Water Policy in Texas: A Comprehensive Overview

The Meadows Center for Water and the Environment

Acronym List

Bay/Basin Stakeholder Committee (BBASC)

Bay/Basin Expert Science Team (BBEST)

Best Management Practices (BMP)

The Clean Water Act (CWA)

Coastal Barriers Resource Act (CBRA)

Coastal Coordination Council (CCC)

Coastal Erosion Planning and Response Act (CEPRA)

Coastal Management Program (CMP)

Coastal Zone Management Act (CZMA)

Community Rating Systems (CRS)

Compensation and Liability Act of 1980 (CERCLA)

Desired Future Conditions (DFCs)

Domestic and Livestock (D&L)

Edwards Aquifer Authority (EAA)

Edwards Aquifer Recovery Implementation Program (EARIP)

Endangered Species Act (ESA)

Environmental Defense Fund (EDF)

U.S Fish and Wildlife Service (FWS)

General Land Office (GLO)

Groundwater Availability Models (GAMs)

Groundwater Conservation Districts (GCDs)

Groundwater Management Areas (GMAs)

Habitat Conservation Plans (HCPs)

House Bill (HB)

Informal Science Efforts (ISE)

Integrated Water Resource Management (IWRM)

International Boundary Commission (IBC)

International Boundary and Water Commission (IBWC)

Kay Bailey Hutchison Desalination Plant (KBHDP)

Lower Colorado River Authority (LCRA)

Millions of Gallons per Day (MGD)

Municipal Utility Districts (MUDs)

National Association for Environmental Literacy (NAEE)

National Pollutant Discharge Elimination System (NPDES)

National Science Foundation (NSF)

Non-Governmental Organizations (NGOs)

Nonpoint Source Pollution (NPS)

Pesticide General Permit (PGP)

Priority Groundwater Management Area (PGMA)

Office of Compliance and Enforcement (OCE)

Regional Water Planning Areas (RWPAs)

Regional Water Planning Groups (RWPGs)

Recreational Water Quality Criteria (RWQC)

Science Teachers Association of Texas (STAT)

Senate Bill (SB)

State Board of Education (SBOE)

State Water Implementation Fund for Texas (SWIFT)

Storm Water Management Program (SWMP)

Tarrant Regional Water District (TRWD)

Texas Coastal Watershed Program (TCWP)

Texas Commission on Environmental Quality (TCEQ)

Texas Department of Agriculture (TDA)

Texas Association for Environmental Education (TAEE)

Texas Education Agency (TEA)

Texas Essential Knowledge and Skills (TEKS)

Texas Environmental Education Advisory Committee (TEEAC)

Texas Natural Resource Conservation Commission (TNRCC)

Texas Open Beaches Act (TOBA)

Texas Parks and Wildlife Department (TPWD)

Texas Partnership for Children in Nature (TCIN)

Texas Pollutant Discharge Elimination System (TPDES)

Texas State Soil and Water Conservation Board (TSSWCB)

Texas Statewide Systemic Initiative (SSI)

Texas Water Development Board (TWDB)

The National Oceanic and Atmospheric Administration (NOAA)

The Texas Surface Water Quality Standards (TSWQS)

Total Maximum Daily Load (TMDL)

U.S Fish and Wildlife Service (FWS)

United States Geological Survey (USGS)

US Environmental Protection Agency (EPA)

Water Supply Corporations (WSCs)

Water Quality Management Plans (WQMPs)

Watershed Protection Plan (WPP)

Water Quality Standards (WQS)

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Executive Summary

Over the last 500 years, the evolution of water policy in the Texas region has expanded to accommodate developments in industry and population growth across a geographically diverse region. Increasingly erratic weather patterns, projected and occurring population growth, and regional development have all resulted in over-taxed resources, and new legislation to secure funding for water conservation efforts and projects. In a state in which the majority of land is privately owned and subsurface water resources are managed differently from those aboveground, comprehensive approaches to this evolving system will require effective use of environmental education techniques and incentivizing conservative water use for landowners, as well as greater efficiency in current surface and subsurface water use practices, particularly for agricultural and domestic purposes. This requires that our citizens understand the limits of our existing water resources, including the difference between water "needs" and "wants," and that decision-makers explore options for instituting effective landowner incentives in the changing physical and social climate.

