, conservation, protection, recharge, prevention of waste and subsidence through evaluating seven factors:

aquifer uses,

water supply needs and management strategies,

hydrological conditions,

environmental impacts,

socioeconomic impacts,

ecosystem services,

private property interests and rights, and

feasibility.

Groundwater Valuation

Information about private and public water transactions would help Texas groundwater owners to evaluate the financial consequences of setting DFCs for an aquifer. Without that knowledge, an alternative is to improve the CV survey instrument and associated calculations by using better proxies for this currently small and transactional private market. Improving question order and language, along with surveying methodology, will help to optimize the apparent preference values.

GCDs could use several tested approaches to improve groundwater valuations, such as (a) conducting pre-tests or focus groups; (b) simplifying question language; (c) selecting fewer critical questions; (d) sending out multiple iterative versions using the early valuation data collected to perfect valuation ranges; or (e) conducting surveys in person or over the phone.

Additional recommendations include addressing stakeholder environmental concerns through accounting for the complexities of natural uncertainty. In GMA 9 this might include efforts such as improving and updating the GAM 10-005 run climate change groundwater modeling efforts and modeling the implications of ecosystem services from resources such as Jacob's Well. Reporting hydrosocial or human pressures in the GMA report required for adopting DFCs might lead to GCDs discussing future groundwater governance paths such as Ohio's permitting approach which considers nine use parameters for drilling wells: (1) purpose, (2) suitability to the aquifer, (3) economic value, (4) social value, (5) level and magnitude of harm caused, (6) feasibility of circumventing harm by changing use or process by affected parties, (7) feasibility of changing volumes extracted by affected parties, (8) guarding existing use, land, financial interests, and businesses, and (9) fairness in loss by parties affected [2]. These recommendations might lead to better understood and quantified water resource development.

Although Texas courts long ago adopted a groundwater management approach from humid England, the argument that it is inappropriately applied in the Texas climate is irrelevant. England's greater groundwater use, more competition and drought led to the rule of capture being abandoned there decades ago. If there were as little water use in Texas statewide today as there was in 1840 or 1904, aquifers would not need regulation. It is interesting that the Texas Legislature has yet to consider evaluating how the DFC process will affect aquifer conditions and groundwater availability. Further analysis for future legislative changes to the DFC policy could include:

- Targeted management approaches specified for each aquifer or certain types of aquifers;
- Developing a resource-optimization program, utilizing groundwater, surface water, rain water harvesting, and conservation methods to supply enough water to the users;
- Incorporating reflective processes for GCDs to evaluate how well groundwater is being managed.

Establishing a DFC is likely to affect aquifer withdrawals over time, even though aquifer conditions may not manifest for many years. In five or ten years after September 1, 2010, all the DFCs should be examined while considering the current policy in place.

Alternative–based choices might influence whatever respondents in this research chose because of the GMA 9 decision maker's publically expressed belief or understanding of what can be or should be attained. However, by the nature of common-pool resources like groundwater, the aquifer outcomes are influenced by stakeholder or user's collective choices as well as natural forces. In the future, changes in uses could result in better aquifer conditions than assumed, such as more conservation and reuse adding to the available water. On the other hand, increased use because of unexpected population increases, confined animal feeding operations (CAFOs), irrigation or industrial and manufacturing uses might increase depletion rates. There is also the hidden component of "free-riding" [3]. For example, exempt users cannot withdraw more than 25,000 gpd in most districts; the amounts of these volumes being withdrawn however are hidden because these groundwater withdrawals are not tracked.

Based on the findings in this dissertation these requirements should be modified to include a structured stakeholder-decision maker partnership to decide on DFCs. Stakeholder survey respondents in GMA 9 agree with its decision makers that historical water levels and groundwater data are the most useful tools for policy development for future aquifer levels. Technical presentations and assistance and climate variables are less important in the decision making, and financial information about groundwater, risk or probability of the DFCs occurring or not, and stakeholder's/landowner's stated preferences, ranked among the least important tools for both groups to decide on the DFC. Stakeholders and decision makers diverged on assessing most other DFC decision components; structured communication such as focus groups about the groundwater modeling, environmental impacts, and socioeconomic needs, would allow stakeholders to understand decision makers' choices and vice versa.

Groundwater Management Area 9 Suggestions

Each GMA 9 district includes educational efforts within their management plans. These efforts could be used to increase understanding and possibly support for GCD-proposed DFCs of relevant aquifers. GMA 9 decision makers proposed solutions such as changing the GCD rules to enforce drought management plans which require mandatory scaling back of use. This proposed stakeholder-decision maker partnership could support and develop this sort of responsive management to fluctuating conditions which necessitates landowner and stakeholder cooperation.

There are risks involved with both making assumptions about future climate effects in GMAs or for ignoring potential changes. For groundwater planning through establishing DFCs, the risks are primarily in either applying the wrong recharge rate to the individual cells in the numerical model or in a water balance model, thus creating an incorrect prediction of recharge and MAGs. In the regional planning process, planning for the drought of record each year of the 50-year planning period is a requirement [4]; when using the DFC process, there is no such requirement [5]. However, some GMA 9 stakeholders have expressed concerns over not including drought of record in the groundwater management area planning effort despite that GAM run 10-005 included the drought of record and two worse droughts. If the GMA planning decision makers apply drought-of-record planning, which means that only the amount of groundwater available during the drought of record is permitted, there is not enough water to satisfy current conditions.

All GCDs in Groundwater Management Area 9 collect data about their aquifers. They could cooperatively develop area-wide monitoring networks to develop a better understanding of how water quality changes and aquifer levels react to stresses from drought and increased pumping.

GCD decision makers and stakeholders may find the GMA 9 DFC system diagram useful for testing the viability of future DFC decision approaches. This tool is available for them to use as they consider new DFCs.

Examples from Other States

Texans can benefit from several other states' experiences in groundwater management (see Chapter 3). Implementation and outcome between states varies widely, with similarly named but quite different implementation of groundwater management practices prevailing. State approaches described in Chapter 3 illustrate the variety of approaches used for the same type of resource and resource issues. Each state has its own policy history, policy leadership, and statutory development of favored management approaches. In many instances, aquifers transcend state boundaries and the management practices are competing for resources and any subtle policy differences and natural conditions can result in unpredictable circumstances for each aquifer without joint planning efforts. Recommendations developed from examining these other states' experiences include that Texas' GMAs and GCDs consider collaboration with Texas' four neighboring states and one country along with approaches such as:

- Oregon’s calculation of groundwater availability by considering water quality in every aquifer
- Nebraska’s approach of groundwater district board members self-imposing conservation actions that could cause personal harm but benefit future generations (that sort of approach is inspired rather than legislated)
- Ohio’s state permitting system that offers a rigorous set of criteria to follow when considering permit applications. This could help Texas offer more equitable permitting in all GCDs.

Legislative Financial Considerations

Existing Texas groundwater laws do not adequately anticipate the financial aspects of the decision making. The cost of posting the meeting and meeting at least once per year is negligible compared to the impacts of issuing permits and limiting available groundwater pumping, petitions, and lawsuits. HB 1763 is perceived to be an unfunded mandate, identified by the decision makers as the primary driver of the DFC system. The bill provided no funding to GCDs to meet and make decisions even though the bill authorized TWDB to provide expensive technical assistance through model development and actual modeling of potential desired future conditions. While some GMAs did not take advantage of this service and hired consultants, GMA 9 requested that the TWDB run several simulations, saving them potentially tens of thousands of dollars in private consultant’s fees for each model run performed and hundreds of thousands of dollars in model development [6]. Funds should be authorized to the GCDs to maintain and improve the DFC process because TWDB no longer is directed to provide such technical services.

An explicit understanding of how much groundwater is available and how much substitutes are worth will be valuable for decision makers to consider. Knowing the property rights implications [7] and financial effects of quantifying and limiting resource production affects the value of groundwater and could affect the DCFs chosen. Two factors, capability of storage and resource mobility, impact how easy it might be to measure the resource quantification costs [8]. In this research, people who withdraw groundwater in Texas usually do not experience direct financial implications from their daily withdrawals until a severe drought occurs because they do not sell groundwater nor do they pay for it. This could lead to mischaracterization of the groundwater's utility or worth. Development of a detailed GMA financial model specific to permitting groundwater according to the modeled available groundwater and GCD regulations could be processed using an optimization model to characterize financial equilibrium. This would help TWDB for ranking and prioritizing groundwater development projects. Funds should be authorized for financial modeling efforts to maintain and improve the DFC process.

The GMA 9 DFC experience provided evidence that decision-making pivots around what the science reveals, which in GMA 9 is primarily the Hill Country Trinity Aquifer GAM model. Some decision makers' survey comments indicated that GAM models were flawed. The GAM model's error terms affected the level of trust for the groundwater availability models for several years in the process. What the decision makers and stakeholders believed to be model prediction errors, where the model error exceeded the desired future condition of 35 feet for the Trinity Aquifer caused confusion about the model results. People thought that if at any one place the model could be off by 100 percent, it would not be a source of a realistic DFC 50 years in the future. GMA 9 decision makers and stakeholders gained some confidence in the model when both understood that the 35 feet was the error for the entire model area, illustrating the importance of people understanding the groundwater model technical components. The model does not address uncertainty, risk, groundwater value, stakeholder preferences, or groundwater quality; groundwater-surface water interaction is poorly defined. The Hill Country GAM model did not originally address climate variability; the TWDB used Monte-Carlo simulations for climate variability in future groundwater pumping scenarios in later modeling efforts. Future modeling efforts could incorporate climate uncertainties into modeling groundwater in all GAM modeling efforts, and update water levels in the models to recent drought years 2011-2012, as a practice rather than an exception.

Decision maker and stakeholder conflicts could be reduced if they could develop a better understanding of the model's capabilities and applicability in order to develop more trust in the modeling efforts. Stakeholder and decision maker survey responses (see Chapter 7), suggest that stakeholders and the decision makers could better define and improve the DFC system through focus groups.

SUMMARY

While the “rule of capture” may be perceived as an unchanging principle of Texas property, and GCDs may choose more restrictive management methods, the Texas Legislature could choose a more protective system for groundwater resources and equitable system for groundwater capture. Alternative rules exist in other U.S. states. Texas may protect personal rights to groundwater more than any other state. This approach could change depending on political will, the climate, and the success or failure of the DFC process.

One component missing from the DFC process is a program evaluation. Further evaluation of the GMAs decisions about the DFC is not required other than the requirement to revisit and readopt DFCs every five years. Because petitioners may or may not find fault with the DFCs, TWC Section 36.108 indirectly addresses that effort either through petitioners who find an area’s decision unreasonable or through the area’s own progress and self-evaluation of their aquifers over time through a management plan goal. For example, each GMA defines the DFC of relevant aquifers and can modify their decision every year. However, because TWC Sections 36.1071 and 36.108 required evaluation of the DFC quantitatively is both open to interpretation and remains an optional selection by each GCD to address in their five-year management plan, further refinement of the requirements would be beneficial. A new mandate articulating a uniform, specific, and relevant way to measure aquifer conditions semi-annually which evaluated the reasonable yield developed on a GMA-wide basis to aquifer conditions would provide an improved and necessary quantitative understanding the DFC process effects on the resource.

This dissertation has discussed a number of issues concerning stakeholder and decision maker preferences about groundwater in Texas. It has used surveys and focus groups of GMA 9 stakeholders, decision makers, and decision makers statewide, and analyzed other states and countries groundwater regulatory schemes. From these, several recommendations seem appropriate. GMA 9 stakeholder financial valuation of groundwater should be expanded to include all the GMAs in the state. These data should be parsed by aquifer, grouped into aquifer types, and rolled up into a valuation for the entire state. Calculating the financial impact could improve through evaluating ecosystem services, modeling land use changes, and property sales.

Calculating the effect of pumping on the age and quality of groundwater being withdrawn would add complexity but improve the groundwater valuation. Some believe the only way to protect groundwater for future use is by promoting alternative sources like rainwater harvesting, water conservation, and voluntary reductions during drought.

Unfortunately, these measures might not be easy for a GCD to pursue and implement due to their limited authority. The complexities of managing groundwater and groundwater science remain challenging even as Texas moves toward more local regulatory control, more aquifers being under regulatory control and less certainty about Texas' groundwater in the future.

Notes

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Appendix A: Surveys

Likert Scale Explanation and Literature Review

The Likert Scale, a gauge for measuring preferences in this dissertation in 62 survey questions, developed around 1930. This qualitative scale, with several permutations, seeks to uncover people's preferences relative to each other without using a numerical scale. This historical account provides evidence for why the scale remains as a standard for surveys in 2013.

In 1932, Dr. Sisert Likert published a testing technique—a continuation of his doctoral advisor Dr. Gardner Murphy's studies from 1929—designed to arrive at a respondent's true attitudes. The rating system he initially proposed had five categories: strongly approve, approve, undecided, disapprove, and strongly disapprove. Likert based his work on Thurstone who clarified survey methodology for arriving at people's true attitudes, analogous to other social behaviors. The clarification was a scale that served reliably and correctly to capture the change in attitude over a scaled interval. However, Likert was bothered by the statistical assumptions—particularly that of the infiniteness of attitudes possible depending upon infinite number of input variables of time, people, and place—necessary for scaling the responses to work.[1]

He observed that quantitative analyses were more complex than qualitative approaches, normally associated with constructing social behavior. Likert explained the statistical impossibility of a measurement of attitude, based on the definition of attitude being "…a tendency toward particular response in a particular situation..." Rather, he believed that grouping the responses served as the way to narrow the number of possible attitudes to a manageable scale for analysis and understanding. When a person answers a question or considers given circumstances, using the Likert system scale as the set of responses measures whether they agree or disagree with a statement or question and how strongly they feel about their response. They may also choose to be ambivalent.[1]

Likert's test case results proved that the simpler way of interpreting the responses were to assign numerical values to the response.

Clason and Dormody[2] clarified the current use of the Likert scale by indicating that the scale is not actually the indicators or points assigned between the values 'strongly agree' versus 'strongly disagree,' but the summation of scores for more than one question. There are disagreements about the variables generated by the survey method. They choose the interpretation that there is an existing latent continuous variable characterizing the respondent's opinion. They explain that although the responses are discrete, the analysis provides an approximation of the latent variable. They argue that Likert never intended that a researcher assign the answers a number for statistical interpretation for those ordered choices. Russell and Bobko[3] indicated that using the broad Likert scale response types operationalizes the dependent variable. They indicated that narrower reaction alternatives diminished the likelihood of identifying interaction effects and forced respondents to shoehorn their true reaction to suit the scale provided. They suggested alternative research methodology using a nearly continuous scale to measure the respondent's attitude, reflecting an increased probability that the underlying interaction effect will be detectable even though when using a continuous response scale the assumption of linearity may not be valid. They concluded that using a Likert scale, based on their research, forces the respondent to respond in a nonlinear manner.

Javaras and Ripley[4] explored how to account for response styles affecting respondent's answers. They defined response style similarly to other researchers as whether a person would consistently respond in one way without regard the question's positive or negative tone. Other studies they cited demonstrated that gender, culture, and other factors can account for people consistently responding in the middle of the scale or on the extremes. They experimented with varying the tone of the questions with a consistent scale order. This was to determine how to adjust the experimental results to neutralize the effect of the survey instrument in the interpretation. In other words, they studied whether people's response was affected by varying the statements to reflect a positive attitude in the first question and a negative attitude in the second question, but the response choices from strongly agree to strongly disagree remained in the same order throughout the survey. They introduced the Multidimensional Unfolding Model to account for these affects.[4]

Clason and Dormody suggested that interpretation would involve inferential errors if the discrete nature of each question using the range of non-continuous indicators is not considered.[2] Jamieson[5], Lubke and Muthen,[6] and [7] indicates some researchers are erroneously using parametric analysis, interpreting ordinals as interval scales, to interpret the responses to Likert-type scaled surveys. They indicate that the t-test is not appropriate because Likert-type answers are not normally distributed. They support using non-parametric tests to analyze Likert-type data, and cites examples of chi-squared or Spearman's Rho [5]. Clason and Dormody [2] noted, however, that 95 out of 188 articles published in **The Journal of Agricultural Education** used the Likert scale and out of those, 54 percent used descriptive statistics to draw conclusions in their studies and 34 percent used parametric analyses, while only 13 percent of the articles used non-parametric statistic to describe their outcomes [2]. Jamieson noted that two recent articles in **Medical Education** used descriptive statistics and parametric statistics to interpret their data [5].

An alternative method to the 5-measure scale is have a primary question or statement with the rating choice of agree or disagree, then determine the level of support for the statement with the modifier strongly or slightly The other alternative suggested is use of a continuous graphic scale where respondents mark their level of support.

2008 Groundwater Management Area 9 Landowners Surveys

Blanco-Pedernales Groundwater Conservation District provided an example of a referendum for establishing the tax rate for its groundwater conservation district. This example served as a template for the landowner survey question three regarding changing the tax rate or fee structure in each GCD (see below).

Groundwater Survey: Blanco County

1. Deciding How Much Groundwater Should be Available in the Future

Would you be willing to take just a few minutes of your time to fill in this survey?

You are being sent this survey because you are listed on the county tax rolls as owning property and you live within a groundwater conservation district. This survey should take about 15 minutes to read and complete.

This survey has no connection with any groundwater district, local, state, or federal government agency.

Please do not provide any personal information on this survey, such as your name or address, as your response will be confidential so that no one will know who you are, not even myself. The results of the survey could be useful to you because they could help indicate how citizens, like yourself, wish to manage groundwater.

Please read the following questions and provide one answer to each question. Alternatively, you can go online and answer this survey electronically. The website address is:
http://www.surveymonkey.com/s.aspx?sm=vSKVk_2bXxM9rEPRJEmrXkLg_3d_3d

Please read the following questions and provide one answer to each question.

Please complete and return the survey by January 30, 2009.

Groundwater Survey: Blanco County

2. Questions

***1. Do you have a groundwater well?**

- ◯ Yes
- ◯ No
- ◯ Do not know

***2. Do you use your well for household use and/or livestock watering?**

- ☐ Yes
- ☐ No

***3. Assume for this evaluation that your groundwater conservation district (GCD) taxes property of well-owners at $0.024 per $100 property valuation. This would mean that if your property is worth $100,000, your annual tax would be $24. The questions below refer to possible "new taxes" proposed for GCD well owners. Please answer the following questions as if this is a real situation to indicate how you would really vote.**

Your county Groundwater Conservation District proposes to increase your groundwater conservation district tax from the current rate of $0.024 to no more than $0.050. What would you be willing to pay next year for your groundwater conservation district to manage the groundwater resource and perform more studies on the groundwater? Please check one answer.

- ◯ $24, no tax increase.
- ◯ $25-30 (around a 20 percent increase).
- ◯ $31-35 (around a 40 percent increase).
- ◯ $36-40 (around a 60 percent increase).
- ◯ $41-45 (around a 80 percent increase).
- ◯ $46-50 (around a 100 percent increase, the maximum tax increase allowed in your district).

Groundwater Survey: Blanco County

***4. The next question is about your groundwater district rules. Assume that the Texas Legislature has required your county Groundwater Conservation District to change its rules. They propose to either limit pumping for everyone in the district or use up some of the groundwater permanently in order to manage groundwater use. These rule changes may or may not cause you and other well owners to have to deepen your current well or drill a new well deeper than your current well. Assume average rainfall conditions. These new rules could also limit growth by causing new people not to establish businesses in your groundwater conservation district or for current businesses not to have sufficient water to sustain current pumping. An initial severe water level decline means more people or businesses are able to use the water now; it also means that eventually fewer people could use water the lower the level drops.**

You use the Trinity Aquifer, usually about 200-800 feet thick, and it is under artesian pressure. Which of the following options do you prefer.

- ◯ No new users should be issued permits so water levels will not drop during an average rainfall year.
- ◯ Your current permitted amount will be reduced to allow new users to share the resource so water levels will drop at the current rate or will not drop.
- ◯ Your well water level may decrease between 0-5 feet over the next 50 years because new permits will be issued.
- ◯ Your well water level may decrease between 0-15 feet over the next 50 years because new permits will be issued.
- ◯ Your well water level may decrease between 0-25 feet over the next 50 years because new permits will be issued.
- ◯ Your well water level may decrease between 0-35 feet over the next 50 years because new permits will be issued.
- ◯ Your well water level may decrease between 0-45 feet over the next 50 years because new permits will be issued.
- ◯ Your well water level may decrease between 0-55 feet over the next 50 years because new permits will be issued.
- ◯ Your well water level may decrease between 55-125 feet over the next 50 years because new permits will be issued.
- ◯ Your well water level may decrease more than 125 feet over the next 50 years because new permits are issued.