In order to plan for more effective water management, we must first understand how much water exists and is available for use. While surface water resources may be readily quantifiable, it is generally difficult to understand the availability of groundwater resources. The Hill Country region of Texas is of especial concern to this research. The region sits upon a fragile karst system, including the Edwards and the Trinity aquifers, and is home to some of the fastest growing urban centers in the nation. Because of the sensitive ecological and hydro-climatic nature of the region, the Hill Country region of Texas may be considered "ground zero" for water management actions.

There is a continuing concern, however, that the scientific information and data needed to address these issues will not be secured in time to create effective conservation legislation. In this new era of technological advancements in energy production, and a marked increase in rural to urban migration across the state, a reanalysis of current water management techniques to ensure that existing resources are sustainable, that they are adequately distributed, and that their quality is maintained. Recent developments involving establishment of new Texas Water Development Board members and The 2012 State Water Plan, which has outlined many projects for conservation in Regional Water Planning Groups, totaled more than $53 billion as of 2013. A primary water-related goal for legislators during the 83rd Legislative Session in 2013 was to identify available funding for addressing the most vital projects outlined through the RWPGs. Important legislation designed to secure permanent sources of funding for water plan projects will be voted upon in November 2013, including Proposition 6 and Senate Joint Resolution 1. If this legislation is passed, $2 billion in associated funding will be diverted from the State Economic Stabilization Fund to the Texas Water Development Board for the purpose of creating the State Water Implementation Fund for Texas (SWIFT).

For all the legislative developments, however, there are significant concerns regarding the methodology for establishing environmental flows and for managing transboundary resources. Over-allocation of surface water resources has highlighted concerns over maintaining essential riparian environments for endangered and threatened species during drought periods. Understanding how, and why, current water-related legislative and regulatory practices came to be will highlight the root causes of existing problems, as well as methods for addressing information and data gaps.

Introduction

To appropriately discuss current water policy in Texas, a comprehensive report providing a general overview of a wide range of water resource topics has been developed. This report will assist in highlighting the state's current water management strategies and in what way such methods could be improved. Currently, a document of this breadth has yet to be made available for individuals and groups to base their projections on Texas' water-related future.

In this report we review the major sources of discussion among Texas residence and policy professionals. These topics can generally be grouped into four criteria. First, a more general basis of Texas water resources is examined in the first three sections. This includes an overview of the historical context of Texas policy, the institutional actors involved in managing and implanting policy, and the geography of Texas water resources. Second, three sections to diagnose specific issues found in the various waters within Texas' boarders, groundwater, surface water, and coastal water. Third, four adaptive management strategies in our state to better manage Texas water: instream and environmental flows policy, habitat conservation approaches, and environmental education. These especially surrounding water resources issues such as: transboundary policy, the energy-water nexus, climate modification, and the 83rd Legislative Session. Additionally, it is important to note the time period that has been observed throughout this report. This frame of reference includes policy made through November 2013. Thus, results of passage of Proposition 6 will not be discussed.

We chose to discuss these sections for their fundamental importance in current and future water policy. As more cutting edge discussion begins to surface, and the complexities of industry, urban expansion and resource scarcity become more important, our policies and institutions must prove their effectiveness and importance within this changing state. In particular, the goal for this review was to expose specific gaps in policy that may need further review and potential amending. Finally, provided here is an opportunity to analyze how policy has adopted new social and economic issues (e.g. hydraulic fracturing, population increase, etc.) in Texas. Such a review will not only give current policy analysts a resource for general education but also initiate a discussion about what it is that could be improved in state policy to better protect Texas' precious water resource and fragile ecosystems.