*** 5. Please answer for each choice of groundwater costs, A through J, one choice per row. People have leased groundwater rights from $1100 per acre-foot to $5500 per acre-foot (the average family would use about acre-foot per year) in the nearby Edwards Aquifer. If your well were to go dry permanently, what would you do for water? Assume that groundwater will cost:**

	Buy surface water through a city or private supplier	Buy or lease groundwater rights	Drill a new deeper well ($100 per foot to drill)	Install a rainwater harvesting system ($9000 on average)
A)$1,000-1,500 per acre-foot	◯	◯	◯	◯
B)$1,500-2,000 per acre-foot	◯	◯	◯	◯
C)$2,000-2,500 per acre-foot	◯	◯	◯	◯
D)$2,500-3,000 per acre-foot	◯	◯	◯	◯
E)$3,000-3,500 per acre-foot	◯	◯	◯	◯
F)$3,500-4,000 per acre-foot	◯	◯	◯	◯
G)$4,000-4,500 per acre-foot	◯	◯	◯	◯
H)$4,500-5,000 per acre-foot	◯	◯	◯	◯
I)$5,000-5,500 per acre-foot	◯	◯	◯	◯
J)More than $5,500 per acre-foot	◯	◯	◯	◯

*** 6. Assume you have a sufficient amount of groundwater for yourself and currently have no plans for irrigating. What if someone came to you and asked to lease your groundwater rights this year for one year? How much would you want to charge?**

◯ A) More than $1,000 per acre-foot

◯ B) More than $2,000 per acre-foot

◯ c) More than $3,000 per acre-foot

◯ D) More than $4,000 per acre-foot

◯ E) More than $5,000 per acre-foot

◯ F) More than $6,000 per acre-foot

◯ G) I would accept whatever the market would allow.

◯ H) I would not want to lease my groundwater rights.

2009 Landowners Survey: Hays-Trinity GCD

6-Question Groundwater Survey 2009

1. Deciding How Much Groundwater Should be Available in the Future

Would you be willing to take just a few minutes of your time to fill in this survey?

You are being sent this survey because you are listed as a district resident owning property and a well and you live within a groundwater conservation district. This survey should take about 15 minutes to read and complete.

Please do not provide any personal information on this survey, such as your name or address, as your response will be confidential so that no one will know who you are, not even myself. The results of the survey could be useful to you because they could help indicate how citizens, like yourself, wish to manage groundwater.

Please read the following questions and provide one answer to each question. Alternatively, you can go online and answer this survey electronically. The website address is:
http://www.surveymonkey.com/s.aspx?sm=ZpU0mLchOE7krNg2fjyTgg_3d_3d

Please complete and return the survey by July 1, 2009, if possible.

Page 1

6-Question Groundwater Survey 2009

2. Questions

*1. Do you have a groundwater well?

◯ Yes ◯ No ◯ Do not know

*2. If you have a well, do you use your well for household use and/or livestock watering?

☐ Yes ☐ No ☐ Not Applicable

*3. Your groundwater conservation district (GCD)currently charges a one-time only well registration fee of $300 with no production fees. The questions below refer to a possible "new tax rate" proposed for all well owners. Please answer the following questions as if this is a real vote.

Proposal:

"Hays Trinity Groundwater Conservation District proposes to use part of the ad valorem tax levy for its normal operating costs. Upon voter approval, the District will enact ad valorem taxation for operational funding at a value between $0.003 and $0.050 per $100 property valuation. This would mean that if your property is worth $100,000, your annual tax would be from $3 or up to $50. Shall the Groundwater Conservation District enact a yearly ad valorem tax of for operating costs for period beginning July 1, 2009?"

In answering this question, you are indiciating what you would be willing to pay each year for your groundwater conservation district to manage the groundwater resource, collaborate on regional groundwater studies, take water level measurements, register and permit wells, and perform scientific studies on the groundwater in order to help manage withdrawals and quantify the resource for the future.

Please check one answer.

◯ $300 one-time permitting fee, no tax.

◯ $ 3.00-10.00 per $100,000 valuation.

◯ $10.00-20.00 per $100,000 valuation.

◯ $20.00-30.00 per $100,000 valuation.

◯ $30.00-40.00 per $100,000 valuation.

◯ $40.00-50.00 per $100,000 valuation.

◯ No response.

Comments:

Page 2

6-Question Groundwater Survey 2009

***4. Assume your groundwater conservation district has to change its rules to comply with a new state law. These new rules require the district to issue a set amount of permits each year to allow larger users to pump groundwater (not home use or livestock watering but irrigation or water supply). They propose to either limit pumping for permit-holders in the district or use up some groundwater permanently. These rule changes may or may not cause you and other well owners including exempt wells (home use or livestock watering), to have to deepen your current well, drill a new well, lease groundwater or change to surface water or rainwater harvesting. An initial large water level decline would mean more people or businesses are able to use the water now; it also means that eventually fewer people could use water the lower the level drops.**

If you use the Trinity Aquifer, usually about 200-800 feet thick, which of the following options do you prefer?

- ◯ No new larger users should be issued permits, my well's water level will drop at the current rate or will not drop.
- ◯ Reduce every current permit equally (not household wells) to allow new users, my well's water level will drop at the current rate or will not drop.
- ◯ Issue new permits, my well's water level may decrease between 0-5 feet over the next 50 years.
- ◯ Issue new permits, my well's water level may decrease between 0-15 feet over the next 50 years.
- ◯ Issue new permits, my well's water level may decrease between 0-25 feet over the next 50 years.
- ◯ Issue new permits, my well's water level may decrease between 0-35 feet over the next 50 years.
- ◯ Issue new permits, my well's water level may decrease between 0-45 feet over the next 50 years.
- ◯ Issue new permits, my well's water level may decrease between 0-55 feet over the next 50 years.
- ◯ Issue new permits, my well's water level may decrease between 55-125 feet over the next 50 years.
- ◯ Issue new permits, my well's water level may decrease more than 125 feet over the next 50 years.
- ◯ No response.

Comments:

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6-Question Groundwater Survey 2009

*5. Please answer one choice per each row (10 answers in all). People have leased groundwater rights from $1100 per acre-foot to $5500 per acre-foot for the first year and an additional yearly fee in the nearby Edwards Aquifer (the average family would use about 1 acre-foot per year). If your well were to go dry permanently, what would you do for water? Assume groundwater will cost:

	Buy surface water through a city or private supplier (cost not available)	Buy or lease groundwater rights at price listed at left	Drill a new deeper well or deepen current well ($100 per foot for everything)	Install a rainwater harvesting system (Average $9,000)	No Response
A)$1,000-1,500 per acre-foot	◯	◯	◯	◯	◯
B)$1,500-2,000 per acre-foot	◯	◯	◯	◯	◯
C)$2,000-2,500 per acre-foot	◯	◯	◯	◯	◯
D)$2,500-3,000 per acre-foot	◯	◯	◯	◯	◯
E)$3,000-3,500 per acre-foot	◯	◯	◯	◯	◯
F)$3,500-4,000 per acre-foot	◯	◯	◯	◯	◯
G)$4,000-4,500 per acre-foot	◯	◯	◯	◯	◯
H)$4,500-5,000 per acre-foot	◯	◯	◯	◯	◯
I)$5,000-5,500 per acre-foot	◯	◯	◯	◯	◯
J)More than $5,500 per acre-foot	◯	◯	◯	◯	◯

Comments:

2008 Decision Makers' Discussion and Survey

An initial survey, shown below with collected responses to the questions and comments, was sent to all GCD district managers or presidents with email addresses to respond to and also to forward onto GCD board members without electronic access to the web.

Groundwater Management Areas Decision on Desired Future

1. Groundwater Management Area Survey 2008 Introduction

Hi, my name is Rima Petrossian and I am a graduate student researching groundwater in Texas. This survey is will help me to complete my doctorate degree at The University of Texas at Austin.

You are being sent this survey because you have been a participant in the groundwater management area process.

Do not put any personal information, like your address or name on this survey. This survey it is meant to be anonymous, except I want to know in which groundwater management area you live. The results of this survey are valuable because they will help me understand the process of making groundwater management decisions in Texas by understanding the participant's viewpoint on the process.

The 46 questions below are designed to help me and others understand your experience and how you view the groundwater management area approach to managing aquifers. Please take a few minutes of your time to help out my studies.

Thank you for your help.

1. What groundwater management area do you live in?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9
- ○ 10
- ○ 11
- ○ 12
- ○ 13
- ○ 14
- ○ 15
- ○ 16

What groundwater management area do you live in?

Groundwater Management Area	Responses
1	7
2	9
3	0
4	4
5	0
6	3
7	10
8	11
9	22
10	5
11	5
12	2
13	8
14	6
15	10
16	2
Total	104

Note: Only 79 out of the 104 actually completed and submitted the survey.

Groundwater Management Areas Decision on Desired Future

2. Groundwater Management Area Survey 2008

1. What do you think about the process used in Groundwater Management Area for determining your desired future condition?

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Yes, it suited our group.	○	○	○	○	○
Yes, but it needs improvement.	○	○	○	○	○
No, it did not work.	○	○	○	○	○

Other (please specify)

2. Note: Originally Senate Bill 3 required participation from a wide variety of stakeholders, but finally resulted in just the Groundwater Conservation District President as the sole vote for a desired future condition of an aquifer.
The current groundwater management area process of deciding desired future conditions encourages public participation from different stakeholders other than groundwater districts outside of the public meeting notice requirement.

- ○ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree
- ○ No Comment

Other (please specify)

3. The public is participating in my groundwater management area by attending the groundwater management area meetings.

- ○ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Diagree
- ○ Strongly Disagree
- ○ No Comment

Other (please specify)

Question 1. What do you think about the process used in Groundwater Management Area for determining your desired future condition?

Responses	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total
Yes, it suited our needs.	4	21	15	9	5	54
Yes, but it needs improvement.	11	34	11	1	3	60
No, it did not work.	7	4	17	9	3	40
Total	22	59	33	19	11	

Due to the question's online programming, many people were able to respond to this matrix question more than once, so there are more responses than respondents. However, despite the procedural error a majority of respondents, 57 percent or at least 45 out of 79 agreed that the process needed improvement but overall most thought it at least worked.

Decision Makers Comments on Question 1:

- There is no set formula or equation for calculating groundwater availability. Groundwater availability requires the guidance of policy as well as the procedures of science. Science provides the understanding of how an aquifer works. Tools such as hydrology, geology and groundwater models can be used to calculate groundwater availability. However, it is policy that provides the guidance that ultimately defines the boundaries of science to calculate available groundwater. Policy includes factors such as management goals, environmental issues, local rules and state laws. "Although science is required to quantify groundwater availability, policy is the most important factor that influences the final value."(Estimating Groundwater Availability in Texas, Robert E. Mace, William F. Mullican, III, and Ted (Shao-Chih) Way, Texas Water Development Board. Proceedings of the 1st annual Texas Rural Water Association and Texas Water Conservation Association Water Law Seminar:Water Allocation in Texas: The Legal Issues." Austin, Texas, January 25-26, 2001.) I strongly disagree because policy (by consensus) can improperly support the possibility of increased groundwater availability of groundwater in Northern Bexar County when science shows otherwise.
- The process is dependent on GAM's that even the TWDB admits have problems.
- Problem is conflict between tax based districts and fee based districts.
- Getting our GAM runs is/was slow. I think we were promised to have the report within a week or two.
- Relies too heavily on faulty modeling.

- Our GMA has done a good job trying to implement a very seriously flawed process the legislature handed us.

Question 2. Note: Originally Senate Bill 3 required participation from a wide variety of stakeholders, but finally resulted in just the Groundwater Conservation District President as the sole vote for a desired future condition of an aquifer. The current groundwater management area process of deciding desired future conditions encourages public participation from different stakeholders other than groundwater districts outside of the public meeting notice requirement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	10	48	12	5	1	3	79

Decision Makers Comments on Question 2:

- I agree in concept. However, in reality, though heard during public forums, action on public comment appears to be generally ignored.
- A collaboration amongst GMA's and public participation at a minimum.
- The public should determine the DFC via a vote.
- The process is like Regional Planning – after 10+ years how many of the “public” know about regional planning?
- Elected board members of GCDs represent the public and all stakeholders that live within their district.
- Every county has been notified both by email and phone.
- If there has been any outreach attempt, I’m not aware of it. The president’ vote determined by his board!!!
- I believe that the boards of WD|CDs understand the local needs better that “other stakeholders” and therefore are in the best position to address the issue. After all the purpose of a GCD is to provide for local control of the resources within that GCD and thereby within the GMA from those districts.
- Revise question, wording unclear. Strongly support public involvement.
- I take this question to refer to GMA 9’s process. I think we have done more than is required.

Question 3. The public is participating in my groundwater management area by attending the groundwater management area meetings.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	10	36	8	17	8	0	79

Decision Makers Comments on Question 3:

- I have not seen much public participation in GMA 8.
- Yes – and at community Workshops.
- We have had only a few public attend any of our GMA meetings.
- Including CAFO, Public Utility, Local Producers.
- The public could care less and do not attend.
- Have a room full at every meeting.
- Limited agreement, there has been little or no attempt in our district to encourage public attendance.
- Many seem to represent identifiable interest groups rather than the general public.

4. The public is participating in my groundwater conservation district by attending our district board meetings.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

5. Groundwater decisions are best made by the:

- Individual landowner or corporation
- Groundwater Conservation District or county
- Groundwater Management Area
- Regional Water Planning Group
- Texas Commission on Environmental Quality (TCEQ)
- Texas Water Development Board (TWDB)
- Environmental Protection Agency (EPA)
- United States Geological Survey (USGS)
- No Comment

Comments

6. The legislature should not change the decision process for deciding the desired future condition in groundwater management areas.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

Question 4. The public is participating in my groundwater conservation district by attending our district board meetings.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	6	24	10	25	13	0	78

Decision Makers Comments on Question 4:

- Notwithstanding "hot button issues", public attendance is minimal and generally limited to a very small, but regular group of participants.
- Sometimes.
- We never have anyone come to the Board Meetings.
- Do not attend.
- Same as above. [Have a roomful at every meeting].

Question 5. Groundwater decisions are best made by the:

Entity	Responses
Individual landowner or corporation	6
Groundwater Conservation District or county	63
Groundwater Management Area	7
Regional Water Planning Group	0
Texas Commission on Environmental Quality (TCEQ)	0
Texas Water Development Board (TWDB)	3
Environmental Protection Agency (EPA)	0
United States Geological Survey (USGS)	0
No Comment	0
Total	79

Decision Makers Comments on Question 5:

- Until true consensual management can be applied over a common aquifer, I would much rather apply rules of a District that is too conservative in managing available groundwater over a neighboring District that issues permits with little concern for the future.
- A concensus at the GMA level is beneficial. We should have a standard of operations at that level.
- A cooperative effort between the GCD and individuals within the District is vital for good decision making.
- Both the individual and the Groundwater Conservation District.
- Note that a GCD and a county are not the same. Groundwater decisions be made by a county nor county decisions by a GCD.

- I am not sure what groundwater decision you are referring. Is it the type of pump or the amount needed to perform business, groundwater conservation districts are the second best decision maker after the individual.
- These boards should be made up of landowner and business people from that area who know there conditions.
- Actually various entities listed above should participate: District, GMA, TWDB, USGS.
- With landowner, and public involvement.
- A consensus of GMA representatives would certainly be helpful.
- Provided the groundwater district has fully shared the consequences of DFC and mismanaging resources.
- The GCD represents those individuals within its district therefore the landowners are represented by them. The less government we have the better (although the GCD is a government entity).
- With landowner input.
- Groundwater Boards are elected officials responsible for the management and protection of groundwater.
- The scientific bases for decision-making are very limited even on a local basis, much less a regional one.

Question 6. The Legislature should not change the decision process for deciding the desired future condition in groundwater management areas.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	25	22	9	13	9	1	79

Decision Makers Comments on Question 6:

- The legislature should not change the process by law. Rather, the TWDB policy should insist putting science before policy.
- Not if the DFC can be decided by one person for an area.
- There are some needed changed to the process, but not the time period for the first settings in 09-10.
- Not at this time, give the current process time to work and then we can work to improve the areas that are weak.
- Problem with fee-based vs. tax based districts, one want to conserve the other sell water.
- All agencies charged with groundwater management like Subsidence Districts should be included with voice and vote.
- Give the GMA’s a chance to complete their task.

- Not at this time! We haven't given it a chance yet! The idea seems plausible but more information and time are needed. We CANNOT start jumping from one things to another just because it's complicated and someone is doubtful.
- What's the point of groundwater management areas if the legislature can willy-nilly override their decisions.

Groundwater Management Areas Decision on Desired Future Conditions

7. The information we have currently available is good enough to adopt a desired future condition.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

8. The groundwater management area is the best collection of entities to make the decision about the future of the aquifers.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral or Not Sure
- ◯ Disagree
- ◯ Strongly Disagree

Other (please specify)

9. The current groundwater models are robust enough to use as the basis for calculating the managed available groundwater.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

Question 7. The information we have currently available is good enough to adopt a desired future condition.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	6	18	13	21	21	0	79

Decision Makers Comments on Question 7:

- When the Hill Country GAM was published, it was designed to include Drought of Record conditions. By TWDB description, this is period between 1950 to 1956. Today, policy is driving us to accept science that is flawed. Expecting elected officials to accept a GAM without a drought of record on behalf of their constituents is simply wrong.
- I believe the GCD that have been collecting groundwater data from well logs, monitor wells, etc. have an advantage over the new districts that have not been in operation long enough to develop the district specific groundwater data. However, through the ability to revisit the DVC the new GCDs will be able to use their groundwater data during updates to the DFC in the future.
- Continuous Improvement Process, as we gather more data. It is OK for the time being.
- We are using the most current scientific information available, however all agree that the models used have flaws.
- Being dependent on a GAM that has serious problems to determining a MAG can result in serious problems down the road.
- GAM runs are guesses! The only fact we have is pumping and level monitoring, both need additional data.
- But more information and better information is badly needed by the GMAs.
- Not yet. I have not seen a GAM run yet which demonstrates the true impact of development.
- GAMs are being used to assist the TWDB and the GMAs. The models are at best yet unproven and need many more data points to prove their validity. I believe that the GAMs should be used for now with the understanding that the decisions made by the GCDs and the GMAs may have to be modified if the goals of protecting and preserving our natural resources are not being met.
- It’s a good start but much more information is necessary to have a realistic and reliable database.
- As long as it remains flexible.
- For new GCD it could and will get better as time goes on.
- More information is needed, however, the current process should proceed along slowly while the additional information is being obtained.

Question 8. The current groundwater models are robust enough to use as the basis for calculating the managed available groundwater.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	4	10	17	26	21	1	79

Decision Makers Comments on Question 8:

- It is crucial to note, that though include in the GMA-9 planning process, lacking a Groundwater Conservation District, half of Comal County in fact has no representation. Though the other half of the county is included within the boundaries of the Edwards Aquifer Authority, virtually no data is available from the Trinity Aquifer for use in the DFC process. Finally, there is the issue of North Bexar County, the Trinity Glen Rose Groundwater Conservation District "going it alone" to develop their own DFC. This despite the fact that this district has a hydrologic connection to the same water bearing formation as the adjacent district (Cow Creek) will be managing after the GMA-9 process is complete and a MAG is assigned. Proponents assert considerable recharge is gained through the Cibolo as a losing stream. These calculations are not representative of Drought of Record.
- The GAMS are the best we have available. They can and hopefully will be improved as GCD provide additional district specific data.
- For the basis.
- TWDB has stated that the models are flawed, however it is the best science currently available.
- As stated above, the E/T Plateau GAM has problems even the TWDB admits. Fix the basic concept of the model and let's try again.
- GAM runs are only guesses with interpolated estimates, not science.
- Models not available for all water bearing formations.
- Model's are a process of someone making money and doing nothing for that money. The models are horrible.
- See Above [Not yet. I haven't seen a gam run yet which demonstrates the true impact of development].
- More data points will make them a very important and predictable resource.
- They are a start but still not detailed enough to be a really good decision making tool.
- Need more data; no one has this 'nailed'!!!
- Data from the current models should be used as a tool for management of the aquifer, however, the MAG should not be construed as an absolute reflection of the actual aquifer conditions.

Question 9. Waiting until better science exists through new groundwater models and more data collection will lead to a better desired future condition choice.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	4	10	17	26	21	1	79

Decision Makers Comments on Question 9:

- To move forward with incomplete data will be disastrous for those who have no water source other than groundwater. Those who can buy alternate sources will, the rest go dry.
- We don’t need to wait for this data to adopt DFC but need to use the new data to update the DFC.
- A continuous process is needed. We need an adaptive model and lots of communication. Something needs to be done now.
- But we must move ahead and adapt to the better science as it comes.
- But reality is that we must move forward while obtaining better science. Problem is with current statute the first DFC and MAG are almost carved in stone with no solution if they have to be cut back when better science or actual conditions warrant.
- A DFC choice is first a foremost what the community wants. Groundwater models will improve. The nature and accuracy of the MAG amount is my biggest concern.
- Need to act now with the FACTS that we have, pumpage and aquifer levels.
- But GCDs do not have that option.
- I don’t think however that nothing should be done while that model is improved. If the models improve the numbers need to be adjusted to support the available information.
- It depends on which part of the State you are talking about, different aquifers have had different levels of research and therefore understanding. Certain well understood aquifers are in need MAGs now to prevent overallocation while others need more study and refinement of the models.
- As we get more information then we can modify our desired future condition plan accordingly.
- Models are only a tool, not the final word.
- I agree but we can’t wait.
- Waiting for better science will lead to a better DFC, however, I believe we can proceed slowly through the process as we obtain the additional information.

Groundwater Management Areas Decision on Desired Future Conditions

10. Waiting until better science exists through new groundwater models and more data collection will lead to a better desired future condition choice.

- ○ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree
- ○ No Comment

Other (please specify)

11. We should make a decision now because we can always change the desired future condition later as we get more information and track the aquifer conditions.