Methodology

The overall purpose of this paper is two-fold: 1) to provide a comprehensive overview of what the state of water-related policy and conservation is in Texas; and 2) what future steps should be taken based on the state of affairs for improving natural resource management.

A thorough examination of water-related policy in Texas is difficult because it affects many different sectors. In order to ensure that a thorough review of policy is completed, each separate section of this document contains separate a conclusion section and an analysis of the information known. The specific format for policy analysis, conclusions, and proposed action based on the knowledge gathered is as follows below.

1. **An overview is presented on the history of the subject and related policy.**

   Subject introduction and policy-related discussion will include a literature review and historical recount of the topic leading up to its present-day status. This includes an account of the evolution of specific policies relating to this matter. Also provided are discussion on public opinion, professional and academic reviews of specific concerns and progress made throughout Texas history, and future projections regarding the topic.

2. **A general conclusions section is developed for each topic.**

   After the topic overview and discussion, a conclusions section will be present for each topic to provide a summary of what is and is not currently being accomplished through existing policy. This section also provides suggestions for solving identified problems not currently addressed by policy, or recommends that steps be given to focus on areas that require immediate attention.

3. **The final analysis section synthesis existing information identifies gaps in knowledge, and recommendations for future research.**

Finally, existing problems and/or gaps in political or scientific data are exposed. Discussion is provided to determine the reason for gaps and suggest methods for ameliorating exiting problems or addressing new topics requiring research. It is expected that this analysis will provide stakeholders and decision-makers with more focused subjects to which attention may be given for developing improvements to existing policy.

Final overall conclusions and discussions will be given at the end of the paper. These will include future projections, possible actions and research to be taken to address multiple sectors, and recommendations for action based on existing policy.

Section 1: Historical Context - Texans and Water

Take-away Points:

1. Groundwater and surface water have, traditionally in this region, been managed separately. Groundwater is considered "property" of landowners.
2. Social conservatism and emphasis on individual property rights liberties in Texas do not allow for readily acceptance of regulatory measures.
3. Population shift from rural to urban settings result in a shift in surface water resources (interbasin transfers). This affects not only existing populations and cities but also has serious environmental ramifications.

Operational Philosophy in Texas

In identifying and analyzing Texas' policies on water and other natural recourses, we must first understand the dominant culture of the state. Comparing Texas and its water management decisions to other states does not provide an appropriate perspective to the dichotomy between resources and popular political ideology. Texas is a diverse state in terms of geography, ethnicities, and social agendas. The recent expansion of urban population has contributed to a notable growth in progressive ideologies, and the influx of Mexican immigrants contributes to Texas' growing complexity.

Texas is of the top ten most rural states in the U.S. as of 2010 (Combs 2013). Internally, Texas culture is influenced very much by the rural population and traditional values attached to private land ownership. A report on Texas politics from the University of Texas at Austin states that Texas' political culture is described as a combination of three main ideological terms; namely classical liberalism, social conservatism and populism (2009). Classical liberalism focuses primarily on the concept of individual liberty, and opposes governmental actions to enact social reforms. This seeming lack of trust of government is partially contradicted in the simultaneous devotion to social conservatism. Social conservatism embraces traditional social relations, and tends to interpret social change as “a threat to established practices and beliefs” (UT Austin 2009). In contemporary circumstances, social conservatives tend to support government ability to facilitate these traditional relations, especially with regard to established religious practices and beliefs, business, military, and religious authorities (UT Austin 2009). Populism, the most ambiguous of political terms, is defined as being concerned with the protection of ordinary people. Although this term can manifest itself in many circumstances, the ideals are specifically rallying behind the working class for most issues and, in Texas, the rural and agricultural sectors of the state (UT Austin 2009).

When approaching the topics of environmental protection or resource management, there is a general belief that the regulation associated with these terms means higher taxes and governmental control. For many approaching these terms with a conservative mindset, four general political climates are common, including: (1) a general hostility towards increasing taxes for state services, (2) an anti-union political attitude, (3) limited environmental regulation, and (4) maintained culturally conservative social policies. Specifically, rejection of overarching authority is seated within environmental regulations and opposition towards taxation, which are the two most common barriers to improved water management strategies (UT Austin 2009). Because environmental protection institutions are inherently a governmental endeavor, the predominant culture provides a difficult political climate to pursue progressive conservation strategies.

The onset of the most significant drought in Texas' recorded history, and an influx of urban population, caused a shift in the perception of government's role in water policy. Environmental regulation has established new possibilities in regard to Texas water relations. A current rural versus urban dynamic is becoming pervasive throughout the state. Not only is this culturally significant, water management strategies also are increasingly rationalized within the perspective of an urban-centered state, rather than a previously rural-centered one.

Rural versus Urban Water Use

When looking at the rural-urban dichotomy as politically and ideologically different, we can generally accept the phenomenon of democratic voting tendencies in urban centers and republican voting tendencies in rural areas (M.S. 2010). We can further explore this by assuming that, in general, democrats are often more concerned with environmental matters than republicans (Van Liere 1980). The difference in the protection of water resources can be understood by its importance for all areas of urban or rural life. Thus, appropriate investment in water resource management is seen to be in the best interest of all Texans. Yet, we can assume that a political ideology based on concepts of individual property rights can inhibit the spread of an inherently altruistic practice of natural resource conservation.

Shifting Population

Population shifts from rural to urban areas in Texas have resulted in a disconnection between water use in these locations and increased competition for existing resources. Stress on water resources due to

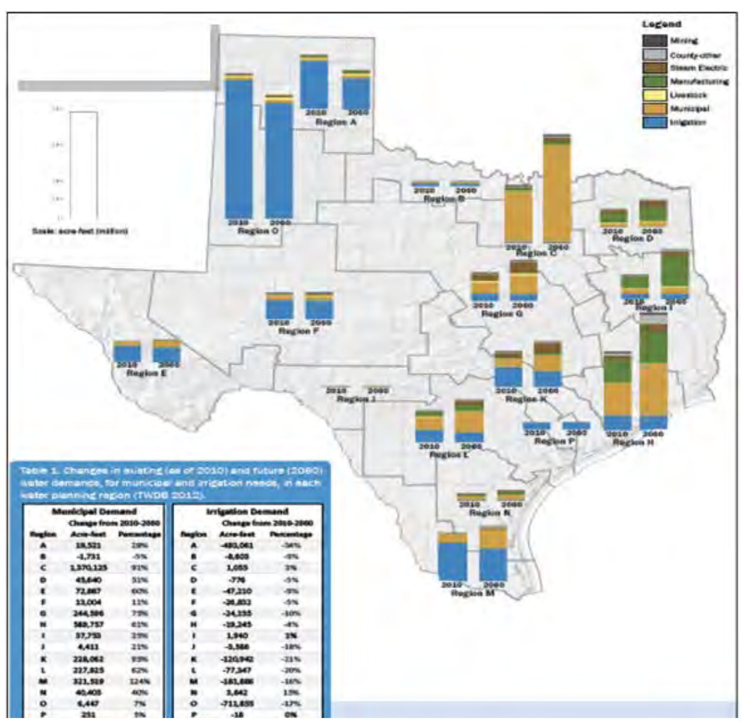

FIGURE 1: CURRENT AND FUTURE WATER DEMAND TRENDS (WAGNER 2012)

an increase in extreme drought conditions is intensified by projected increases in municipal water demands from 4.9 million acre-feet in 2010 to a predicted 8.8 million acre-feet in 2060 (Vaughan 2012). Municipal water demand is rapidly decreasing in west-Texas regions experiencing rural out-migration, and increasing in central and east Texas (Figure 1) (Wagner 2012). While rural populations are decreasing, urban centers are expanding very quickly as is the demand for water for municipal and manufacturing needs. The projected doubling of the Texas population by 2060 will heighten competition for resources between rapidly urbanizing municipalities and irrigated agricultural in rural areas.