- ○ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree
- ○ No Comment

Other (please specify)

12. The groundwater management area process benefits from having consultants or students to help us interpret technical information.

- ○ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree
- ○ No Comment

Other (please specify)

Question 11. We should make a decision now because we can always change the desired future condition later as we get more information and track the aquifer conditions.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	16	40	10	2	11	0	79

Decision Makers Comments on Question 11:

- Now is the time to admit we cannot meet existing demand, much less an increased future demand. Case in point is surface water from Canyon Reservoir being pumped to Fair Oaks Ranch, yet 33 Trinity wells are still part of their water supply system.
- As stated above, unfortunately it is the GCD that will bear the full brunt of adopting a DFC and MAG based on a flawed GAM when the MAG has to be reduced and pemit holders sue.
- The key is to manage the groundwater, not set some artificial level. More work, less talk.
- That depends on the decision that needs to be made.
- The GMA's are under a timeline, and with the GAM runs taking 6 to 8 months to complete. GMAs have no choice.
- GCD's are mandated by law to make a deiciosn, as better is available, it can be changed.
- I do not believe that it will be easy to change a DFC-statements to the contrary notwithstanding.
- Some do need decisions now while others require more study and model improvements.
- This is the only reason we were able to make a commitment.

Question 12. The groundwater management area process benefits from having consultants or students to help us interpret technical information.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	8	39	20	8	3	1	79

Decision Makers Comments on Question 12:

- Not so sure!
- The only "consultant" who has been truly helpful is Robert Mace.
- I'm not sure of what you mean by students. Is this a student at a university or is it a student of groundwater management. We are all actually students of the complicated water issue as each day we learn more.
- I am familiar with the manner in which some of these data were collected by students…at best, methods were questionable.

Question 13. I understand the complicating factors of establishing the desired future condition.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Environmental	20	45	9	2	2	1	79
Financial Consequences	22	43	9	2	2	1	79
Surface Water and Spring Flows Interaction	18	42	9	6	1	3	79
Social Changes	14	37	18	7	2	1	79

Decision Makers Comments on Question 13:

- Change is uncomfortable but many times needed. Lots of education will be required.
- Protection of the resource will soon not be determined by financial factos as much sa environmental and social needs.
- I'm new to the business and try to learn more as time progresses.
- What do you mean by 'social changes'?
- Ambiguous question.
- We need to keep a balance and not have one interest over-ride all others.
- These factors make the decision most difficult.
- By social changes I mean that the DFC process goes around the "good ol' boy" network we're used to.

Groundwater Management Areas Decision on Desired Future Conditions

13. I understand the complicating factors of establishing the desired future condition.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment
Environmental	☐	☐	☐	☐	☐	☐
Financial Consequences	☐	☐	☐	☐	☐	☐
Surface Water and Spring Flows Interaction	☐	☐	☐	☐	☐	☐
Social Changes	☐	☐	☐	☐	☐	☐

Comments

14. The aquifer water levels will not change no matter what we have chosen as a desired future condition.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

15. The desired future condition decision, which establishes a permit cap for each district, does not allow for development and new people moving into our area.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

- **Question 14.** The aquifer water levels will not change no matter what we have chosen as a desired future condition.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	7	5	7	24	35	1	79

Decision Makers Comments on Question 14:

- Where is the science that says otherwise?
- The Ogallala will change no matter what.
- Aquifers will always change.
- They have and are changing right now in our district.
- Wow!
- Whatever is done will effect aquifer levels and the future sustainability of the aquifer for better or worst.
- I just don't know about this. Only time will tell!!!
- It's not the DFC's but the implementation of the MAG's that will influence the future water levels.

Question 15. The desired future condition decision, which establishes a cap for each district, does not allow for development and new people moving into our area.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	7	22	10	31	7	2	79

Decision Makers Comments on Question 15:

- Once the MAG is issued, permits will be issued to this number and no more.
- Entities should always be looking for alternate water sources to meet future needs.
- The DFC's must be changed as development warrants.
- Alternative water supplies methods will have to be obtained.
- It is up to the GMA to set the conditions so that development can occur in the future.
- Depends on the area.
- It is understood that a GCD can reserve resource for future use but statute does not address it.
- Not sure if the DFC actually establishes a permit cap.
- By managing the aquifers levels and drought contingency plans, aquifer levels can be maintained.
- I do not believe it is a cap. It does not account for exempt use, therefore it is not a cap.
- Depends what the DCF/MAG turns out to be.
- It depends upon the DFC that it is approved.

- The above could be true of the GCD and the GMA do not do their jobs well. I think that fairness of managing our resources is paramount. One group of stakeholders should not benefit at the expense of others. Again local control of the resources is what Chapter 36 promotes. Without local control cities and areas within the local districts could be hurt.
- It depends upon the requirements in Chapter 36 to permit up all available water…This does not let us set aside water for future growth if permitted to a marketer.
- It just addresses fresh groundwater supplies. Pumpage caps will direct the focus to alternate supplies such as conservation, brackish water desal, RW harvesting, effluent reuse, ASR, etc. Growth can occur at a sustainable level depending on the development of these alternate supplies.
- It will modify the type developments proposed and require water conservation methods and water alternates.
- Because we will be able to change the DFC.

Question 16. The desired future condition process benefits landowners who already have a high level of groundwater production.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	3	27	20	20	8	1	79

Decision Makers Comments on Question 16:

- If the historic production is documented and allotted by an operating permit.
- But it does depend on how the GCD rules regulate the production to meet the DFC. High level of current groundwater production will still probably benefit under the GCD rules.
- Existing use may be effected in the DFC process, especially if the GCD did not factor in the existing use.
- There is no guarantee on any benefits by the land owners.
- However, it appears that all producers will be required to limit production both existing producers and new producers.
- Depends on GCD rules.
- I don’t really understand the question.
- It depends on the DFC decisions made by the GMA and Districts and the Rules and Management Plans adopted to enforce the DFCs.
- The DFC does not discriminate against anybody.
- Doesn’t benefit any landowner over another landowner. District rules may alter that.

- The rules of the GCD are determined by the board and the citizens within the district (and other stakeholders).
- Depends on the DFC, how the aquifer is regulated and how a GCD managed the resource. Historical Use can only be maintained for those who don't change the use type (Guitar vs. Hudspeth GCD).
- It all depends on what the proposed cap is and what a reasonable use is and determining what waste is.
- It depends on how the GCD's apply their MAGs.

Groundwater Management Areas Decision on Desired Future Conditions

16. The desired future condition process benefits landowners who already have a high level of groundwater production.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

17. More people should be voting on the desired future condition of aquifers other than the groundwater conservation district Board presidents.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

18. A state agency should be responsible for providing all the information resources for making a decision about the desired future condition of aquifers.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

Question 17. More people should be voting on the desired future condition of aquifers other than the groundwater conservation district Board presidents.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	8	8	9	31	23	0	79

Decision Makers Comments on Question 17:

- Though I may disagree with the method the public can participate, the public has an opportunity and obligation to let their representative know how they want their vote cast.
- GCD are charged with management, regulation and conservation of the resource. Other group have other interests to protect in their decision making process such as use of the resource.
- Collaborative effort is beneficial.
- That is not a true statement because other's can in lieu of presidents.
- Statute says president or representative, but unless the goal is for the process becomes like Regional Planning then only GCD should have the vote since they are the state's preferred method of groundwater management. Refer to 36.0015.
- The board presidents represent municipal, irrigation, industrial users in a groundwater conservation district. Do you want special interests to have a place at the table?
- All board members need to agree, then the rep to the GMA cast their vote.
- Board Presidents are guided by their individual district which allows for local public involvement in the process.
- Certainly not until the general public or stakeholders have greatly invested in their knowledge of the issues & challenges.
- Same comment as Question 6 [All agencies charged with groundwater management like the Subsidence Districts should be included with voice and vote].
- The knowledge is not available to people outside of the water industry.
- GCD board's have more knowledge about the decision that needs to be made than most people.
- That is why we have directors: to keep people in our precincts informed and getting their comments.
- See my comment on Question 5 [The GCD represents those individuals within its district therefore the landowners are represented by them. The less government we have the better (although the GCD is a government entity)].
- Not unless they have been involved in the process.

- GCD presidents are generally elected by their constituents to make these decisions.
- Of course our elected board instructs the president. I don't know how common that is.

Question 18. A state agency should be responsible for providing all the information resources for making a decision about the desired future conditions of aquifers.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	4	13	9	26	26	1	79

Decision Makers Comments on Question 18:

- Water Conservation Districts have good info in many cases.
- Information should be considered from all sources.
- This would turn into a money pit with the big city's (with the money) getting the water.
- Districts & GMAs must be able to do research and hire consultants when the state does not meet their informational needs.
- State agency's cannot take care of their own business, much less the decision of a GMA.
- Any state agency is not capable of performing the assigned duties now, much less take on groundwater management.
- All districts, when capable, should be doing site specific studies, on their own or with contractors.
- The temptation is to agree because the GCD could save money. Accurate information is what will make this puppy fly, where the information comes from is unimportant. All sources of information must be synchronized. I like the idea that all GAM models are run with the same TWDB model. The results can then be compared.
- In some cases. GCD consolidation into larger areas generally shaped like the aquifers benefits economy of scale and the District's ability to provide the resources needed to manage the groundwater. Single County Districts just can't generate enough revenue to do this without assistance from the State.
- The State should provide the information provided it is what the deicison making body requested.
- I really don't know the correct answer here; but, wouldn't this just complicate the process?!
- Lots of our local information seems much more reliable than the state GAM.
- In cooperation with the groundwater districts.

Question 19. The state should fund the desired future condition process.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	21	30	9	11	6	2	79

Decision Makers Comments on Question 19:

1. If they fund it they will want the power to dictate the policies.
2. Then the State would be inclined to control the process.
3. If the state funds then the state controls.
4. That depends what you mean by funding. They should help cost share in the information gathering process.
5. Not fully fund, but assist with grants, and by providing information as the TWDB currently does.
6. As the bill is currently written, the GMA's do not have a choice except the TWDB even though better information is available from outside consultants.
7. The citizens of the state are already funding the process through their GCDs. The local districts can make the decisions themselves!
8. See No. 17. [GCD's could support themselves if they covered a large enough area from which to collect taxes and fees (i.e. the EAA).]
9. Including special studies of specific areas of concerns.
10. Leave it local!!!
11. State should help with funding 50-50 match.
12. I'd rather see the legislature put extra money into the TWDB so we could have quicker answers and updates.

Groundwater Management Areas Decision on Desired Future Conditions

19. The state should fund the desired future conditions decision process.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

20. State funding would improve the desired future conditions decision process.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

21. The cost of groundwater in a groundwater conservation district will increase because of the desired future condition decision.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

Question 20. State funding would improve the desired future condition process.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	18	25	15	15	6	0	79

Decision Makers Comments on Question 20:

- Only if science is allowed over policy.
- Proper funding to the DFC process, like the SWP process, will allow the GMAs to hire a common set of processionals to assist rather than have many professionals trying to come to an agreement.
- Only if the funding could be used to improve the GAM and collect new data – not rehash the old.
- Depends on what you mean would improve the desired future conditions.

13. Same as above. [As the bill is currently written, the GMA's do not have a choice except the TWDB even though better information is available from outside consultants.]

- The process needs better data, and better models that are capable of predicting the future on a county basis vs a GMA basis.
- Not sure. It would help districts help themselves but I don't know about the entire process.

14. See Question 18. [The citizens of the state are already funding the process through their GCDs. The local districts can make the decisions themselves!]

- Many small single county Districts need assistance.
- Maybe yes; maybe no!
- It would really help if we could hire consultants as the regional planning bodies do.

Question 21. The cost of groundwater in a groundwater conservation district will increase because of the desired future condition decision.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	6	21	20	21	9	2	79

Decision Makers Comments on Question 21:

- When water is limited, it will take on a price. Water as a commodity already has a value in the Edwards Aquifer. Rights are sold up to $6,000 an acre-foot. The same for Trinity groundwater, an estimated $300 an acre-foot at the SAWS Oliver Ranch/BSR Project.
- I would hope so, ours is absolutely free. Supply and Demand Economics needs to come into place.

- In fact groundwater could decrease due to the reduction of use that may come in some areas.
- Not if managed properly.
- It will go up because of supply and demand and greed.
- The cost of groundwater is not ties to DFC decisions in many Districts.
- Maybe; maybe not. I assume you mean the cost of drilling deeper wells.
- The cost of groundwater will increase in the future regardless of the GCD or the DFC established. The demand will be higher and the resource will be more limited.
- It should but not until statutory caps on gw fees are lifted.
- The value of groundwater will increase but the cost of extraction should change excluding inflation.
- I don't know why this would be true.
- The cost of groundwater will increase but not because of the DFC's; it's just a limited resource for a growing population.

Question 22. The value of groundwater in a groundwater conservation district because of the desired future condition decision.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	6	21	20	21	9	2	79

Decision Makers Comments on Question 22:

- See 21. [However, the true value will be reflected in real estate. Should groundwater not be available county-wide, property values will decline and the once profitable (for governments and owners) tax base disappears.]
- If supply is estimated low and demand is high.
- The value will increase over time because groundwater is a finite resource, but not automatically for every DFC.
- Define you use of "value."
- See comment in Question 20 [The cost of groundwater will increase in the future regardless of the GCD or the DFC established. The demand will be higher and the resource will be more limited.]
- Perhaps but it remains to be seen.
- Values depend on demand & supply. DFC does not affect these.

Groundwater Management Areas Decision on Desired Future Conditions

22. The value of groundwater in a groundwater conservation district will increase because of the desired future conditions decision.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

23. The desired future condition decision will increase the cost of groundwater in an area without a groundwater district.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

24. The desired future condition decision will increase the value of groundwater in an area without a groundwater district.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

Question 23. The desired future condition will increase the cost of groundwater in an area without a groundwater conservation district.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	5	16	23	24	10	1	79

Decision Makers Comments on Question 23:

- See Comal County, with Groundwater Conservation District in place, no one knows until the wells begin to go dry. At this point those with water will be able to name their price.
- Groundwater has very little value outside of a GCD because of the Rule of Capture – no protection between well owners.
- People who have no stake in that district will be in it for the money not the good of the district.
- Define cost.
- The value of groundwater will increase but the cost of extraction shouldn't change excluding inflation.
- Same thought as for #21 (Values depend on demand & supply. DFC does not affect these).

Question 24. The desired future condition decision will increase the value of groundwater in an area without a groundwater district.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	6	26	24	15	5	3	79

Decision Makers Comments on Question 24:

- See above # 21 (See Comal County, with Groundwater Conservation District in place, no one knows until the wells begin to go dry. At this point those with water will be able to name their price).
- Is this to see if we answer the same way twice? #22 and 23 are exactly the same.
- If there is no district to monitor or set usage rules or enforce the DFCs the value will be what it will be.
- See above (define cost).
- See above #22 (This remains to be seen).

Question 25. The desired future condition process will help to establish a more functional water market and help to further define groundwater rights.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	2	32	22	11	10	2	79

Decision Makers Comments on Question 25:

- Water marketing will ultimately deny rural, to include domestic exempt users access to groundwater. This is due to municipal use taking priority.
- The current rules and laws governing the DFC process will clog the TWDB and our legal system with petitions and litigation regarding the DFCs. This may or may not further define groundwater rights, which are defined in statute already, but certainly will hinder the progress of the process.
- Litigation will define rights.
- The point is not to create legislation, but to manage groundwater at the local level.
- I don't believe that there is any correlation to groundwater rights, and the MAG. If there was it would severely damage one's groundwater rights.
- The DFC process itself may imply greater rights or marginally enhance market controls, but the courts or legislature will ultimately determine rights.
- Statement ambiguous and needs to be more than one statement. Define functional water market.
- Again, water marketing and water rights issues will be in our future even if we don't set DFCs.
- This may happen as these cases are litigated but probably not until direction is provided by the courts.
- I don't think we know enough at this time to answer this.
- I fear the process has already spurred the water marketeers to try to lock up water rights which should remain publicly owned.

The DFC process will result in winners and losers in the water market which will result in more legal challenges.

Groundwater Management Areas Decision on Desired Future Conditions

25. The desired future condition process will help to establish a more functional water market and help to further define groundwater rights.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

26. The Rail Road Commission should control the price of groundwater.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

27. The Texas Water Development Board should control the price of groundwater.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

Question 26. The Rail Road Commission should control the price of groundwater.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	0	0	4	8	65	2	79

Decision Makers Comments on Question 26:

- They do not care about groundwater, just OIL/GAS and state funding, let the free market set the price!
- It is the function of the free market system to control the cost of anything.
- The market will determine the value of groundwater.
- I don’t have any idea what this statement means. How is groundwater priced now?
- Less government, not more.
- Keep government out of it and let free markets control.
- I prefer more local input.

Question 27. The Texas Water Development Board should control the price of groundwater.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	2	1	9	10	55	2	79

Decision Makers Comments on Question 27:

- Land Owner and property rights will enter into this and it will get complicated.
- Let the Free Market set the price!
- Same as above. [It is the function of the free market system to control the cost of anything.]
- See above [I don't have any idea what this statement means. How is groundwater priced now?]
- See above [The market will determine the value of the groundwater].
- Keep government out of it and let free markets control.

Question 28. The Public Utilities Commission should control the price of groundwater.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	0	3	8	9	57	2	79

Decision Makers Comments on Question 28:

- Let the Free Market set the price!
- Same as above. [It is the function of the free market system to control the cost of anything.]
- See above [I don't have any idea what this statement means. How is groundwater priced now?]
- See above [The market will determine the value of groundwater.]
- Keep government out of it and let free markets control.
- Hell NO.

Groundwater Management Areas Decision on Desired Future Conditions

28. The Public Utilities Commission should control the price of groundwater.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

29. The Texas Commission on Environmental Quality should control the price of groundwater.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

30. Texas groundwater should stay in Texas and not be exported directly (bottled beverages are not considered as exports).

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

Question 29. The Texas Commission on Environmental Quality should control the price of groundwater.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	0	1	6	11	60	1	79

Decision Makers Comments on Question 29:

- TCEQ will make it more complicated. Supply vs demand conditions weighed against cost to develop will determine price of water.
- Let the Free Market set the price!
- Same as above. [It is the function of the free market system to control the cost of anything.]
- See above. [I don't have any idea what this statement means. How is groundwater priced now?]
- See above [The market will determine the value of the groundwater.]
- Keep government out of it and let free market forces control.
- On 25-28…let the free market decide in our free market system!!!
- See #27 comment. [Hell NO.]

Question 30. Texas groundwater should stay in Texas and not be exported directly (bottled beverages are not considered as exports).

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	19	33	17	7	3	0	79

Decision Makers Comments on Question 30:

- Water should stay in each county.
- If others have a need and we have a bounty, we should share if the need is real.
- Water availability will and should control land use and type of development within a given area.

Question 31. Texas groundwater should be transported around the state as needed.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	3	19	17	21	15	4	79

Decision Makers Comments on Question 31:

- Should not be transported from an area that will show a need for the water within the future planning of Regional Water Planning Groups.
- Junior water rights need to be changed so that all the groundwater of the state doesn't have to move.
- Water transport from one area to another should be looked at and studied as to the impact on satisfying the current and future needs of those where the water is before it is moved to another area.

- If one area has a need and one area have a bounty, we should share if the need is real.
- As agreed to or negotiated by Districts & GMAs, but not solely on need alone.
- If in-district and county needs are met first.
- It depends on if in-county needs are met first.
- As long as in district or county needs are met first.
- If a surplus exists within one GCD and is needed by another entity that groundwater should be available if it complies with the GCDs rules.
- So we [take] from the haves and give to the have nots and in the process insure that those that HAD no longer have the ability to grow.
- Question needs to be expanded. Is this mandatory share the wealth?
- Groundwater should remain in its recharge area. Cities could strip remote area in the state of groundwater.
- Agree, only if the amount of water available for transport coincides with the DFCs and MAGs set by the groundwater districts.

Groundwater Management Areas Decision on Desired Future Conditions

31. Texas groundwater should be transported around the state as needed.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

32. The desired future condition process will help to establish groundwater rights and how much groundwater is available legally for property owners.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

33. The desired future condition process is an improvement for managing Texas' groundwater resources.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

Question 32. The desired future condition process will help to establish groundwater rights and how much groundwater is available legally for property owners.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	2	30	12	19	12	4	79

Decision Makers Comments on Question 32:

- This process is already established through the rules and management plans of a Groundwater Conservation District.
- See comment on Question 24 [The current rules and laws governing the DFC process will clog the TWDB and our legal system with petitions regarding the DFCs. This may or may not further define groundwater rights, which are defined in statute already, but certainly will hinder the progress of the process.]
- Groundwater rights are already established in 36.002. If the goal is to have correlative rights (which in my opinion is not feasible) then maybe.
- We do not have a clue how much water is down there! Just a GUESS.
- If we were to grant every landowner their fair share of water rights based upon the MAG, it would greatly hurt one's ability to produce groundwater.
- Depends on how define a right.
- The operative phrase is "will help to establish"…rights and availability.
- How in the heck would it do that?
- Again, this may happen if the process generates litigation where the courts will decide.
- If there are caps on groundwater permits then first come, first serve. Everyone else is left out – Lawsuits.
- The jury is still out on this.