Rural and Agricultural Water Use

In Texas, 57% of surface water is permitted for agricultural use in rural areas, making it the single largest sector area of water use (Wagner 2012). Most of the water used for agriculture is dedicated to irrigation and comes from private water rights or irrigation companies and districts. Other than these sources, rural communities receive water supplies through municipal systems, rural water supply corporations, owners of private water supply companies, and privately operated wells (Jensen 1985). These distinctions typically fall into four categories with rural communities: Municipal Utility Districts (MUDs), Water Supply Corporations (WSCs), private water suppliers, and individual well operators. Each source provides differing levels of quality and associated costs (Jensen 1985). According to the 2012 State Water Plan, projected water use in 2060 will be significantly lower in irrigation agriculture in rural areas, decreasing from about 60% to 38% and increasing in municipal use from about 25% to 38% (TWDB 2012). The notable decrease in rural use is a combination of more efficient irrigation strategies and less actual agricultural practices compared to the incredible influx of population to Texas cities.

Urban Water Use

Rural-to-urban migration and the shift of suburban sprawl into traditional agricultural land underscores the need to ensure adequate water supplies for rural residents. Treated drinking water is distributed by various entities, including MUDs and municipal water services. Water usage in urban centers is on the rise even when considering per capita results. While some cities, like El Paso and San Antonio, have instituted successful conservation programs at a municipal level and have reduced per capita water use overall in 2011, water use in single-family households rose by 17% in a single year in those cities (Theobald 2012). These changes occurred even with conservation plans in place. Increased usage has been linked to a desire for green and well-maintained lawns that require substantially more supplemental water during droughts (Theobald 2012). In 2012, the rural lake community of Spicewood Beach outside of Austin, TX became the first town to run out of water during the drought (Henry 2013). This has resulted in the citizens having to pay for more water infrastructure to ensure that resources will be sustained during drought.

The Future of Texas' Water Allocation

With an increasing concern for water resources in the growing urban centers throughout Texas, and the potential state funding the 2012 State Water Plan will be receiving, the rural populations of the state have voiced concern about future projects. Questions of water rights being sold or transferred to more populated cities have made questions of water distribution from rural to urban areas more important. Future water projects, such as reservoir and dam building for future use, have also concerned landowners in proposed sites (Combs 2013). As natural population distribution throughout the state continues to favor urban areas, water appropriations are expected to shift accordingly.

Section 2: Institutional Actors

Take-away Points:

1. Freshwater quality and quantity are managed by the TCEQ, TPWD, TWDB, and localized sub-groups such as GCDs, GMAs, and through HCPs.
2. Coastal resources and projects are managed through the GLO and Texas CMP.
3. Prioritization of water management projects is handled through the TWDB.
4. HCPs are established in part to maintain freshwater flows in ecosystems containing threatened and/or endangered species.
5. Major changes to the TWDB have been proposed and ratified in the 83rd Texas Legislature.

Explanation of Water Governance

In Texas, it is necessary to understand that water law, as it exists, considers water resources in three different states (Brown n.d.). The first of these, groundwater, is all subsurface water other than underflow of a surface water river or stream. Watercourse is the second state in which water may be regulated. This is referred to in Brown's paper, *A Primer for Understanding Texas Water Law* as water belonging to the state, or "surface", "public" or "state" water. This is known as water in a watercourse.[1] The final category of water in Texas is "diffused surface water", which is defined as water in its natural state that occurs on the "surface of the ground prior to its entry into a watercourse, lake, or pond" (Brown n.d.).