Question 33. The desired future condition process is an improvement for managing Texas' groundwater resources.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	4	40	20	7	6	2	79

Decision Makers Comments on Question 33:

- It is a start!
- Only time will tell. I think it rather doubtful.
- Only a slight improvement. Is a roundabout way of circumventing the rule of capture.
- Maybe…I consider the DFC process just an idea that needs to be tried and fleshed out.

Question 34. The desired future condition process will cause of [sic] lot of lawsuits to be filed.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	16	36	16	7	0	4	79

Decision Makers Comments on Question 34:

- There are already some petitions against the process so yes, lawsuits will be filed.
- There will no doubt be some litigation-at least one lawsuit has already been filed in GMA 1 over [D]FCs.
- Not the DFC but the MAG, which a GCD is required to permit up to. And if down the road conditions and science determining that the DFC and MAG were too high then every permit holder that is cut back will sue.
- Our DFC decisions may produce some lawsuits when we enforce rules to comply with the DFCs, but like all uncharted legal territory, some will contest the decisions.
- If you limit the available groundwater then do you prevent landowner's future development rights?
- Maybe…we gotta try it first!

Groundwater Management Areas Decision on Desired Future Conditions

34. The desired future condition decision will cause of lot of lawsuits to be filed.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

35. A variety of stakeholders should vote on the desired future condition of aquifers, similar to the regional water planning group process.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

36. Voting on a desired future condition should be weighted by groundwater conservation district size and population (i.e. the higher population districts would get more votes).

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

•

Question 35. A variety of stakeholders should vote on the desired future conditions of aquifers, similar to the regional water planning group process.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	1	20	15	22	21	0	79

Decision Makers Comments on Question 35:

- See question 16 [Though I may disagree with the method the public can participate, the public has an opportunity and obligation to let their representative know how they want to cast their vote].
- Stakeholders should be permitted to provide input and be informed.
- Why have both set up alike? If that is the goal, do away with GMA since regional planning is already set up.
- The only stakeholders not represented at the table in the GMA process are those stakeholders outside of a GCD.
- In order to participate in the DFC process one must be educated to understand the models, how they work, what information is needed, and generated from the models. It takes someone who is involved and educated to make these finds of informed decisions.
- Regional water planning groups should not exist, just the GMA's should make decisions on groundwater.
- Lack of knowledge by whoever is put on the GMA.
- County judges and unelected officials do not take the DFC seriously and do not take the time to become informed.
- Isn't this this same as #2 above? Are you attempting to evaluate strength of convictions?
- Again, not unless they have been involved in all the planning and work group processes.
- Increased involvement is good, not sure about the regional water planning group process.
- Board Directors are elected to receive input from constituents (stakeholders) and make decisions.
- Their voices should be heard but the votes should be limited to board members.
- But, I think the public hearing process will take care of this.
- The regional water planning process is not a good analogy as they make no binding decisions on stakeholders similar to the DFCs and MAGs.

Question 36. Voting on a desired future condition should be weighted by groundwater district size and population (i.e. the higher population districts get more votes).

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	1	8	6	24	40	0	79

Decision Makers Comments on Question 36:

- Size maybe, population NO WAY.
- If voting is weighted then why should a little GCD participate? Population and money will rule regardless of what it does to the less populated areas.
- Perhaps it should be on the estimated amount of groundwater in the districts.
- One's population and size should have bearing on my district's desired future condition, rural versus urban, not good.
- The DFC is about the aquifer, not how big you are.
- The DFC is about the aquifer, not the voting of a District.
- No – The large demand centers (cities) would strip the rural areas of their water and economic futures.
- Population size does not equal good scientific decision making.

Question 37. The Texas Supreme court needs to resolve the rule of capture and establish groundwater rights.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	9	27	9	12	20	2	79

Decision Makers Comments on Question 37:

- The state has done this by empowering Groundwater Conservation Districts as the preferred method of groundwater management.
- This is a legislative issue.
- The State Legislature, NOT Supreme Court.
- The rule of capture has been resolved, it is a tort or non liability rule. The court should clarify whether or not groundwater is owned in place.
- A GCD by design has already modified the ROC with spacing and pumping limits.
- The Legislature needs to resolve this issue.
- GCDs manage to permit, and allow production of groundwater without granting rights.
- State legislature needs to deal with it first.
- Correlative rights will not work Statewide. Reasonable use guidelines – what is reasonable – lawyers feast.
- This is the legislature's job.

Groundwater Management Areas Decision on Desired Future Conditions

37. The Texas Supreme Court needs to resolve the rule of capture and establish groundwater rights.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

38. I know more about my groundwater resources from having participated in the desired future conditions decision process.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

39. The desired future condition decision process is a well-conceived policy.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

•

Question 38. I know more about my groundwater resources from having participated in the desired future conditions process.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	16	38	15	4	4	2	79

Decision Makers Comments on Question 38:

- These meetings are very useful, not only by the information provided, but by the representatives of the TWDB who attend.
- I know more about other district's groundwater resources than I previously did.
- I have been around groundwater management for a long time.
- Actually, I have benefitted more by doing my own reading/research and results of contracted studies.
- This was a hard one. In some ways I have learned more yet so far the process has not been that great due to the problems with the TWDB GAM.
- But it still leaves a lot of unanswered questions about reliability and accuracy.

Question 39. The desired future condition decision process is a well-conceived policy.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	1	21	27	23	7	0	79

Decision Makers Comments on Question 39:

- Consensus to trump science is bad policy.
- Requiring groundwater district to permit "up to" the MAG is not a good concept.
- Probably necessary but not well-conceived - ,limited involvement by stakeholders.
- DFC determination should have been added as a requirement for GCD management plans long ago without the GMA process.
- We are forced to use GAM runs, not facts.
- I believe that it is a good process, but lacks the tools to make good policy.
- Time will tell.
- I don't know for sure how the policy was derived. I don't think anyone consulted the districts.
- The idea may be good but the process is not so well conceived.
- The bill establishing DFCs never even got debated in committee. It was a floor amendment that got added to a bill that was intended to establish administrative procedures for GCDs at the last minute.
- The only question is how does a groundwater district manage and enforce the desired future condition plan.

- My comment is that it is OK. I think we still need to decide after we test it for a period.
- The DFC concept is good. The process could be improved.

Question 40. The desired future condition will result in a fair and reasonable outcome for individual landowners wanting to sell or lease their groundwater rights at some point in the future but currently are not producing high volumes of groundwater.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	0	15	26	29	8	1	79

Decision Makers Comments on Question 40:

- Depends on what the GMA arrives at for the DFC for themselves.
- Conceivably, if a "cap" is established when a District permits "up to" its MAG non-producers may not have an opportunity to produce.
- Fair is in the eyes of the seller.
- Only if facts are used.
- I don't believe that there is any correlation between the two. The GCD ultimately decides who gets to pump, and how much.
- Depends on how a GCD elects to allocate groundwater.
- I don't think it will have much effect on their being able to sell water. The ability to sell water is more closely tied to location.
- It will depend on each GMA and the DFC they approve.
- The first people to apply for the excess in the MAG will be the people that receive the water, not good.
- I left my crystal ball at home. Who knows? Will there be a fair and reasonable outcome for anyone?
- I sure doubt it.
- Landowners selling their water rights are also stripping their neighbors of their water without compensation.
- Depends on the individual groundwater district decisions.

Groundwater Management Areas Decision on Desired Future Conditions

40. The desired future condition decision will result in a fair and reasonable outcome for individual landowners wanting to sell or lease their groundwater rights at some point in the future but currently are not producing high volumes of groundwater.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

41. The desired future condition decision will clarify groundwater rights for non-exempt well owners.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

42. The desired future condition will result in a fair and reasonable outcome for:

	Land Owners	Land Developers	Farmers/Ranchers	Municipalities	Exempt Well-Owners	Non-Exempt Well Owners	Water Marketeers
Strongly Agree	☐	☐	☐	☐	☐	☐	☐
Agree	☐	☐	☐	☐	☐	☐	☐
Neutral	☐	☐	☐	☐	☐	☐	☐
Disagree	☐	☐	☐	☐	☐	☐	☐
Strongly Disagree	☐	☐	☐	☐	☐	☐	☐
No Comment	☐	☐	☐	☐	☐	☐	☐

•

Question 41. The desired future condition decision will clarify groundwater rights for non-exempt well owners.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	0	23	15	28	11	2	79

Decision Makers Comments on Question 41:

- This group in particular has virtually no advocate. Ultimately, the organized municipal demand will take all available groundwater leaving nothing for those (the landowners, who actually preserve and protect the land through management practices) who have no alternate source.
- See answer to Question 24 [The current rules and laws governing the DFC process will clog the TWDB and our legal system with petitions regarding the DFCs. This may or may not further define groundwater rights, which are defined in statute already, but certainly will hinder the progress of the process].
- Litigation will clarify rights.
- Their rights are already established in 36.002.
- Again I see no correlation between groundwater rights and DFCs.
- How would the DFC clarify groundwater rights. Seems to me a bad question.
- No, the resulting court cases will.
- This issue is one of the biggest defects of the process.

Question 42. The desired future condition will result in a fair and reasonable outcome for:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment
Land Owners	4	23	23	10	8	9
Land Developers	4	25	23	10	5	9
Farmers/Ranchers	5	26	16	16	6	9
Municipalities	6	28	18	11	5	9
Exempt Well-Owners	5	24	24	9	7	9
Non-Exempt Well Owners	4	20	25	13	5	9
Water Marketers	8	24	22	9	4	9

Question 43. The groundwater management area is the best collection of entities to make the decision about the future of the aquifers.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	8	50	6	8	5	2	79

Decision Makers Comments on Question 43:

- I agree only if science is the deciding factor, not policy.
- The Texas Water Development Board should make the decision with input from the Areas.
- If groundwater districts are following protocol in getting info from stakeholders.
- For now, when new tools are developed then I could see use of a science advisory committee.
- As long as it is the GCD's making the decision. The boards are elected and must perform.
- As the GMA's currently stand, if added people with little or no knowledge of the process, it would be a disaster.
- With the proviso that all 'stakeholders' have an opportunity to participate through their district board.
- The GCDs are the best entities to make the decision about the future of the aquifers as they understand local needs and their individual districts best.
- In theory, perhaps, in practice, the cards are not all on the table yet to make that determination.
- The State will ultimately take over and control everything. This exercise is just the start.
- The only improvement would be to do it by aquifer.'
- But sometimes the boundaries are questionable.

Groundwater Management Areas Decision on Desired Future Conditions

43. The groundwater management area is the best collection of entities to make the decision about the future of the aquifers.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

44. The decision making process about the future of the aquifers should be left for to each groundwater conservation district to make on their own.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree
- No Comment

Other (please specify)

•

Question 44. The decision making process about the future of aquifers should be left for to each groundwater conservation district to make on their own.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	18	25	10	22	3	1	79

Decision Makers Comments on Question 43:

- A cooperative effort is necessary for the exchange of ideas and coordination of….
- Nice loaded question. GCD need to work together for the good of their residents and neighbors. One size does not fit all.
- I think the GMA's have a role to play in the process if a consensus of the members of GMA can agree on the DFC's that will be beneficial to an area aquifer[s], but individual districts should have the final determination.
- Locally elected board are the best avenue for groundwater management as they are responsible to the electorate.
- In some way I agree with this statement but in others I realize that planning needs to cover a larger area.
- If there is an overlap of districts, consultation is required.
- If a CD managed an entire aquifer but not for GCDs that have shared jurisdiction with other GCDs.
- The groundwater districts have a better understanding of the areas needs and potential supplies.
- Some larger, more inclusive entity is needed for this. The GMA is good for now.

Groundwater Management Areas Decision on Desired Future Conditions

45. The development of groundwater supplies is best planned by the:

- ◯ Municipalities
- ◯ Industry
- ◯ Groundwater Conservation Districts
- ◯ Groundwater Management Areas
- ◯ Regional Water Planning Groups
- ◯ Texas Water Development Board (TWDB)
- ◯ Texas Commission on Environmental Quality (TCEQ)
- ◯ Environmental Protection Agency (EPA)
- ◯ United States Geological Survey (USGS)
- ◯ No Comment

Other (please specify)

46. More technical understanding of the groundwater models and the water levels is needed for groundwater management area decision makers to make an informed decision.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Comment

Other (please specify)

Question 45. The development of groundwater supplies is best planned by the:

Municipalities	1
Industry	0
Groundwater Conservation Districts	52
Groundwater Management Areas	11
Regional Water Planning Groups	3
Texas Water Development Board (TWDB)	8
Texas Commission on Environmental Quality (TCEQ)	0
Environmental Protection Agency (EPA)	0
United States Geological Survey (USGS)	0
No Comment	4
Total	79

Decision Makers Comments on Question 45:

- More than just the districts.
- Those that owner the water…Landowners until the rule of capture is changed.
- Industry, too.
- Development should be by the user/seller not a specific group/entity/agency.
- Again, probably should be combined effort including GWA, Regional Planning Groups, TWDB, and USGS.
- Must have some form of joint planning with adjacent districts.
- Again, I think the GMA can also have a very important role to play. All the other groups listed have too much politics involved to make decisions that would be best for the aquifers.
- GCD's must have the benefit of clear and concise water laws. Legislature can't duck this one!
- Groundwater Conservation Districts need the authority to enforce their water management plans.
- All entities should be involved in the decision making process.

Question 46. More technical understanding of the groundwater models and the water levels is needed for groundwater management area decision makers to make an informed decision.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No Comment	Total
Responses	34	33	4	8	0	0	

Decision Makers Comments on Question 46:

- Some held more information.
- Do you mean the GCD representative needs more understanding or that the GAM needs more refinement?

- More data will enable better decisions in the future, but the existing data base is sufficient for current decisions.
- More information is needed but decisions can be made on available information &revised as more information is available.
- More information is always better, but decisions in my GMA could be made at this time.
- The models are very inaccurate, and need updating to accommodate the needs of the GMA's.

2011 GMA 9 Decision Makers 14-Question Survey/Results

Decision Makers Survey 2011

1. Deciding How Much Groundwater Should be Available in the Future

Chapter 36.108 requires groundwater conservation districts in a groundwater management area to follow this guidance when adopting a desired future condition for a relevant aquifer:
1) The Groundwater Conservation District Board Presidents (the "decision makers") must meet at least once a year
2) The groundwater management area must review each district's management plan, the planning impacts, and how effective it is at meeting the identified goals
3) The groundwater management area must adopt the desired future conditions of relevant aquifers by a 2/3 of 2/3 majority
4) The groundwater management area must consider the aquifer uses and conditions that differ substantially from one geographic area to another when deciding desired future conditions
5) The groundwater management area must consider the groundwater availability models and other data or information.

For this survey, the stakeholders are those who own land within a groundwater conservation district.

Please read the following statements carefully. Respond using your situation and your understanding of the current process.

2. Questions

***1. Do you have a groundwater well?**

○ Yes ○ No ○ Do not know

***2. If you have a well, do you use your well for household use and/or livestock watering?**

☐ Yes ☐ No ☐ Not Applicable

***3. The groundwater management area is the best collection of entities to make the decision about the future of the aquifers.**

○ Strongly Agree
○ Agree
○ Neutral or Not Sure
○ Disagree
○ Strongly Disagree
○ No Comment

Other (please specify)

Decision Makers Survey 2011

***4. Do you believe that the guidelines from Chapter 36.108 of the Texas Water Code are specific enough to develop a reasonable desired future condition of an aquifer?**

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral or Not Sure
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No response

***5. Do you believe that the decision makers can make a reasonable decision about desired future conditions using the currently available models, data, and information?**

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral or Not Sure
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Response

***6. Do you believe that stakeholders articulating their desired future condition through a filmed or recorded interview or anonymous survey would help the decision makers?**

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral or Not Sure
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Response

Decision Makers Survey 2011

7. Do you believe that if the decision makers were able to easily run groundwater models themselves and test out pumping scenarios in a short time frame they could develop a better or more reasonable desired future condition?

- Strongly Agree
- Agree
- Neutral or Not Sure
- Disagree
- Strongly Disagree
- No Response

8. Do you believe that if the decision makers knew about the potential financial implications associated with their decision about future aquifer conditions they would develop a better or more reasonable desired future condition?

- Strongly Agree
- Agree
- Neutral or Not Sure
- Disagree
- Strongly Disagree
- No Response

***9. The decision making process about the future of the aquifers should be left for to each groundwater conservation district to make on their own.**

- Strongly Agree
- Agree
- Neutral or Not Sure
- Disagree
- Strongly Disagree
- No Response

Other (please specify)

Decision Makers Survey 2011

10. Do you believe that if the decision makers reviewed and analyzed past conditions of the aquifer, groundwater use patterns and trends, and groundwater elevation changes, they could develop a better or more reasonable desired future condition?

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral or Not Sure
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Response

11. Do you believe that the decision makers could develop a better or more reasonable desired future condition if they considered possible climate change (rainfall and temperature) implications for groundwater resources?

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral or Not Sure
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Response

***12. More people should be voting on the desired future condition of aquifers other than the groundwater conservation district Board presidents.**

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral or Not Sure
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Response

Other (please specify)

Decision Makers Survey 2011

13. Please rank from 1 to 7, from most important to least important, the importance of the following items on developing a desired future condition:

- Historical Groundwater Data/Current Aquifer Conditions
- Landowner's/Well owner's stated preferences
- Technical presentations and assistance
- Future financial implications for entire local economy
- Decision makers running groundwater models/testing scenarios
- Rainfall and temperature variation and changes
- Probability/likelihood desired future condition will happen

Other (please specify)

14. The best individuals to decide on the desired future conditions of an aquifer in my area are:

- Stakeholders/Well Owners
- Groundwater Conservation District Board Presidents
- Regional Water Planning Groups
- Texas Water Development Board
- Texas Commission on Environmental Quality
- Texas Railroad Commission
- A Cross-section of Appointed Citizens in each Groundwater Management Area
- A Cross-section of Elected Citizens in each Groundwater Management Area
- No One

Other (please specify)

Decision Makers Survey 2011

SurveyMonkey

1. Do you have a groundwater well?

	Response Percent	Response Count
Yes	66.7%	6
No	33.3%	3
Do not know	0.0%	0
	answered question	9
	skipped question	0

2. If you have a well, do you use your well for household use and/or livestock watering?

	Response Percent	Response Count
Yes	55.6%	5
No	22.2%	2
Not Applicable	22.2%	2
	answered question	9
	skipped question	0

3. The groundwater management area is the best collection of entities to make the decision about the future of the aquifers.

	Response Percent	Response Count
Strongly Agree	**55.6%**	**5**
Agree	44.4%	4
Neutral or Not Sure	0.0%	0
Disagree	0.0%	0
Strongly Disagree	0.0%	0
No Comment	0.0%	0
	Other (please specify)	0
	answered question	**9**
	skipped question	**0**

4. Do you believe that the guidelines from Chapter 36.108 of the Texas Water Code are specific enough to develop a reasonable desired future condition of an aquifer?

	Response Percent	Response Count
Strongly Agree	0.0%	0
Agree	**66.7%**	**6**
Neutral or Not Sure	22.2%	2
Disagree	11.1%	1
Strongly Disagree	0.0%	0
No response	0.0%	0
	answered question	**9**
	skipped question	**0**

5. Do you believe that the decision makers can make a reasonable decision about desired future conditions using the currently available models, data, and information?

	Response Percent	Response Count
Strongly Agree	11.1%	1
Agree	**55.6%**	**5**
Neutral or Not Sure	33.3%	3
Disagree	0.0%	0
Strongly Disagree	0.0%	0
No Response	0.0%	0
	answered question	**9**
	skipped question	**0**

6. Do you believe that stakeholders articulating their desired future condition through a filmed or recorded interview or anonymous survey would help the decision makers?

	Response Percent	Response Count
Strongly Agree	0.0%	0
Agree	11.1%	1
Neutral or Not Sure	**44.4%**	**4**
Disagree	33.3%	3
Strongly Disagree	11.1%	1
No Response	0.0%	0
	answered question	**9**
	skipped question	**0**

7. Do you believe that if the decision makers were able to easily run groundwater models themselves and test out pumping scenarios in a short time frame they could develop a better or more reasonable desired future condition?

	Response Percent	Response Count
Strongly Agree	**33.3%**	**3**
Agree	**33.3%**	**3**
Neutral or Not Sure	11.1%	1
Disagree	22.2%	2
Strongly Disagree	0.0%	0
No Response	0.0%	0
	answered question	**9**
	skipped question	**0**

8. Do you believe that if the decision makers knew about the potential financial implications associated with their decision about future aquifer conditions they would develop a better or more reasonable desired future condition?

	Response Percent	Response Count
Strongly Agree	11.1%	1
Agree	**44.4%**	**4**
Neutral or Not Sure	11.1%	1
Disagree	33.3%	3
Strongly Disagree	0.0%	0
No Response	0.0%	0
	answered question	**9**
	skipped question	**0**

9. The decision making process about the future of the aquifers should be left for to each groundwater conservation district to make on their own.

	Response Percent	Response Count
Strongly Agree	0.0%	0
Agree	11.1%	1
Neutral or Not Sure	11.1%	1
Disagree	33.3%	3
Strongly Disagree	**44.4%**	**4**
No Response	0.0%	0
	Other (please specify)	1
	answered question	**9**
	skipped question	**0**

10. Do you believe that if the decision makers reviewed and analyzed past conditions of the aquifer, groundwater use patterns and trends, and groundwater elevation changes, they could develop a better or more reasonable desired future condition?