Surface water and groundwater are governed and managed separately. Governance of surface water is divided primarily among four state agencies: the Texas Water Development Board (TWDB), the Texas Commission on Environmental Quality (TCEQ), the Texas Parks and Wildlife Department (TPWD), and the Texas General Land Office (GLO). Groundwater

[1] First defined in the 1925 court case Hoefs v. Short, 114 Tex. 501-511, 273 S.W. 785, 40 ALR 833 (1925), a watercourse is, "a definite stream of water in a definite natural channel, with well defined bed and banks, from a definite source or sources of supply. However, the bed and banks may not be discernable for the watercourse's entire length. The flow of the stream may be intermittent or at irregular intervals" (Brown n.d.).

Management Areas (GMAs), Priority Groundwater Management Areas (PGMAs), the Edwards Aquifer Authority (EAA), and Groundwater Conservation Districts (GCDs) play an important role in implementing local groundwater management strategies.

Texas Water Development Board

Until the late 1950s, the primary state water regulation agency in Texas was the Board of Water Engineers.[2] Unfortunately, this governing body was only responsible for managing water rights and had essentially no staff. Texas relied on the United States Geological Survey (USGS) to provide water calculations and measurements for resource management (Brown n.d.). Founded in 1957, the original purpose of the Board was to supervise funds from bonds sold in order to assist political subdivisions with financing surface water resource projects. The current mission of TWDB is "to provide leadership, planning, financial assistance, information, and education for the conservation and responsible development of water for Texas (Texas Water Development Board 2013)." Funding water-related needs has been a concerted effort in Texas Legislature only since the creation of the TWDB. The agency maintains data regarding surface and groundwater resources, provides financial assistance for water planning, offers technical advice, approves GCDs, and assists with water planning initiatives across the state.

Groundwater Management Areas and Priority Groundwater Management Areas

Created in 1995 by the 74th Texas Legislation, GMAs "provide for the conservation, preservation, protection, recharging, and prevention of waste of the groundwater, and of groundwater reservoirs or their subdivisions, and…control subsidence caused by withdrawal of water from those groundwater reservoirs or their subdivisions, consistent with the objectives of Section 59, Article XVI, Texas Constitution" (Texas Water Development Board 2013).

[2] The Board of Water Engineers was created in 1913 through the adoption of the Burges-Glasscock Act (also known as the Irrigation Act of 1913). This Act centralized water rights permitting and brought together the "patchwork" of conflicting water laws. (Legislative Reference Library of Texas 2013)

Established within the Texas Water Code[3], a GMA is a geographical area that coincides with the boundaries of aquifers and is ideal for the management of groundwater resources. The TWDB is responsible for overseeing the actions of established GMAs (Figure 2).

Groundwater is a major source of water in Texas, annually providing about 60% of the 16.1 million acre-feet of water used in the state (Texas Water Development Board 2013). By dividing the state into several different hydrologic basins, and then designating appropriately sized GMAs and PGMAs, governance of groundwater is in the hands of local decision makers. The legislature has authorized TCEQ, TWDB, and TPWD to study, identify, and delineate GMAs and PGMAs.

There are a total of 16 GMAs in Texas and seven PGMAs. A PGMA is a region declared by the TCEQ that is experiencing (or is expected to experience within the next 25 years) critical groundwater problems such as surface or groundwater shortages, land subsidence, and contamination of groundwater (Figure 3) (Texas Commission on Evironmental Quality and Texas Water Development Board 2011). Once an area is classified as a PGMA, state officials determine the threats facing the local aquifer. In many cases, TCEQ recommends the formation of a GCD in order to prevent further degradation, though the classification of a PGMA is not a prerequisite for the creation of a GCD (Groundwater Protection Committee 2011).

[3] Full purpose and explanation for GMAs exist within the Texas Water Code §35.001.

Groundwater Conservation Districts

A GCD is developed by a consensus of landowners, an act of the Texas Legislature, or by a recommendation from TCEQ. "Groundwater conservation districts are units of local government with the authority to regulate the spacing and production of water wells" (Groundwater Protection Committee 2011). The creation of a GCD allows for more localized control over groundwater resources in regions where there is a risk of over pumping; it is the state's preferred method for groundwater management (Figure 4).

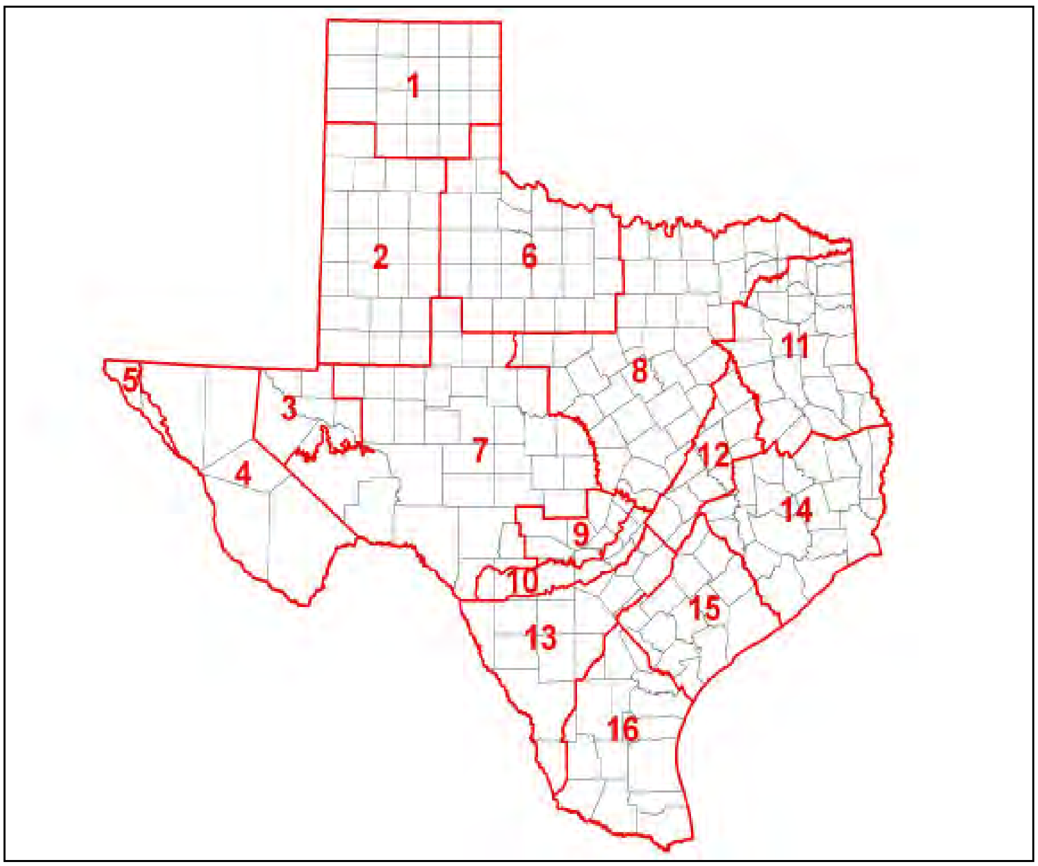

FIGURE 2: GROUNDWATER MANAGEMENT AREAS (TEXAS WATER DEVELOPMENT BOARD 2013)