	Response Percent	Response Count
Strongly Agree	33.3%	3
Agree	**66.7%**	**6**
Neutral or Not Sure	0.0%	0
Disagree	0.0%	0
Strongly Disagree	0.0%	0
No Response	0.0%	0
	answered question	**9**
	skipped question	**0**

11. Do you believe that the decision makers could develop a better or more reasonable desired future condition if they considered possible climate change (rainfall and temperature) implications for groundwater resources?

	Response Percent	Response Count
Strongly Agree	0.0%	0
Agree	33.3%	3
Neutral or Not Sure	**44.4%**	**4**
Disagree	11.1%	1
Strongly Disagree	11.1%	1
No Response	0.0%	0
	answered question	**9**
	skipped question	**0**

12. More people should be voting on the desired future condition of aquifers other than the groundwater conservation district Board presidents.

	Response Percent	Response Count
Strongly Agree	11.1%	1
Agree	22.2%	2
Neutral or Not Sure	11.1%	1
Disagree	22.2%	2
Strongly Disagree	**33.3%**	**3**
No Response	0.0%	0
	Other (please specify)	1
	answered question	**9**
	skipped question	**0**

13. Please rank from 1 to 7, from most important to least important, the importance of the following items on developing a desired future condition:

	Response Percent	Response Count
Historical Groundwater Data/Current Aquifer Conditions	77.8%	7
Landowner's/Well owner's stated preferences	0.0%	0
Technical presentations and assistance	0.0%	0
Future financial implications for entire local economy	0.0%	0
Decision makers running groundwater models/testing scenarios	11.1%	1
Rainfall and temperature variation and changes	0.0%	0
Probability/likelihood desired future condition will happen	11.1%	1
	Other (please specify)	8
	answered question	**9**
	skipped question	**0**

14. The best individuals to decide on the desired future conditions of an aquifer in my area are:

	Response Percent	Response Count
Stakeholders/Well Owners	0.0%	0
Groundwater Conservation District Board Presidents	**77.8%**	**7**
Regional Water Planning Groups	22.2%	2
Texas Water Development Board	33.3%	3
Texas Commission on Environmental Quality	0.0%	0
Texas Railroad Commission	0.0%	0
A Cross-section of Appointed Citizens in each Groundwater Management Area	0.0%	0
A Cross-section of Elected Citizens in each Groundwater Management Area	33.3%	3
No One	0.0%	0
	Other (please specify)	3
	answered question	**9**
	skipped question	**0**

9 of 9

2012 Stakeholder Focus Group Pre-Discussion Survey

In 2012 fourteen focus groups met in eight counties to take a survey about groundwater decision making and the DFC process. An example survey shown below from Comal County, is the same as the other counties except for the title. Data is included in the attached electronic database.

Comal County Groundwater Survey 2010

1. Deciding How Much Groundwater Should be Available in the Future

Chapter 36.108 requires groundwater conservation districts in a groundwater management area to follow this guidance when adopting a desired future condition for a relevant aquifer:
1) The Groundwater Conservation District Board Presidents (the "decision makers") must meet at least once a year
2) The groundwater management area must review each district's management plan, the planning impacts, and how effective it is at meeting the identified goals
3) The groundwater management area must adopt the desired future conditions of relevant aquifers by a 2/3 of 2/3 majority
4) The groundwater management area must consider the aquifer uses and conditions that differ substantially from one geographic area to another when deciding desired future conditions
5) The groundwater management area must consider the groundwater availability models and other data or information.

For this survey, the stakeholders are those who own land within a groundwater conservation district.

Please read the following statements carefully. Respond using your situation and your understanding of the current process.

Comal County Groundwater Survey 2010

2. Questions

*1. Do you have a groundwater well?

○ Yes ○ No ○ Do not know

*2. If you have a well, do you use your well for household use and/or livestock watering?

☐ Yes ☐ No ☐ Not Applicable

3. Do you believe that the guidelines from Chapter 36.108 are specific enough to develop a reasonable desired future condition of an aquifer.

○ Strongly Agree ○ Agree ○ Neutral or Not Sure ○ Disagree ○ Strongly Disagree ○ No response

4. Do you believe that the decision makers can make a reasonable decision about desired future conditions using the currently available models, data, and information.

○ Strongly Agree ○ Agree ○ Neutral or Not Sure ○ Disagree ○ Strongly Disagree ○ No Response

5. Do you believe that stakeholders articulating their desired future condition through a filmed or recorded interview or anonymous survey would help the decision makers.

○ Strongly Agree ○ Agree ○ Neutral or Not Sure ○ Disagree ○ Strongly Disagree ○ No Response

6. Do you believe that if the decision makers were able to easily run groundwater models themselves and test out pumping scenarios in a short time frame they could develop a better or more reasonable desired future condition.

○ Strongly Agree ○ Agree ○ Neutral or Not Sure ○ Disagree ○ Strongly Disagree ○ No Response

7. Do you believe that if the decision makers know about the potential financial implications associated with their decision about future aquifer conditions they would develop a better and more reasonable desired future condition.

○ Strongly Agree ○ Agree ○ Neutral or Not Sure ○ Disagree ○ Strongly Disagree ○ No Response

8. Do you believe that if the decision makers reviewed and analyzed past conditions of the aquifer, groundwater use patterns and trends, and groundwater elevation changes, they could develop a better and more reasonable desired future condition.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral or Not Sure
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Response

9. Do you believe that the decision makers could develop a better and more reasonable desired future condition if they consider possible climate change (rainfall and temperature) implications for groundwater resources.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral or Not Sure
- ◯ Disagree
- ◯ Strongly Disagree
- ◯ No Response

10. Please rank from 1 to 7, from most important to least important, the importance of the following items on developing a desired future condition:

- ◯ Historical Groundwater Data/Current Aquifer Conditions
- ◯ Landowner's/Well owner's stated preferences
- ◯ Technical presentations and assistance
- ◯ Future Financial Implications for entire local economy
- ◯ Decision makers running groundwater models/testing scenarios
- ◯ Rainfall and Temperature variation and changes
- ◯ Probability/likelihood desired future condition will happen

Other (please specify)

Comal County Groundwater Survey 2010

11. The best individuals to decide on the desired future conditions of groundwater in my area are:

- ◯ Stakeholders/Well Owners
- ◯ Groundwater Conservation District Board Presidents
- ◯ Regional Water Planning Groups
- ◯ Texas Water Development Board
- ◯ Texas Commission on Environmental Quality
- ◯ Texas Railroad Commission
- ◯ A Cross-section of Appointed Citizens in each Groundwater Management Area
- ◯ A Cross-section of Elected Citizens in each Groundwater Management Area
- ◯ No One

Other (please specify)

Notes

[1] Likert, Rensis. 1932. A Technique for the Measurement of Attitudes. *Archives of Psychology* 22 (No. 140):5-41.

[2] Clason, Dennis L., and Thomas J. Dormody. Analyzing Data Measured by Individual Likert-Type Items. *Journal of Agricultural Education* 35 (No. 4):5.

[3] Russell, Jack, and Philip Bobko. 1992. Moderated Regression Analysis and Likert Scales: Too Coarse for Comfort. *Journal of Applied Psychology* 77 (3):336-342.

[4] Javaras, Kristen N., and Brian D. Ripley. 2007. An "Unfolding" Latent Variable Model for Likert Attitude Data: Drawing Inferences Adjusted for Response Style. *Journal of the American Statistical Association* 102 (478):454-463.

[5] Jamieson, Susan. 2004. Likert scales:how to (ab)use them. *Medical Education* 38:1212-1218.

[6] Lubke, Gitta, and Bengt Muthen. March 24, 2009. *Factor-analyzing Likert-scale data under the assumption of multivariate normality complicates a meaningful comparison of observed groups or latent classes*. University of California 2004 [March 24, 2009]. Available from http://www.gseis.ucla.edu/faculty/muthen/Likart.pdf.

[7] Prickett, T.A., and C.G. Lonnquist. 1973. *Aquifer Simulation Model for Use on Disk Supported Small Computer Systems, Circular 114*. Urbana, Illinois: Illinois State Water Survey.

Appendix B: Survey Methodology

Surveys were sent to landowners in six of the nine counties in Groundwater Management Area 9. These surveys, designed to gather respondent's preferences about groundwater, serve as part of the proposed method for collecting data from all the groundwater management areas.

The five databases were originally in alphabetical order by last name. In order to sample the landowner population a pseudo-random number was generated by using the RANDNUM operation in a blank column in Excel. Those pseudo-random numbers, equaling the total number of records in each database, were then copied and pasted next to the names and addresses in each row of the spreadsheet. This process automatically generated another number sequence by default in the Excel program. Each database was reordered using those random numbers by highlighting and resorting in descending numerical order. Depending on the number of the records in the database, records systematically sampled retained about 1000 people for each district with over 1000 records. Only one district, northern Bexar County had less than 1000 records and all of those landowners were sent a survey.

A second survey sent out to the Hays-Trinity Groundwater Conservation District landowners corrected several issues pointed out by the respondents in the original survey. For example, rewording the confusing parts of question three, both the answer choices and the question, result in parallel construction of the response choices and a shorter question. Questions three through six included additional space, labeled "Comments" and a choice of No Response", not available in the previous survey.

Procedures

A web-based company—SurveyMonkey.com collects and stores the survey information and results electronically—hosted the online survey. The district general managers received the online survey link through one electronic mail sent out on December 5, 2008. The survey directed district managers to forward the survey onto their board of directors or print out the attached digital copy for those without online access. The Texas Water Development Board maintains the district database electronic mail addresses used to deliver this survey although a few addresses were incorrect. Individual follow-up emails were sent to alternative addresses for districts that had changed their addresses. A reminder note—sent out on January 28, 2009—encouraged respondents to participate in the survey and to remind them of the survey closing date. The online survey closed on February 10, 2009.

The United States Postal Service delivered the series of landowner surveys, titled by corresponding county name, specific to each district, and consisting of six questions (see Appendix A). Only 10 respondents took the option of responding to the landowner survey online by typing in the web link address and completing the survey online. Response duplication was possible between the mailed and online survey. Both groundwater conservation districts and county tax appraisal districts provided the names and addresses.

Contingent Valuation Data and Explanation

Contingent valuation (CV) of groundwater is calculated using responses to Landowners Survey 2009 Question 5. The following algebraic equation served as the method for calculating the contingent value of groundwater. A person's change from one method of securing water to another served as the input for the variable switch. Solving this equation using the six counties surveyed as inputs results in a groundwater value = $ 2,855 per acre-foot.

$$\boldsymbol{CVG} = \left[\sum \boldsymbol{n_{switch}} * \$_{\boldsymbol{switchmin}} + \sum \boldsymbol{n_{switch}} * \$_{\boldsymbol{switchmax}}\right] \div \boldsymbol{n}$$

where	CVG =	Contingent Valuation of Groundwater
	switch =	respondent changing their water resource as lease price increases
	min =	low end of lease dollar value range
	max =	high end of lease dollar value range
	n =	number of respondents completing the survey

Question 5 provided a matrix of decision choices for the landowner to decide where to secure their water resource should their well become dry. If a respondent chose to buy groundwater rights or lease groundwater and matched this to the potential groundwater pricing options, this provided a more direct contingent valuation of groundwater. Ideally, respondents could have directly provided their value of groundwater through evaluating the choice of buying groundwater in order to secure their water supply against the range of prices then change the source as the price increased.

Only 54 percent of respondents indicating that they owned a well or did not know if they owned a well, or left that response blank answered this question completely. Respondents that indicated they did not own a well were not included in this measure. Out of this 54 percent complete response rate, only 181 responding changed from one choice to purchase or get water to another choice at least once depending upon the groundwater lease price given.

In order to develop a contingent value, or 'willingness-to-pay' through this method, by using the change from when respondents changed their option of getting water, the change in choice served as a proxy for a contingent valuation of groundwater. Several respondents changed their choices among the four categories two or more times: 59 people changed twice, 12 changed three times, two changed four times, and only one changed five times. Table 1 lists those contingent values and the corresponding choice of water source.

Table 1. Landowners' WTP Weighted Average Groundwater Contingent Valuation

Base Lease Value	Number that Switched	Lease Value Interval	Average of Lease Value Interval	Number that Switched Multiplied by Average lease Value Interval	Average Value for All Who Switched
$1500	35	1500-2000	$1750	61250	
$2000	52	2000-2500	$2250	117000	
$2500	24	2500-3000	$2750	66000	
$3000	20	3000-3500	$3250	65000	
$3500	25	3500-4000	$3750	93750	
$4000	14	4000-4500	$4250	59500	
$4500	7	4500-5000	$4750	33250	
$5000	4	5000-5500	$5250	21000	
$5500	0	5500-6000	$5500	0	
Total	181			516750	$2854.97

Source: Rima Petrossian, 2010

Table 2. Landowners' WTAP Weighted Average Groundwater Contingent Valuation

Sale Price	Count	Interval Average	Number that Would Sell Multiplied by Interval Average	
$1000+	7	1500	10500	
$2000+	13	2500	32500	
$3000+	14	3,500	49,000	
$4000+	4	4,500	18,000	
$5000+	4	5,500	22,000	
$6000+	16	6,500	104,000	
Market Value	60			
Not Lease at Any Price	447			Weighted Average
No Response	3		Total = 236,000	$4068.97

Source: Rima Petrossian, 2010

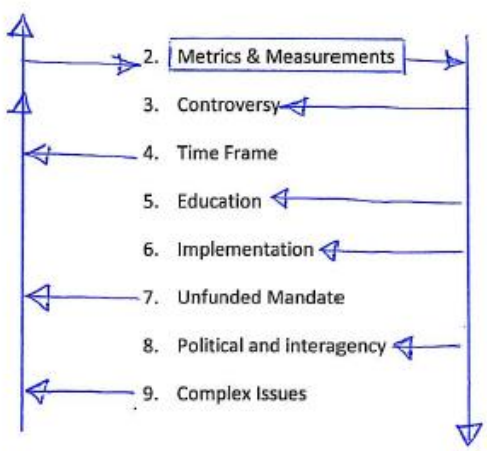
Appendix C: Decision Maker's 2011 Elements Driver Diagram

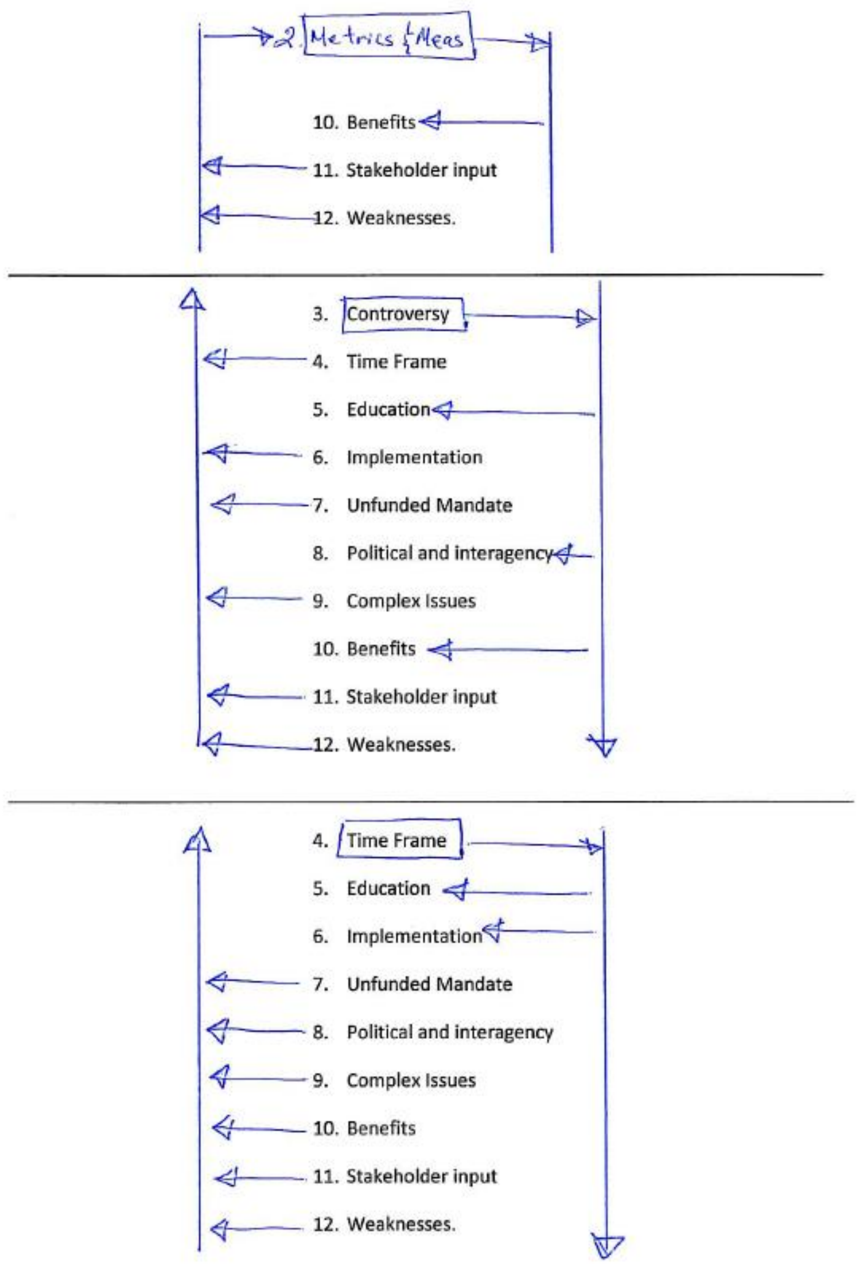
Completed Decision Makers' DFC Element Driver Choice Survey

Six GMA 9 decision makers met in a focus group. Initially, each participant filled in an 11-question survey, included here, then responded to the statement, "Tell me about the desired future condition process." The participants wrote down their responses on small pieces of paper, and together sorted them into cohesive categories, or elements. Each decision maker participated in developing these elements as a group and agreed on the naming convention. Decision makers identified the driver in each pairwise relationship, shown in the example driver diagram included here. This data provided input for developing the SID diagram describing the DFC system.

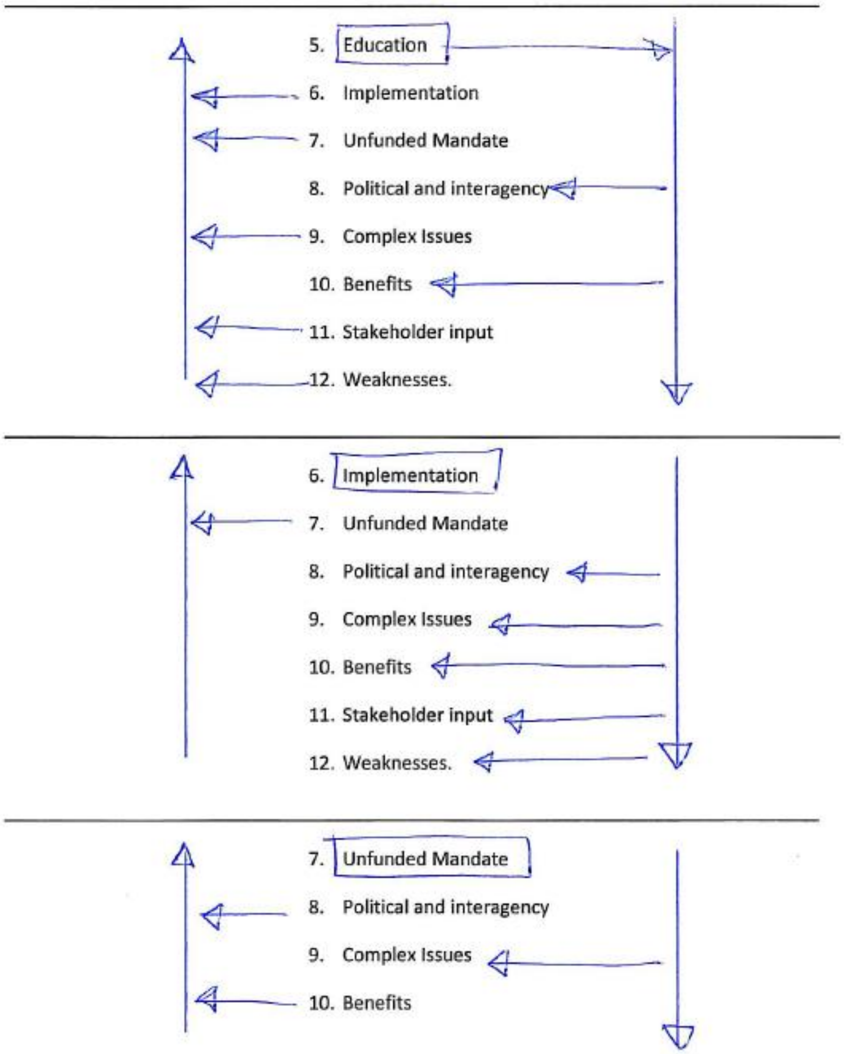
Decision Maker's Elements for the Desired Future Conditions: Focus Group December 2011:

Are the elements related? If they are, which element causes the other to occur or drives the relationship? Start with the top of the column and compare the top element to each of the next elements, like 1 to 2, 1 to 3, 1 to 4 and so forth to 1 to 12. Draw an arrow in from the driver to the driven, i.e. 1 causes 2 so the arrow points to 2. It is easiest to draw the same direction on one side of the diagram, all downward arrows on right (1 to 3), all upward arrows on left (2 to 1), like lines of longitude on the earth.





2. Metrics & Meas
10. Benefits
11. Stakeholder input
12. Weaknesses.
3. Controversy
4. Time Frame
5. Education
6. Implementation
7. Unfunded Mandate
8. Political and interagency
9. Complex Issues
10. Benefits
11. Stakeholder input
12. Weaknesses.
4. Time Frame
5. Education
6. Implementation
7. Unfunded Mandate
8. Political and interagency
9. Complex Issues
10. Benefits
11. Stakeholder input
12. Weaknesses.


5. Education
6. Implementation
7. Unfunded Mandate
8. Political and interagency
9. Complex Issues
10. Benefits
11. Stakeholder input
12. Weaknesses.
6. Implementation
7. Unfunded Mandate
8. Political and interagency
9. Complex Issues
10. Benefits
11. Stakeholder input
12. Weaknesses.
7. Unfunded Mandate
8. Political and interagency
9. Complex Issues
10. Benefits

11. Stakeholder input

12. Weaknesses.

---

8. Political and interagency

9. Complex Issues

10. Benefits

11. Stakeholder input

12. Weaknesses.

---

9. Complex Issues

10. Benefits

11. Stakeholder input

12. Weaknesses.

---

10. Benefits

11. Stakeholder input

12. Weaknesses.

---

11. Stakeholder input

12. Weaknesses.

Affinity Table Calculations

The Affinity Table shown below shows the DFC process' Pareto-optimal calculation for identifying the pair relationships that are most frequent but the fewest number needed to describe the DFC system in order to develop a SID illustration (see Figure 7.2). For example, only the top 20 percent of paired affinities would be necessary to properly define a system. Rows seen below marked 8 < 12 and 11 < 12 show where the power is optimal indicating that the pair affinities above those rows optimally can describe the entire DFC system. These data are taken from the counts generated from each participant's analysis of the paired affinities and what drives each pair, shown in the survey "diagram" above. Another aspect of identifying the fewest amount of pair affinities to describe the system is to choose all the affinities above the 80 percent cumulative frequency, shown in the row marked 3 > 6.

Table 2.1 Pareto Optimal Table

Affinity Pair Driver	Frequency Sorted (Descending)	Cumulative Frequency	Cumulative Percent (Relation)	Cumulative Percent (Frequency)	Power
1 > 6	9	9	0.8	1.5	0.7
1 < 7	9	18	1.5	2.9	1.4
2 < 7	9	27	2.3	4.4	2.1
3 < 7	9	36	3.0	5.9	2.9
3 < 8	9	45	3.8	7.4	3.6
5 < 7	9	54	4.5	8.8	4.3
6 < 9	9	63	5.3	10.3	5.0
7 > 12	9	72	6.1	11.8	5.7
1 > 5	8	80	6.8	13.1	6.3
1 > 10	8	88	7.6	14.4	6.8
2 > 3	8	96	8.3	15.7	7.4
2 > 10	8	104	9.1	17.0	7.9
3 > 5	8	112	9.8	18.3	8.5
4 > 6	8	120	10.6	19.6	9.0
4 < 8	8	128	11.4	20.9	9.6
4 > 9	8	136	12.1	22.2	10.1
5 < 9	8	144	12.9	23.5	10.7
5 > 10	8	152	13.6	24.8	11.2
6 < 7	8	160	14.4	26.1	11.7
6 < 8	8	168	15.2	27.5	12.3
10 < 11	8	176	15.9	28.8	12.8
1 > 9	7	183	16.7	29.9	13.2
2 < 4	7	190	17.4	31.0	13.6
2 > 6	7	197	18.2	32.2	14.0
3 < 11	7	204	18.9	33.3	14.4
4 < 7	7	211	19.7	34.5	14.8
4 > 11	7	218	20.5	35.6	15.2
5 < 8	7	225	21.2	36.8	15.6

Table 2.1 (continued) Pareto Optimal Table

Affinity Pair Driver	Frequency Sorted (Descending)	Cumulative Frequency	Cumulative Percent (Relation)	Cumulative Percent (Frequency)	Power
5 < 12	7	232	22.0	37.9	15.9
7 > 11	7	246	23.5	40.2	16.7
8 > 10	7	253	24.2	41.3	17.1
9 > 10	7	260	25.0	42.5	17.5
9 > 12	7	267	25.8	43.6	17.9
1 < 2	6	273	26.5	44.6	18.1
1 > 3	6	279	27.3	45.6	18.3
1 < 4	6	285	28.0	46.6	18.5
1 < 8	6	291	28.8	47.5	18.8
1 > 11	6	297	29.5	48.5	19.0
2 > 11	6	303	30.3	49.5	19.2
2 < 12	6	309	31.1	50.5	19.4
3 < 4	6	315	31.8	51.5	19.7
3 < 9	6	321	32.6	52.5	19.9
3 < 12	6	327	33.3	53.4	20.1
4 > 5	6	333	34.1	54.4	20.3
4 > 10	6	339	34.8	55.4	20.5
5 > 6	6	345	35.6	56.4	20.8
5 < 11	6	351	36.4	57.4	21.0
7 < 8	6	357	37.1	58.3	21.2
7 > 9	6	363	37.9	59.3	21.4
8 < 9	6	369	38.6	60.3	21.7
8 > 11	6	375	39.4	61.3	21.9
9 > 11	6	381	40.2	62.3	22.1
1 > 8	5	386	40.9	63.1	22.2
2 > 5	5	391	41.7	63.9	22.2
2 > 8	5	396	42.4	64.7	22.3
2 > 9	5	401	43.2	65.5	22.3
2 > 12	5	406	43.9	66.3	22.4

Table 2.1 (continued) Pareto Optimal Table

Affinity Pair Driver	Frequency Sorted (Descending)	Cumulative Frequency	Cumulative Percent (Relation)	Cumulative Percent (Frequency)	Power
3 > 4	5	411	44.7	67.2	22.5
3 > 9	5	421	46.2	68.8	22.6
3 > 10	5	426	47.0	69.6	22.6
4 > 12	5	431	47.7	70.4	22.7
5 < 6	5	436	48.5	71.2	22.8
6 > 10	5	441	49.2	72.1	22.8
6 < 11	5	446	50.0	72.9	22.9
7 > 8	5	451	50.8	73.7	22.9
8 < 11	5	456	51.5	74.5	23.0
8 < 12	5	461	52.3	75.3	23.1
11 < 12	5	466	53.0	76.1	23.1
1 > 2	4	470	53.8	76.8	23.0
1 < 11	4	474	54.5	77.5	22.9
1 < 12	4	478	55.3	78.1	22.8
2 < 9	4	482	56.1	78.8	22.7
3 > 6	4	486	56.8	79.4	22.6
3 > 11	4	490	57.6	80.1	22.5
4 < 5	4	494	58.3	80.7	22.4
4 < 12	4	498	59.1	81.4	22.3
5 > 11	4	502	59.8	82.0	22.2
6 > 11	4	506	60.6	82.7	22.1
6 > 12	4	510	61.4	83.3	22.0
7 < 9	4	514	62.1	84.0	21.9
8 > 9	4	518	62.9	84.6	21.8
8 > 12	4	522	63.6	85.3	21.7
9 < 11	4	526	64.4	85.9	21.6
1 < 3	3	529	65.2	86.4	21.3
1 > 4	3	532	65.9	86.9	21.0
1 < 9	3	535	66.7	87.4	20.8

Table 2.1 (continued) Pareto Optimal Table					
Affinity Pair Driver	Frequency Sorted (Descending)	Cumulative Frequency	Cumulative Percent (Relation)	Cumulative Percent (Frequency)	Power
1 > 12	3	538	67.4	87.9	20.5
2 > 4	3	541	68.2	88.4	20.2
2 < 6	3	544	68.9	88.9	19.9
2 < 8	3	547	69.7	89.4	19.7
3 < 10	3	550	70.5	89.9	19.4
4 < 9	3	553	71.2	90.4	19.1
5 > 8	3	556	72.0	90.8	18.9
5 < 10	3	559	72.7	91.3	18.6
6 > 9	3	562	73.5	91.8	18.3
6 < 10	3	565	74.2	92.3	18.1
6 < 12	3	568	75.0	92.8	17.8
10 < 12	3	571	75.8	93.3	17.5
11 > 12	3	574	76.5	93.8	17.3
1 < 5	2	576	77.3	94.1	16.8
2 < 3	2	578	78.0	94.4	16.4
2 < 5	2	580	78.8	94.8	16.0
2 < 11	2	582	79.5	95.1	15.6
3 > 8	2	584	80.3	95.4	15.1
4 < 6	2	586	81.1	95.8	14.7
4 > 8	2	588	81.8	96.1	14.3
4 < 11	2	590	82.6	96.4	13.8
6 > 7	2	592	83.3	96.7	13.4
6 > 8	2	594	84.1	97.1	13.0
9 < 12	2	596	84.8	97.4	12.5
10 > 11	2	598	85.6	97.7	12.1
10 > 12	2	600	86.4	98.0	11.7
1 < 6	1	601	87.1	98.2	11.1
1 < 10	1	602	87.9	98.4	10.5
2 < 10	1	603	88.6	98.5	9.9

Table 2.1 (continued) Pareto Optimal Table					
Affinity Pair Driver	Frequency Sorted (Descending)	Cumulative Frequency	Cumulative Percent (Relation)	Cumulative Percent (Frequency)	Power
3 < 5	1	604	89.4	98.7	9.3
4 > 7	1	606	90.9	99.0	8.1
5 > 7	1	607	91.7	99.2	7.5
5 > 9	1	608	92.4	99.3	6.9
5 > 12	1	609	93.2	99.5	6.3
7 < 12	1	610	93.9	99.7	5.7
8 < 10	1	611	94.7	99.8	5.1
9 < 10	1	612	95.5	100.0	4.5
1 > 7	0	612	96.2	100.0	3.8
2 > 7	0	612	97.0	100.0	3.0
3 > 7	0	612	97.7	100.0	2.3
4 < 10	0	612	98.5	100.0	1.5
7 < 10	0	612	99.2	100.0	0.8
7 < 11	0	612	100.0	100.0	0.0
Total Frequency	612	Equal Total Frequency	Equals 100%	Equals 100%	Power = E-D

Appendix D: Interactive Qualitative Analysis Stakeholder Focus Group Results

Stakeholders met in 14 focus groups to discuss their ideas about groundwater, in response to three questions:

- If you were to become a decision maker in this process, what would you like your desired future conditions of your aquifer to look like over the next 50 years?
- If you were a voting member of the group that makes the decision about the desired future conditions of the aquifer, what information would you like to have in order to make the decision?
- To you what are the implications of deciding the desired future condition of the aquifer?

The conversations were recorded and transcribed verbatim. The following paragraphs synthesize the comments, listed in quotes, into similar categories or elements, similar to the elements the decision makers identified. Each quote is paragraph combines people's voices from multiple views about similar topics into one voice. The Interactive Qualitative Analysis (IQA) methodology includes reporting focus group responses in this manner, which illustrates the commonality of viewpoints by combining them into what appears as one voice. An opening sentence in bold is extracted from the comments about that element which characterizes the dialogue. Raw transcripts are included for all focus groups.

IQA Stakeholder Participant Narratives: DFCs

Planning

Open space is not all waiting to be developed. Stakeholders recognize the need for *planning* and collaboration among interest groups, especially to encourage open-space and heritage preservation. "So something, some implications that the planners have to understand is that when people start paying more and they are not adequately prepared for that cost they will take it out on other entitiess that may not deserve it. But you are right though when you talk about water planning you get to talk about what people are eating. But I do not think we are going to be making decisions in this area or district that are going to cause people to not be beefeaters and shift over to eating chickens and pork instead of beef. I do not think we are going to achieve that goal, create an area of vegetarians I do not think that is coming. Planned development, that is right. And that should be taken under consideration when you start having a bunch of development also you look at the water situtation into the future. I would like my desired future conditions to be, to ensure that when I turn my faucet on I have water that in the middle of a drought, if possible, a severe drought, the drought of record I would like conditions, to manage conditions to at least try to influence the fact that I have some water during the drought of record. So what we have got to hope is that we stay in our normal weather patterns but you do not know what can be normal and the implications are if we get into a seven year drought everybody can get into a world of trouble but if it stays normal things are good but then people get to thinking there is plenty, there is plenty but then when the next drought comes you are back into a possible bad situation.

The desired future conditions, if I was king, would be a recognition that open space has value to water quality and water quantity and instead of all the incentives being to break up family lands there ought to be incentives to hold together. You can do that but if you want to have a sustainable, visible groundwater system then that has implications on growth and development and all that kind of thing and I think one of the implications is that probably needs to happen that is very political is to give the county the authority to do the planning in those areas that are outside municipalities, you all have planning and zoning commission and city council's that can orchestrate what your growth patterns are going to be and I think you guys are doing the core to dense rural outside which is good but in the county there is very limited ability that they have other than to set some standards, that says it cannot be more than this but otherwise it is pretty wide open game out there. I think that is something that the county and the groundwater district and the state legislature need to work together on. And then we would not be worried so much about where the water is going to come from for the next 50 years. So that would be my desired future condition, would be for an understanding among urban public that open space is not all waiting to be developed. There are some probably most who would like to keep their heritage intact. But instead are driven to break it up and pave it over, asphalt and rooftops because of development pressures, property taxes, and estate taxes. You fix those problems, the water problem is not going away but it is going to be alleviated a great deal. That has a whole lot different situation than having an entire county covered with rooftops and an entire county covered with well-stewarded cow-calf operations and good rangeland conditions. So somehow we have to figure out how we are going to keep the folks who in fact contribute water to the water budget to keep them doing that. That is on the supply end, and on the demand end, you have to reduce the demand and somehow all that will balance out. And the science, I mean you know how much water is in Canyon Lake, that is pretty easy. It is a little bit harder when you are trying to find out how much water is in the Hensell Sand and where the recharge comes from. Brush control, how much of our water do we waste on cedar and mesquite brush? All those programs have to be looked at as a whole, as part of this. We cannot just say , "OK, I always want there to be the same amount of water in the aquifer as there is today, end of story." No, that is just the beginning of the story. I would like for the amount to be at least what it is now, but I think we could have more. Our water levels in our aquifers could come up with some smart planning and it does not have to, development does not have to be thwarted in order to accomplish that. Now how are we going to do that and not tell ourselves that we are going to stagnate economic growth, that we cannot accept a new business into this area that has a water requirement for it. It has all got to be part of a plan. And if this an area of Texas that we can only allow so much sustainable growth we must face those facts.

Legal

People provided a brief discussion about *legal* issues and expressed confusion and conflicting views of the Rule of Capture. “You hit is right on the head, there is nothing more important than water. And that something that can be snuck away from you. The laws, the water laws, I have seen it I lived in states where if somebody has the water rights, you could have the water flowing right across your land and you could never take a bucket of it out because you did not have the water rights. And I do not quite understand the, the theory that these little water companies all over can drill holes and become a business, why do they think it is their water? You know it is, I do not know. I do not understand that. But then I do not understand Texas law the way that you do not have a conservation district that you can pump everything out that you want to, and I think that is one of the protections we have here, is that you cannot pump it out fast enough. As Willie Werner used to tell me that, that you'll never see a 12 or 24 inch well here because of the density of the aquifer.

I know that, if I may, and this is what I try to, I advocate when I am on the planning and zoning is, I will give an example, when we had water quality awards come in we had, I remember two gentlemen in particular, one we were going to have very strict water quality buffer zones, very big ones right? And one of the gentlemen came in and he said, "If you pass this water quality ordinance I am going to sue you because you are taking away 80 percent of my land and making 80 percent of my land undevelopable." And another gentlemen came in just a few minute later and he said, "If you do not pass this water quality ordinance I am going to sue you because my well water is going to go bad." And so I am not sure where I am going with this but it is a matter of there is a lot of competing demands out there, we want the water to be clean, we want folks to want to live here. I am finding that there is ways, I have friends and relatives who are using rainwater collection and they could use it to mitigate how much water they have to pull from the ground. We have monitors that are determining what is going into certain recharge features. In Hollywood Park there is a monitor there that quantifies how much water is making it in. There is a valve that opens and closes based on allowing that first flush where the alleged contaminants that could be coming in from runoff or passing by that recharge probably going to the one just down the street from it but the opportunity is there to say can we determine how much is going into the ground. I guess we would open ourselves up to lawsuits regarding when that valve should be opened or closed but that is a pipe dream we have, no pun intended, how much water could we recharge when we could push that button to allow more water in.”

Governance

Our reward is they sent Gary Eldridge out there to hassle me about property taxes.

Although *governance* in Groundwater Management Area 9 is primarily through groundwater conservation districts, other governing influences can impact people's attitudes. "I am thankful we have got the board that we have, I do not know them all that well but we have got the whole board back in and there was a bunch of them running. I think they were just running to pick a fight but they did not get in. But now because there is a district and a person in charge of gathering that information and putting it together where it makes sense we are starting to see a lot of good information where you can actually go to a map and say in this area it is proven there is water and in this area it is proven there is not much water. Well so far they have made good decisions. I have not paid that good attention but it is something, that water is going to be a big factor for us. When everybody, I wanted zone watering, if you are going to water, this zone waters then this zone waters, do not put River Hills and Comanche Trace at the same time because they are professional water users or over off of West Bluff, they have got the greenest yards. But I think you would have to look at what long term, where are they going to be putting subdivisions and there would have to be some type of changes in the ordinances to be more conservation minded where, these people will use, and if you know they are going to be using this many gallons per connection that would help you make your decision because you have to start looking for alternate sources or more surface water rights. And there is some way to control the waste. A number of years back after I retired from Department of Highways, I worked for the county for a while doing addressing and I was all over the county. And it just burned me up when I went out to Tapatio Springs, a pretty golf course, it was in the middle of a drought, fourth of July weather, and here there was a pipe that big pumping water into the pond just so it looks pretty. That is just one of so many that are doing that. And I was worried about having water for my livestock. Like a golf course is a good example. You cannot put in four golf courses and expect to irrigate them. Where are you going to get that water? You have got to find out what people start demanding a large amount of water where are you going to get it from and what is it going to do to the existing aquifer? And the volume, that is a big thing. Just like in San Antonio, come in there and they built three or four new golf courses that are going to be the most wonderful place to play golf in the world and they could do that here, but you had better find out where is the water going to come from. That is the only thing I say, you had better know where it comes from. It is just that right now with the economy like it is, with development in place, there is nothing happening but as times improve I am sure that there will more development in this area and that is one way of limiting what can be done as to what the water will support. Equilibrium more than anything else.

Your comment about wealthy people reminded me of a true story, it happened several years ago. I think it kind of points out some problems with one area and one conservation district and another area and another conservation district and they do not always do things equally. A wealth guy bought a ranch that bordered Kerr and I believe it was Kendall if my memory serves me, I cannot remember the counties anyway. He came to

Headwaters, Kerr County and he wanted a surface pond, fishing pond, something wanted a well to fill this and keep it full. And they turned him down, and said no too much evaporation loss, that is a waste. Well, he moved it over to the other county's side, and they agreed, and he drilled his well. So there really needs to be some mutual agreement on how we regulate our groundwater. The county regulations require now that test wells and monitor wells be provided on developed areas and if it shows that there is only enough to support a house every 5 acres, or every 10 acres, or every 100 acres, then that is what is allowed to be developed. And that is in place and that needs to be enforced and it is. Monitor wells. We have monitor wells, what they are is old municipal wells, they used to produce water and now they do not and we just use them as monitor wells. They are all into the same aquifer, the Lower Trinity, the Hosston, and we take readings and that gives us an idea and that is good to have. You have got to have the production usage, how much are they going to use. I think it preserves the water for our future. But one of the things that I have always campaigned for that as we are going to have more residential development we should require the developers to be doing rainwater capture, rainwater use, rainwater harvesting. But we have so many other factors such as irrigating, landscaping and we really do have to look at regulating that sort of thing. El Paso is going that way already of course they are in a worse situation than we are but the reuse of water, are we going to put our water reuse system in effect. Are we going to actually do that?

So I would like to see, I do not really want to sound like a big-government guy but I would like to see some rules put in place that are understanding of how Texas, this area is different than a lot of folks who have come from California or the northeast where water is in abundance and they put these thirsty plants in. So there is I would like to see somehow some more professionals who know how to negotiate with some of these developers and I think Dripping is getting better at it and a lot of people, folks say they have done a good job, I think that because they did not know what they were doing at the beginning, I think they have learned a lot of lessons. I am concerned when you see these guys come in and that is what they are paid to do, they are paid to go from community to community to community to promote the interest of their businesses. So I would like some coordination, and in terms of protecting where I want my aquifer to be I would like to have better coordination between city, county, and state governments to somehow making sure we understand what we are doing. I see it as very complex. But I think if we do not do that we are going to start getting dirtier aquifers even if we do get aquifers that are at an OK level. I know Scott Roberts at the Salt Lick, he is going to use rainwater collection on all his houses he puts in there but he is going to use well water to water some new vinyards he is going to be putting in, and he is also, this is something that we would see, he is going to be pumping and feeding his vinyards when we get another drought and he made an agreement with them, if you get a drought whatever the municipality or the government organization will be he has agreed to shut off that water to his vinyards during those periods when a drought has been declared, and what I would like to do is as we work with individuals and new developments coming in that are wanting to use well water we have rules that are put into place. If we get into a drought condition, what measures do you take, what measures do you have to take that can be regulating mainly not as an incentives as much but as a regulation saying "You need to shut this down, your vinyards may die." But I do not know yet, but I would like to see something that when we get to those the points. I do not think we should allow people to be doing new developments in this area without including rainwater harvesting capability. We have got to start conserving more water. Well that kind of goes back, way back there people used rainwater because that was the cheapest way we knew how to do it. It is hard to do that when you are a private individual that bought this house that you are barely able to afford and then you are going to put in $50,000 worth of improvements so that you can use rainwater? You cannot do that, there is no dinero for that, the water is too cheap to buy, you cannot afford to do that. I think the developers ought to be, they should be required to do that when they are developing the property. And it might come to a time when it would be a requirement for builders to put in a rainwater system.I cannot understand, well I can understand very well why it is not done, it is not lucrative to developers and they do not want it but I wish we could require that.And I think that we run a real risk of that by not having an active district where the developers have got full opportunity to move ahead. But I just think that we have got to know more and somehow protect the people living here. This is our water and I do not think we even want to think about selling this water. If it would be possible to allow anybody to ship water out of this county, this water district or whatever, then I think that somehow you have got to control these big high-volume wells. And from 1960 to now we are down from a water level of about 125 feet to about 170 feet so my family has in effect donated almost 50 feet of water to the growth of Kendall County and our reward is they sent Gary Eldridge out there to hassle me about property taxes.

Uncertainty

They would do anything. Despite all the unknowns and *uncertainty* in the groundwater planning process, population increase seems to be the biggest factor seen as derailing local plans. Development is seen as a driving factor in how the area has changed over the past few decades and in the way the area will emerge over the next 50 years. “There are a lot of unknown factors that have to be dealt with but if there is a way to figure out how much population can be sustained here and what kind of population and we need to make sure that we do not ever go over that point. In the longer range it is going to have to do with is there going to be a place for my children and grandchildren to live here. And not just here, the water goes down if you share it. If they figure out a way to pump out more water, San Antonio is sitting there just dying to have more water, they would do anything. And we come along and dig for water, we had the equipment that would dig for and now it is getting expensive. Let us say Randy and Doug and me, we were looking for the Cow Creek. I drilled 505 feet I think the driller run out of stem and quit. The driller said it was at the Cow Creek. The more I think about it the more I doubt that. I think we have the Cow Creek Formation down there and like he said, what is below that? There are lots of studies to know what is underground. It is hard to know what is down there. They do not know what is down there. They have done lots of studies and they know more every year but they still do not know how to find that. Go back to the way, going back in circles, who knows if we find something else that takes the place of water, we do not know

People's belief that conservation efforts work and are going to be successful might bring more positive outcomes. "Are we going to keep our bays and things like that? I doubt that people are very hopeful, as they should be, unless you have experienced changes that have been created at Bamberger Ranch, you may not feel that progressive efforts can be very successful, but if you look at the further you look, the more reason you would find to be optimistic about the good results that you have. If you are just looking locally I think that you have to be pretty jaded and tend to focus on other efforts that we have made that have failed, if you cannot have a bigger horizon that can see all that can be done. Just like an oil well, they are getting down, they drill so far down they they have ever before, there might be water there, who knows? They are studying all this stuff, 50 years from now makes a lot of difference. I really think that in my opinion we will do most of our work from underground than from surface water. Surface water, we will catch surface water and we will put in underground because it costs too much to put surface things up, buy the land, put up the dam, fill the lakes so it can go back underground and then come out."

Water Uses

Well, no damn wonder there is not any water. Having a green lawn becomes an un-neighborly action when it comes to gauging the best use of groundwater, conservation is seen as the primary solution. *Water uses* includes agriculture, livestock watering, commercial or industrial, municipal and domestic use, recreational and environmental. "We will have to find better ways to conserve water and to replace water with what we think we have to have. This is going to have tremendous implications as far as development, it is going to have implications as far as highways, it is going to have implications as far as water useage, what people can do with water commercially and individually. And those streams and the ability to have water available for recreation, for wildlife, and just for the simple beauty of that stream or creek or whatever it is, is really important, I think, to this area because we are a colony around here first of all that is pretty heavily dependent upon tourism. And that is one of the things that attracts people to this area is that concept of water and the naturalness of the area and so forth. I think we have to be real careful about overuse of the aquifer. I would want to encourage more rainwater systems to conserve what falls, educate people how to use a well, and not so much irrigation. I am strongly for year-around conservation measures where here in the city they cannot run sprinklers between the hours of 10 am and 6 pm because you have 50 percent evaporation rate on a hot, dry, sunny, windy day and so you are just are wasting the water. That is going to have to do with who can plant what in their yard. A big part of the water, particularly in the cities is used for lawn irrigation. I would certainly agree and I think conservation is a very important part and I would look towards education. In fact I think probably the future of our aquifers in the 9 through12 year olds are going to school today. We need to teach those people conservation. Because quite honestly we are not going to change some of the gray-haired folks around here. And to have a future in 50 years or whenever we have got to look towards the kids and I quite honestly was a little disappointed. I made personally an attempt to try to get KISD to do more, I am not sure what they do because I do not have kids in this area, I moved to this area long after my kids were born. But I did not get much of a reception. And I think that is a real shame. And I know UGRA and I think Texas Water Development Board put together Major Rivers, are you familiar with that? Well I do not know how well it works, but hey it is something, and I do not know if it is used or not. I have a teacher in the neighborhood that teaches in an elementary school and she is not too aware of it so, anyway that is my spin."

A variety of sources and conservation practices, even on an individual level can make a difference. "My wife has 8- 1 3/4 acres in the yard but she only waters a little bit of it. It is going to have to do with golf courses.I am concerned about recreational water use…I think that it is important that we have it, recreational water. Where does the water come from, if you do not utilize the rainwater. If you put the rainwater in lakes and let it evaporate from huge surface there will not be, we will not have the water. And it just actually started flowing here a few months ago when it got back into a normal rain pattern but even then the supply from Canyon Lake, with all the straws they have pulling out of it, they were getting a little concerned there would be enough to cover everything that they had promised to people that had access to the lake water. And, too, so many people think there is endless water in that lake I think. We will be dealing with water from desalination, pumped up from the Gulf, that is expensive. Quit poking all those holes, in other words. But it is scary to me to think that they might come up with a way to draw more water out of our aquifer and if they do that and you see them start pumping water like the catfish farms, you know, then you have got a scary situtation. And they could do it someday, there are all sorts of new ideas and new things coming up they might a way to drill a 24-inch well and drop down some sort of explosives or something other to open that up, that is what is scary. Because they could take a lot of water fast out of here. And I think that, like I heard one story by Boerne a woman lost her well. A local water company drilled a deeper well next to her and started pumping it and her well went dry. They said "...the problem was that your well was too shallow." Well that is not the problem, the problem was that they drilled a new well. They should have served her with water or drilled her a new well or done something. She did not have a problem intil they started drilling. I think they have to take consideration of the existing users. Anyway, this last year I have got a tank over at the Grasstown, and it was drilled at 400 and something feet, and the pump was set at 300 feet and I ran out of water last year. So I got them in, they went in and lowered the pump to 390 feet and I have had plenty of water since, but I know that at the house if we pump too much, we try to water the grass or get out there with two or three sprinkler, it would run that well dry and take it overnight to recover. And I think that I could remember a few years ago where we had a problem in the eastern part of the county where they were first opening up that big expensive subdivision over there that they were getting as little as two gallons per minute out of wells that they were drilling. And if you get down to that, and I have been there on an old windmill well, where you cannot fill a stock tank, you just keep sucking air. I mean people do not realize yet what a problem. The thing that concerns me too, like where I live on a hill we have a well and the more people that come in, I am concerned about wasting the water and stuff like that, too. If we improve our well whatever we use water like your bath water, we have to ge off that way and get rid of the what I call using all the water we have been using. And that is why I say that we have got to pay attention to anybody who gets ideas about moving water out of here out from under us somewhere else. Nobody has thought about it yet, I have talked to different ones and it would not be hard to if you figure out a way to drill a big old hole here, and pump it out here, and pump it into the river and take it out down Canyon Lake, you already have got a pipeline. I mean that is the pipeline right there, the Guadalupe River and I think they have to be very cautious of new people and coming in and wanting high volumes of water and subdivisions, multi-houses in subdivision, you know Falling Waters and Reserve are not going to hurt you, there are not that many people living there. But you start to see some around San Antonio and even Boerne. There are some pretty tight places where they put four or five or six places on an acre of land."

Golf courses tended to be disparaged as big water users. "I like to say too, you have got to watch these golf courses, they tell me that 50 percent of the water in San Antonio goes for landscaping and that includes golf courses. Well, no damn wonder there is not any water. Fifty percent of all the water used is landscape water and that is a waste. We are going to have to take what we use drinking water for, find other ways, what we use water for now and get rid of some. Well a lot of that depends too, I mean if you are going to have development like is developed around San Antonio over this part of the Hill Country where we are going to spend or use what is 60 percent or 70 percent of the water on Saint Augustine grass? I would like to see it remain the same or increase through either artificial injection of treated surface water or possibly more impoundment dams in our recharge area to artificially fill it instead of waiting for rain and through conservation measures whether it be restricting what type of grasses the elimination of St.Augustine and the golf course grasses in the yards. Comanche Trace is sitting pretty over there because they get to water their greens out of the river when the rest of us are rationed. With land use before any of these larger tracts are developed, I guess it would need to be proven what the land will support. If you had people building houses like they build out there in Santa Fe, you could probably have a lot more growth. I am not anti-growth, growth is good. What frustrates me is that, and I agree that science, and I also agree that I think that the East case is probably correct where it described groundwater as mysterious and occult".

Natural Environs

Rivers that no longer exist. Groundwater systems are only visible at the surface as springflow, but when people look at rivers and the *natural environs,* they have a well-developed sense of how much water Texas has each year as we pass through annual rainfall cycles. They are also concerned about having good water quality. "Yes, the thing that I think too, that we need to recall is that this does have implications on where the area is going and the growth patterns that we are going to have because with the sustainability of the aquifer and if we want to have a flowing steams and that sort of thing that means that there is a certain percentage of the aquifer that is above the point where the streams actually work, you can suck the aquifer down, the creeks will stop flowing the springs will not flow but there will still be water in the aquifer. Problem-wise in fact that it probably goes back in slow, so if you get a high volume of rain you lose that rain going downstream because the aquifer will not absorb it. Now I am only guessing that but if it comes out slow it is going to go in slow. How much is being drawed right now, what is projected to be drawn out of it, also based on the climate conditions of what the recharge is going to be of the aquifer. So check the goes in and goes out and see and try to compare the history and see what is happening to the aqufier. If it starting to decline and nothing more is being drawn out then you have got a problem with the aquifer, it might be migrating somewhere so you need to check the goes in and goes out, it gets back to the equilibrium situtation again trying to measure what the future draws are going to be on the thing and what all can be supplied."

You could probably park a car in there sideways. Legendary droughts and aquifers were not just hyperbole to these people. "Another thing people have to realize is the droughts. I am 75 years old, and I well remember the 50's drought and we have had quite a few droughts in the last 10-20 years. And in those days too you put in a windmill and it pumped 2-3 gallons a minute and that was all it would do, as fast as the wind blew. You would not use much water then. I am much more concerned about environmental quality, maintaining springs. Now I know the Cow Creek bottoms out or comes out down at Spring Branch Meadows, down Spring Branch Road had a well there that is artesian, or was, at the McAllister Ranch down off Spring Branch Road. Spring Branch Creek starts on their place and that spring there, which is Cow Creek water, is tremendous, I mean you would not believe you could probably park a car in there sideways and it would not block it off. You could actually walk into the caverns. I went in there 50's, during the drought of the 50's and it was something to see then. We sat down there, to get a drink of water, to see all that water. And some of the cedar problems that would need to be adressed in some areas in Blanco County. Yes, I have cleared the cedar several times on my place and in fact I have to go back again. But I noticed, Turkey Creek runs through my place, and I have noticed the difference in the amount of water in that creek because of the cedar clearing I have done. But the cedar is just getting out of control in other areas and if there could be some more money available for cost share programs on cedar eradication it has been shown that does a lot toward generating the springs coming back, the creeks flowing, it is one of the quickest and easiest ways to generate more water for the aquifers. There are also issues for the aquifer, as it pertains to supplying water downstream and I think those things are important. Well they also do not realize too there are going to be problems coming down the road where they cannot take all the water out they want because there are going to be some federal rules on making it go downstream to serve the whooping crane population to fall and consequently you are going to find that those people are going to have the law on their side over and above people, just like the Edwards did, when they said you got to have enough water to keep these springs flowing are going to see the same thing in Canyon Lake if they say you cannot draw more water out of here for San Antonio Bay. And that is what people do not understand. Also in Rebecca Creek, to the west where the golf ball is, go back in there to the creek and that was the same kind of a spring there, started at the creek there. They would not let, I do not know, the Texas Commission on Environmental Quality would not let them use the water out of the spring for public water system, so Charly Keun, a well driller went about 100 feet upstream and drilled a hole down to the spring and that is their water system. Well McAllister did the same thing, they went upstream and sunk an irrigation well."

A misconception around here is that when it rains aquifers fill up, whoopee. Aquifers can be a source of misconceptions and clearly understood issues. "Most people do not care until they have a problem themself when they cannot get a bucket of water then they will care. It really never bothered me until my pump went dry, until I could not water my goats. Then you worry about it, you say what are you going to do when you do not have enough water to water your livestock. The bay, fisheries and the estuaries at the Gulf Coast suffer, I think you need to look at that whole picture, what is going to bring the largest population increase. Now I think our area could, the water that we have here comes more from some other area of Texas than this right here. In other words its a flow underneath from way off. Well you have got, what they talk about now is the Edwards-Trinity or the Upper Trinity and the Edwards Aquifer, the Edwards in Bexar County is totally different from the Edwards up here. There is a fault, the Edwards up here is just really basically mostly groundwater, you know what falls and mostly goes along the river. But there is a fault near San Antonio, well I do not know if it a crack or a fault, where in fact they do end up with a lot of water down there which we do not have up here. Up here we talk about the Edwards-Trinity sort of as one issue because it is porous but then you have the middle Trinity that is a contained aquifer that is a hole in the ground that, that is an oversimplification, is it not? The middle Trinity and below that you have the lower Trinity. When it rains, a misconception around here is that when it rains aquifers fill up, whoopee, but that is not what happens. When it rains here in Kerr County you get recharge, you get the Edwards, the upper levels get some, the rest of it runs off into the rivers, so it does not sink down in the middle and lower Trinity, it runs of to the southeast of us. When we drive around Texas one of the things that we see are rivers that no longer exist and when you look at history you can see that probably the same thing is going to happen to our area. When I say what I would like to see in my aquifer, I am not sure in 50 years that I should be saying that I would like to see my aquifer full, because you know that is like pie in the sky. I am saying that it would be absolutely unacceptable for the the aquifer to be depleted, or the protected species are not protected or that the springs do not flow, I think that is absolutely unacceptable."

"What I would like to see, the future condition I would like to see for our aquifer and our groundwater is that the quality, you got to always think about quality, so I would like the quality to be at least as good as it is now. You get less of a good quality water the lower the water levels drop and other people have to end up lowering their pumps or redrilling because you are pulling down the whole aquifer level. And the other thing is too you might drill another well but then you have got bad tasting water, bad smelling water, bad hardness, I mean you cannot wash in it.Well I think we can all agree with what you said, we want the quality and the level."

Political

Our boards are popularity contests or wealth contests. *Political* races and actions are a big part of Texas history, including groundwater management and not much has changed over the years. People expressed concern over the development forces in a relatively dry area. "Before Texas became part of the United States it was a huge cattle operatation and I know there were huge fights over the water. I am concerned that same scenario will happen again and we will not be prepared for it. I mean people who have investments in other than the land itself in any county. And I think it is the same with politics anywhere, with decision makers anywhere. They do try to affect decisions and I think you have to take those people into account, those industries into account, those kinds of things. Because I feel that a lot of times our boards are popularity contests or wealth contests, and I do not have much faith in those as you can see by my ranking. I think the biggest misconception is you see the mindset with individual pumping rights is that, and I have heard one of the Headwaters Groundwater District Board members say this in his seat on the Board, that the water belongs to "he who sits on top of it." So as long as we have that mindset, people can develop and dig their wells and have their vanity ponds and claim that is their right. I think you have to have the input from the landowners. I think that if you do not start there before you start making decisions it does not really matter in Comal County what you say because if they are not into it it is not happening. And then we have not talked about all the conflict that come from when you have a water shortage, you do not have enough water, where people killing each other over water like you have people killing each other over oil. That is another thing, I think that Kendall ought to consider like Kerr, do not ship any water out of this county. Kerr County has a rule that you cannot ship any water out of the county. Up there at Falling Waters, they have got two wells, did you know that? They have got one that is in Kerr County, and because they had some land in Kendall County they had to drill another one down below to furnish the lots in Kendall County, because Kerr, the law says it cannot be shipped out across that county line, and I think Kendall County should do the same thing. Protect your water that you have got here because otherwise some sneaky San Antonio or somebody is going to come along and buy up. Now I know that there are some people that sold their water rights out of the river to people in San Antonio. And when it comes down to it, your best friend, you do not know him until it comes to money. Most of the land out there is not really suitable for more residential development and it is the economics that are forcing people into selling property, they do not develop it but somebody else will, who, that is their business. But their are just in business to make money. Yes, I see people, it is a, it has been used in Kerr County as a scare tactic forever. I have been at meetings and when a developer or a big financier, when they want to threaten the commissioners, or the board members, whether it is UGRA or Headwaters, or whoever, they bring up the meter issue and I have yet to hear at any meeting any body talk about...They come in, the real estate people threaten them, if you want to charge us, complicate things for public water supplies, then we will just tell everybody to drill their own well so you have got 100 people out here with 100 plots of land drilling 100 wells where you do not have any control. Realtors do that. If the conditions were there they could do that in a different more orderly manner more efficient use of resources. We are not one to stop growth, but we do need to channel it. And we need to get over this idea that the ideal is this five or ten acre tract of land with one house on it sitting out in a endless row of subdivisions across the hills. We need to accept a idea that growth should be more channeled, more intense, denser, and in certain areas leaving more of the other areas that are not really suitable for it to be kept natural. I am a big believer that there are, that our regulations are actually disincentives right now for what we need to be focusing on, the direction that we need to be going with growth, and that is my business is advising those kind of people. Would you like incentives? There is a rule that you end up having police regulators come in and say, "you are breaking the rules" and you get fined, but if there were incentives saying here is an incentive that you will get a tax rebate or something like this say if you put in a rainwater collection system or if you do water conservation and some xeriscaping. I think incentives are easier to handle by the public instead of rules, rules are meant to be broken. And a lot of times rules were made for not really hammered on people but more of a we would like you to follow this rule. But if you have an incentive and you see some tax savings or money savings you might be more willing to work within those incentives or within those rules of the incentives, something like that. I think a rule is somewhat harsh especially when you are talking about your own private well. You know you are trying to rule me as to what I do with my water, but if I have an incentive, well I will look at it a little different. So I think incentives are much better than a rule or an ordinance or something like that. And I will tell you we went to Kendall County, there is very little of Kendall County that is really suitable for more residential development away from the currently developed areas. We do not have the infrastructure, we do not have the resources it is going to be far too expensive. The water is either not available or scarcely available. To get water brought to those areas it is just, it is silly to waste money building pipeline to areas that do not really need them when we have pipelines and water infrastructure in areas that can be developed. And I think that the development industry, if you direct them someplace, if you show them that development is capable and it is facilitated in this area that is where they will go because the land price is really not the determining factor for that, it is the developed land price, what does it cost in the end to deliver developed land. But the price component has got to drive the political will to work on the solutions."

Data/Technology

What is the aquifer doing? Stakeholders felt that they needed all the available *data/technology* to make decisions about groundwater. They specified different types of relevant information necessary, including population projections, hydraulic properties, aquifer levels through well measurements, economics, case studies of effective land management and water management, models, mathematical inputs, hydraulic connectivity, and groundwater availability. “I want all the data I could get. We really, I feel like, lack for the hard data for how thick is the aquifer, how many aquifers, how do the aquifers that we do have communicate, why is the affect on his well, why have they dropped, because it is not as he says development in his area, where is that water going? How much water is used, who uses it, and where it goes. Or has it just been naturally a drier period since then. Of course, so if you are talking about the sixties, you just came off the drought of record it should of been a relatively historically low level then so I would have to go along with your assumption although I am not a scientist that it has gone somewhere. Currently we are doing an ASR project, we have been doing it since 1990, and under the city it is artificially raised because it displaces the native groundwater. We take measurements of the aquifer every day in certain areas and all of our wells on twice a month, monitor, and we can see changes when some outside the city are using their wells because everything to the northwest of us travels to the southeast. We can see when it is pulled down and I know we affect people outside the city when we kick on everything we have. I think I would like to see the latest scientific data, I do not want something that is years old or hydrogeologist or somebody say, "well I think this is what we have." One of the pieces of information that is really missing in all the modeling is the actual water use of the exempt wells. That it is a big missing number. They are making assumptions of usually around 300 gallons per day per well. I think it is 350, something like that in the modeling process, but there are a lot of folks that do not use that much and or there could be a lot of folks that use a lot more. And I think one of the points of information that would be very helpful in the modeling process, and I agree that the modeling is one of the key things to make this all work is to get an adequate sample of the exempt wells by actually going out and putting meters on those exempt wells on a voluntary basis for folks that want to provide that information to the groundwater district or whoever it is that operates that model and put those meters on those exempt wells in a random fashion so that it can be statistically valid. There probably needs to be a sample of somewhere around 5 to 6 to 8 percent of the exempt wells that could be randomly selected and metered and recorded on a monthly basis. And would provide a world of statistically valid data to the modeling process. I think that would be a great benefit to help us decide on our desired future conditions.I want more detailed study of the particular aquifer, be able to have that aquifer be sustainable for additional growth.” “But how do you get the money, how do you get this information? Test wells is a step in the right direction, maybe more test wells, more monitoring wells and get a better picture of the aquifer. And it takes the monitoring wells and means to get the scientific information but you cannot make decisions without that scientific information. So I think the geological information would be real helpful. We need more geological information to understand where the fault lines where the recharge areas are what areas of the county actually have water and which areas do not. And I am a believer that we have different pockets or different amounts of water throughout the Kendall County, if we could just find out how these pockets are and that type of thing. Our recharge in the middle Trinity we are fairly sure comes from, y'all correct me if I am wrong, comes from up around

Llano and comes from the northwest, from way, many miles away and it takes many years sometimes for it to trickle down this way but the lower Trinity they do not know, that is really old water, and they do not know really how that gets recharged or if it does get recharged. So what has happened with all this rain we have had is the river is better, it is not back to full running capacity but it is better. And wells that are in the Edwards Trinity, Edwards Trinity or Upper Trinity are doing better but the levels in the middle and lower Trinity have not improved that much. If you graphed it out it has been steady downhill and we have had some improvement but not much in the Trinity's, middle and lower Trinity. One of the things that you find in this country is different strata, I will not say stratas of water, but different amounts of water, particularly in the Lower Glen Rose. For example up here at Landings Crossing, it is about three miles out of town on the east side of 281, and up on the south side of Landings Crossing, water is normally around the Blanco area, limited to about 5 gallons a minute, 10 gallons a minute, or maybe 15, but then as you go north, and it is only about one-half a mile wide north and south, you start getting into wells that produce 60-65 gallons of water a minute. I gave five well logs of wells we drilled, I was a surveyor and engineer, to the newspaper man he published them in the paper. He caught all kinds of flack, called him all kinds of name, he told me "I will not do that again." And we are finding that information. It is starting to filter in from the water district because of the monitoring wells, more information is being compiled. Every time a new well is drilled, plot that information as to what formations they went through and how deep and how much water. Have you seen what Ron got accumulated? He is generating a lot of information but there is still a lot of blank areas there that he does not know anything about. The science I think is there, the science will always be refined better as we go along if we care to study it. And in this particular area there has been a real movement, over the last 5-6 years to study the aquifer more intensly and folks have done a pretty good job coming up with some answers but you know the science is never going to be complete it is always going to be evolving and so to me the thing that is key is to have the aquifer sustainable for this current set of users and future users who may need the aquifer. And water has always…developed or caused the development, it was rivers in the beginning or you would go where you have water. Well, it has been shown in this last, we have really just come off a two year drought,and one little shallow well that I have, basically it is 60 feet, it is basically backed up from the river, when the city drains the reservoir, that well gets really, really weak but as soon as it started raining and the river filled up it all came back. And for the future development and to help control that development I think we must have this information. Changing the mindset too, it was easy to drive around last year and see who had the greenest yard and knew who was watering and who was not. I am interested in permeability how much non-permeable groundcover is there versus permeable groundcoverand how much are we actually getting into the ground versus what is running downstream to Corpus and not being utilized here. But it is scientific information. In the past there was not anything like that put together. The well drillers did a well log it was sent to Austin and put in a file and that was probably the last time it was ever seen. I would want to know all about population, I would like to know about the parcels of land. I would be interested in examples of places where certain land management approaches and water harvesting approaches have been effective. I think it has got to be driven by better science, you have got to know more what is in the aquifer, how fast the aquifer recharges, and what the demands are on it. I have always thought that this whole idea of exempt domestic wells was just kind of a gaping hole in the planning. You cannot…we are always going to have these exempt there may not be room for that. But I think it has got to be science-driven first and that is where I have seen that there has been the biggest gap. You are asking somebody to plan on what desired future conditions are it is really kind of an incomplete idea of what they have now or what is likely to be there in the future based off of just the natural occurence.. I would also want to hear the anticipated economic results of different approaches while I say that I do not want that to govern my decision too much I would certainly want to know that because for one thing I might find the economic support for a environmentally directed approach that over the long run if this is a, this area has ample water and is a wonderful place to live in the long run that is going to pay off financial dividends in the long term picture. I would also like to have a lot of information from other geographical areas in the state and out of the state, what has worked elsewhere. I would like to know about how many wells there were, I would like to know about the aquifer itself. Thanks to record keeping now and the Texas Water Development Board and people, where you get information on wells that will be, that we can maybe in the future model better you can put all those wells in and water depth. The only one things I have got to say about that is most of these well drillers drill a lot better well that what actually turns out to be from the amount of water and 25, 35 gallons a minute and it turns out to be 15, when they first pump it that is where they get that information I do not doubt their word but a short time later it will not be producing that. Right, just like he just said, you need to know first of all, what is the aquifer doing? In studying the formations, right now we have got Upper Glen Rose, and in my place incidently there is a 20 foot layer of gypsum from 200 to 220 feet in the Lower Glen Rose, and somewhere down there in a lot of cases is the Cow Creek. You know you have got different levels of aquifers. I think like back before in the 50's you thought you had to go about 250 feet, that was about as far as you could go with a cable rig, that is where our water was and you would get 2-3 gallons. Now with different types of equipment you can go 500-600 feet and now we get 50 gallons of water in most places. I know that in where I live you have got a one level at 210 feet and you've got another level at 200 or 340 feet I think it is. And you need to find out, you know, what is the average level of that aquifer? And you need to know, you know, how much are we using and how much are we putting back in, is that level going up or going down? You need to find out the history, whether if you are drawing water from a different area like you are talking about, you know, is this water coming from Junction, is it coming from. You have got to find out how much available water do we have? We do not have an infinite availability of water here. You cannot draw all the water you want in the whole world out of here, and that is what you gotta find out, is what...how much is available? I agree it is hard to argue with good scientific defensible data that is wide open for the public and it is easy to understand for your average lay person maybe that is coming in from Nebraska and wants to move to the Hill Country.

They understand that it is not a financially driven decison it is not a greed driven decision, it is a scientific "we do not have enough water, groundwater resources to support certain development. That simplifies the conservation a little bit, instead of a lot of finger-pointing, it is one of those hard things to figure out though. If we do not then we probably run out, is the implication, if they do not know what is going to happen. I have got no problem with telling the guy that wants to move from Nebraska to build out here, fine, build out here, but you are going to have to put in a rainwater catchment system and live off of that because we have tapped out the groundwater permits for this area and you are not going to get a groundwater well. But if you want to go out there and live on a rainwater harvesting system it is perfectly acceptable, go ahead and do it! I would like any kind of models that I could rely upon since I have built some models of other things I am somewhat suspect of models so I would want to know all about how it came. I would want to know the math to it, and I would want to know how to do it. But you know I mean the water comes from different areas than what is right here. That's something I think they need to do some testing on, to find out because the thing that worries me most about the people that want to draw all the water they can out is that if we start using antique water that's water that was put in years and years and years ago, you know, its going to have an effect on the future. You cannot take it out if you cannot put it back in fast enough. I think carrying capacity is something that is critical and when you start bringing in natural resources because you cannot provide them with what currently existing I think that speaks volumes or maybe you could use like a mass balance approach, how much is coming in and how much is leaving information you need more of I would think to make those educated decisions as long as the bottom line is money. You are working towards an ubanized area."

Costs

Go right ahead, because our bar tab is bigger than that. Stakeholders seemed aware of the *costs* associated with groundwater use, and the implications of the relative health of the economy and socio-economic factors for affecting people's choices on water use and groundwater management. Although groundwater for many people in the Hill Country was not represented as a monthly bill, they understood that there were other components of the system that might necessitate factoring in the value of groundwater. "So I guess that I want a conservative approach but I think we have to be pragmatic in the approach also because what you are going to have to marry into this to see any ultimate success with any of it is the ability not only to sustain the aquifer you have got to find some way to sustain the economic system that is on top of the ground it is going to help you accomplish things for the aquifer, for the area and what would be good and reasonable and sustainable growth. I think the back door to conservation is expense. I think water is too cheap. We do not conserve things that are too cheap. Piece of plastic, a piece of paper, we throw it away, and get another one. If water was more expensive I think we would have a lot better argument for conservation. The rates, and I have spoken about this to the city council, the rates are entirely too cheap. They need to be, the rate structure needs to be, I know right now if you use 1-1000 gallons it is a penny a gallon or something and once you go over 1,000-2,000 maybe it is 2 pennies a gallon. Well, once you cross that boundary, all your water should be at that higher rate, not just that portion that went over the 1,000 gallons. So the guys that are really using it, they get socked in the bank. But yet, you can set it low enough that small families or fixed income families can live within that budget of water and it does not cost an arm and a leg but big users they get slammed. So I think you have got to make expensive and I know that is not really a tool per se but it is I think really key to conservation. A few years ago in 2004 the city went to a tiered system to where the more you used the higher you paid a rate and you conserve you pay a lot less, and they did not do as strict of a system as some communities. The city of Kerrville had cheap rates, I mean Aqua Texas has some expensive rates and I will bet you they do not have near the abuse and use that the city does because there are some people, they will spend, private individuals $1100-1200 a month on water because they can. And there is not really that big a penalty to them for that. They could change the upper tiers to where when you get up to more than a 100,000 gallons a month and you are just a homeowner then it may have to increase that or the percentages. You are right, in conservation you have to hit them in the pocketbook. I know that people who disregard, I have had people who will tell me when we have written courtesy notices will say, "Go right ahead, because our bar tab is bigger than that." They do not care. You get over to River Hills or Comanche Trace and they will just look at you and keep right on watering. Economics will dictate whether or not, we know how much we have locally, these are our resources. Then if you want to grow beyond that point then you are going to have to have some sort of additional water source and that is an economic decision as to whether or not you can do that. I think there are economic implications, we are going to have to do something about electricity, the way we produce electricity there may not be electricity anymore the way we are producing it and we are beginning to look at those kinds of wind generators instead of water generated plants and things like that. And this is a very rich area and there are a lot of millionaires, we even have a billionaire living between here and Bandera and so they can come in and they can drill the $75,000 to $100,000 well that will pump the 1,000 gallon a minute that you would expect from a municipality. We try to achieve between 135 and 165 gallons per person per day and if somebody out here drills a big well there may be 10 to 15 people on this ranch and they are moving a lot of water, and that gallons per person per day is a lot higher out there. I think those are things a lot of people do not think about in our industrial water society that uses water. It is expensive, what does it cost to build a new well today, drill a 350 foot well, I imagine it is going to cost you what, $15,000. They are paying what right now, $6-8,000 dollars an acre-foot for water out of different aquifers. Maybe it should be considered a several hundred dollar value. I think there is a, I guess there is it may be just because I am not in y'alls business, but certainly there are economic forces at play, not just here but all across the country. You have people on the loop here and it becomes an economic thing of whether they can afford to live here or not but unless you change the constitution that is not going to change. It does not have to be free but it should be economical for people's basic living necessities, but for the guy that has got 25,000 square feet of Saint Augustine wrapped around his house and he wants to water it four times a week, yes.”

“Texas is going to be an attractive place for people to come and live especially the Hill Country and so you have people wanting to live here and then you have people wanting to fulfill that need and at some point in time there has got to be a point on the axis where we know more or less how much sustainable water there is going to be here on the long term and then how many people that will support. Yes I think that getting to the question of what we want our desired future condition to be my thoughts are first of all we have to have a sustainable aquifer, one that will serve not only this current group of folks here who are dependent on it but those future folks who are going to be there because it relates to our property values for most folks. A lot of folks are able to go to rainwater collection after the fact and a lot of new homes are being built with rainwater collection but there are a lot of folks that cannot afford to do that. And again that would tie back to what I was talking about. I encourage rainwater systems because the homes that are built on the tracts, the rural tracts, if they can afford to pay that price for that tract of land, then a rainwater system would mean nothing to them as far as price is concerned.And then back away from that and maybe your policies or laws or whatever address that particular issue.”

Personal Right

I am not sure that I can have well water forever. People are not sure groundwater will be around in the future for them but they believe they have an inherent *personal right* to groundwater. “Well I know the proposal for putting the meters on the wells, my mom got very upset about that because wells she is real protective, she is 86 years old and that is her well and nobody is going to touch it. If I had my wishes, I would wish that the desired future condition would guarantee me to have water in my well and my neighbors to have water in their wells as long as they needed it. And I am concerned that that is not going to happen. I made my plea to the city council not the last session but the previous session. In the last session a guy got up, who I know, and said, "No, it is basically a human right..." that he has a green yard. That was basically his opinion, do not stop me from watering my yard. Give me all the water, I do not want any of these stage 2 or stage 3 where I cannot water my yard. And he is a grey-haired guy like I am, he is not going to change, but it is just crazy. I am like you where we have to be careful about the amount of straws we put in the ground but I do not want to be overly regulated by the government if it was my own private well. Now I understand as a private well owner I think I need to conserve as well. There needs to be something, either some kind of incentive or something that 1) allows me to use the water as I need to but in conditions of drought I need to be regulated just like the water companies when they have to reduce their pumpage. When I had to sell the front 245 acres back in 2002, I spent over 2 hours in different meetings with Dr. Weldon Hammond whom I think has the most information on the Trinity Aquifer. I wanted to know, excuse my language, damn sure that I had well water until I could get city water and the city limits is on my fence line otherwise I would have sold the whole thing. But that is true in real estate, because your property, whatever it is sitting upon owns all the rights unless the rights have been sold like the oil, the gas, the water. And I am not sure that I can have well water forever. At some point in time I am going to have to go to the city to get that water because of the development. But the problem is, now this issue came up the last Headwaters meeting and it really gets to what you were talking about. They have have not been giving any water, any well permits to underneath 5 acres, plots of land underneath 5 acres, 5 acres or less. But they are having to do that because some of these old family plots have been broken up and people need water. So the question came up about putting meters on these people on these small plots just to gradually get into the idea. Well, of course, nobody really wanted to go there, but still the question was what is to prevent a person with 2 or 3 acres from pumping all the water out from underneath his neighbors, and you see there is not, and that is the big issue with real estate development, developers. And I do not think that the Cow Creek or any of these other conservation districts are going to be able to solve this problem on these aquifers conditions. But if I had my wishes that is what it would be especially those people that have been here all along that they would have water. To take care of the water, the main thing I am thinking. Seems like it ought to be. To take care of what we have and know where most of it is coming from and study it a little bit and to know find out where the water is coming from and try to take care of it and pro-rate it so it will last."

Human Density

What are they doing, growing rice? Previously, the Hill Country was a semi-arid, sparsely populated but naturally beautiful ranching and farming area different from the rest of the state because of the abundance of rock formations home to the remaining springs. Now, the Hill Country has become a popular retirement and weekend home destination for an increasing population. The *human density* projections increase through 2060. "Growth is coming it is just the manner in which we manage it. I think it is coming, the demand will be here you just have to have a way to take care of it. You have additional people coming in and you have a limited amount of water so ultimately if your community starts getting too big and you have a limited amount of water, then you are talking about rationing. I would like to be able to support growth in the community anyway. The main thing is knowing what is going to happen in all these years past, the amount of people it is going to take, that are going to use more water than maybe have or we will have if we continue using it like we are using it. I remember in the seven year drought we had, we did not have the water problem that we had in the last three years because we did not have the people in the 50's that we do now. And we did not have as many homes around like we have now and people did not use as much water back in the 50's. The city was 100 percent groundwater up until 1980 and they used a lot of groundwater. In fact, July of 1957 they used 108 million gallons, July of 2007 we did 130 million gallons, and that is only 22 million gallons difference between 2007 and 1957, and the population back then was probably 5-6,000 people and now you are probably talking about 23,000 and so either they had a lot of leaks or they had a lot of green lawns. It is just ridiculous. And the drought broke in 1957 but we do tour and I talk about conservation, where the water comes from, where the river comes from and our aquifer, where it comes from in this area and how deep it is. Well was not the situtation last year when we were having the terrible drought problem, and we were drinking 20,000 year old water or something, did you not say that a lot of the development north of 1604 in San Antonio have something to do with our problem? Well that information should really control the population growth because you can bring in all kinds of other resources but water you are pretty limited there and it should really control any projected growth. And what areas you can grow it can grow in. So I think that you can have a lot of wells, straws poked in the ground outside the city. I have seen this change over the last 22 years. The surface water has changed. The groundwater levels do fluctuate but summertime you can see, we have been charting this for twenty years, and you can during the summer it takes a bigger dip quicker because there are a lot more houses out in the country. I think one of the issues related to the overuse of groundwater is density in this area, and I think we need to be aware of that there has been some movement in the direction of recognizing that lot size and well location and well spacing is a big factor in the ability of an aquifer to be sustainable. The county has now moved in the direction of a 6-acre minimum lot size for the areas that have individual water wells. I think, in rural areas, I think is that very good. There are studies that show that it probably, realistically that should be more like 30 acres but politically that is not tenable. So that 6 acres was a big compromise. What is going to happen in my experience is that, if you do make it 30 acres, then any developer is going to come in and say, well if it is going to be 30 acres to get a well, then if I do buy this property I am not going to put 6 acre properties here, I am going to put 1/5 or 1/4 or 1/2 acre properties here and pay for the cost of bringing surface water in there, and what you get is very dense development and this brings up am issue I am concerned about is the amount of pollution with those developments introduced because you need to keep the aquifer level high but we also need to keep it clean. I see this issue, and maybe it should be 30 acres but unless you get it right you are going to get guys saying lets build density and you build density you are going to have these other issues about how much pollution you introduce so the 6 acres maybe was a compromise. I think you touched upon a point that I find important to address also, I mean we are concerned about the conditions as far as volume but one of my concerns is definitely about the pollution and the fact that we do not have industries here which is fortunate but we do have certainly point sources. I find myself applying, just as a homeowner a lot of pesticides, or I used to but now I have realized more and more because the groundwater conditions here in Texas are different from where I moved from which is from California that with this type of karst that we have it just all goes down to the groundwater and so we do not . So I am not sure it that is a portion of what people are concerned about but I do not hear the discussion of that as much in the area because I think maybe we are just not there yet, it is like the next level of concern. There are people coming here from Houston, Dallas, California, and Europe and building big houses and drilling big holes in the ground and they are not permitted wells because they are private and they are not metered and they fill ornamental lakes and ponds to, because they are pretty, but everybody around them is affected by them and I would like to see levels remain the same or increased through conservation measures or artificial injection. And you get a lot of people from Houston, they have dirt. You drive along the interstate here, we have one inch of dirt on top of rock. These people will bring in dirt and build them a nice yard. And their water bills are real high and it is running down the street. And you say what are they doing, growing rice? I mean, this is dry."

Water conservation is on everyone's mind, supportive or in violation of local drought planning efforts. "And I explain to a lot of people because we had a lot of, we went to Stage 3 this past summer and we were in Stage 1 for over a year, then we went into Stage 2, Stage 3, out of Stage 3 back to Stage 2 and then back in 3 again and had a lot of angry people. They had $20,000 lawns they had put in and that they wanted to take care of, well under the rules they could of had they been out there hand watering but they had automatic sprinkler systems that they wanted to turn them on and set them and walk away. Well, we would drive around and write up a lot of people for drought restriction violations. PD did it, Code Enforcement did it, and water production did it. I had one guy doing overtime just driving around a night, and I would tell him, "Make a big deal out of it, turn on your overhead lights, run the spotlight," and you would send them a courtesy notice and then when they get enough of them they would go to court. We had a lot of upset people but then one thing you did see, you would see a lot of people out in the yard talking to each other, your neighbors, watering. You know, standing there watering your yard talking to the guy next door who he probably had not talked to since 2005 when we were on drought restrictions then and he had to water. So maybe every 2-3 years when we go into Stage 3 they can talk when they are out in the street. But it was difficult then and so this time, they say, OK, we need to change it because we had several businesses that were really hurt by, car washes, power wash people, I mean they do not use much water anyway."
"When it comes to drainage regulations, we play a zero sum game. I do not want there to be any more drainage or it coming off at a faster rate than what there is before I started developing. Maybe we ought to do the same thing with recharge. You want to put 30 percent impervious cover on this property, fine, figure out a way to enhance the recharge features on the property so that we still get the same amount of recharge going into the aquifer after your development and I do not think that is an insoluble problem. I think that from a civil engineering perspective you can do that. Things have been looked at through the years to build more reservoirs but the problem with that is if you started today it may take 30 years to get all the necessary permits to complete a new reservoir but that is, things that have been talked about years and years, to try to build more surface water storage and off-channel and all different kinds of ways to get prepared for more future growth and more demand."

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Vita

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