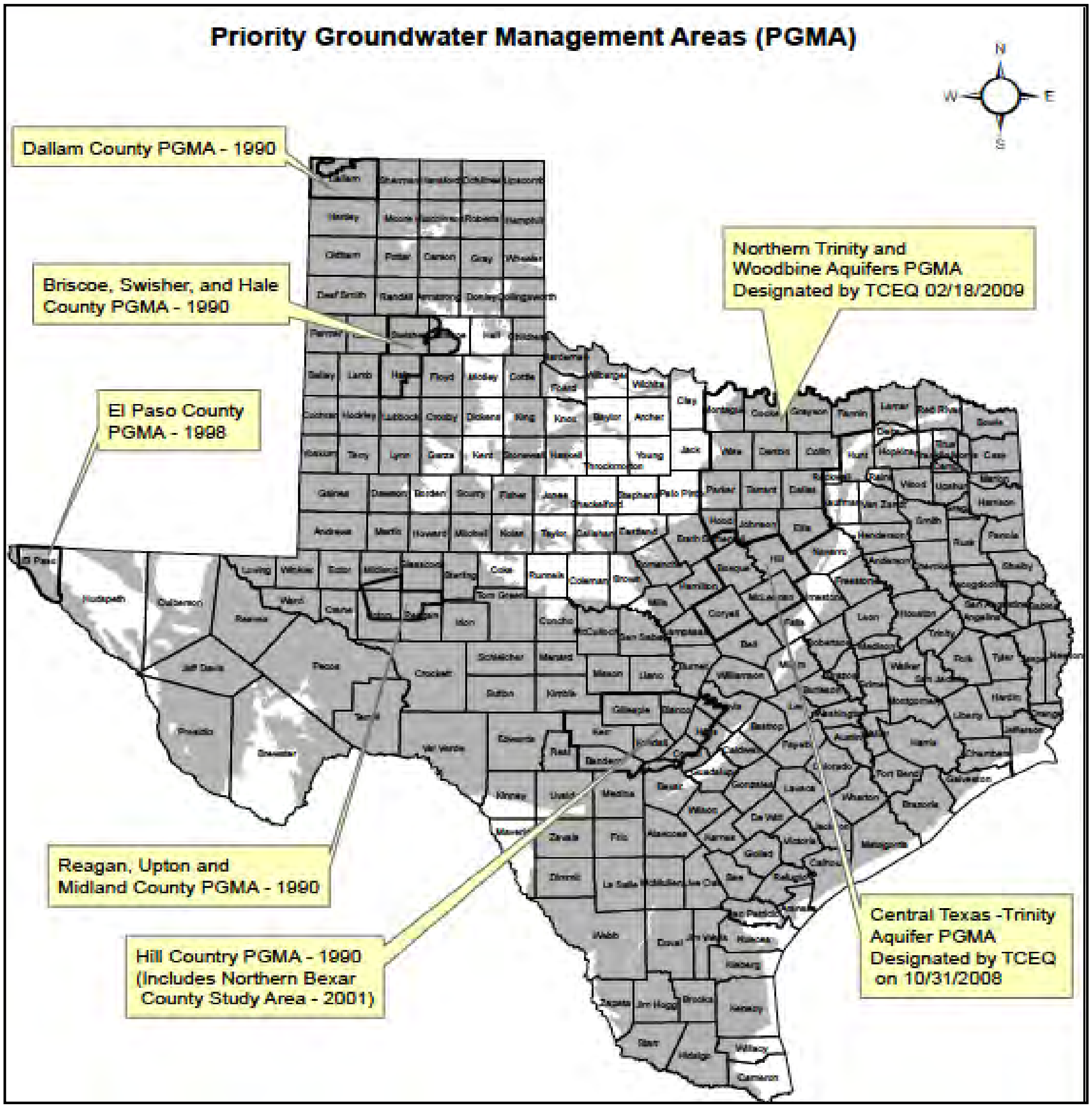

FIGURE 3: PRIORITY GROUNDWATER MANAGEMENT AREAS-TEXAS (TEXAS COMMISSION ON ENVIRONMENTAL QUALITY 2011)

Although Texas utilizes the *rule of capture* for groundwater, a GCD can help regional landowners jointly manage aquifer drawdown. Groundwater Conservation Districts have the ability to regulate the number of wells, including appropriate spacing and production, while also protecting current water user rights, and identifying a long-term aquifer management plan, which is contingent on Desired Future Conditions (DFCs). These are a set of quantifiable targets to control aquifer drawdown (Far West Texas Planning Group 2011).

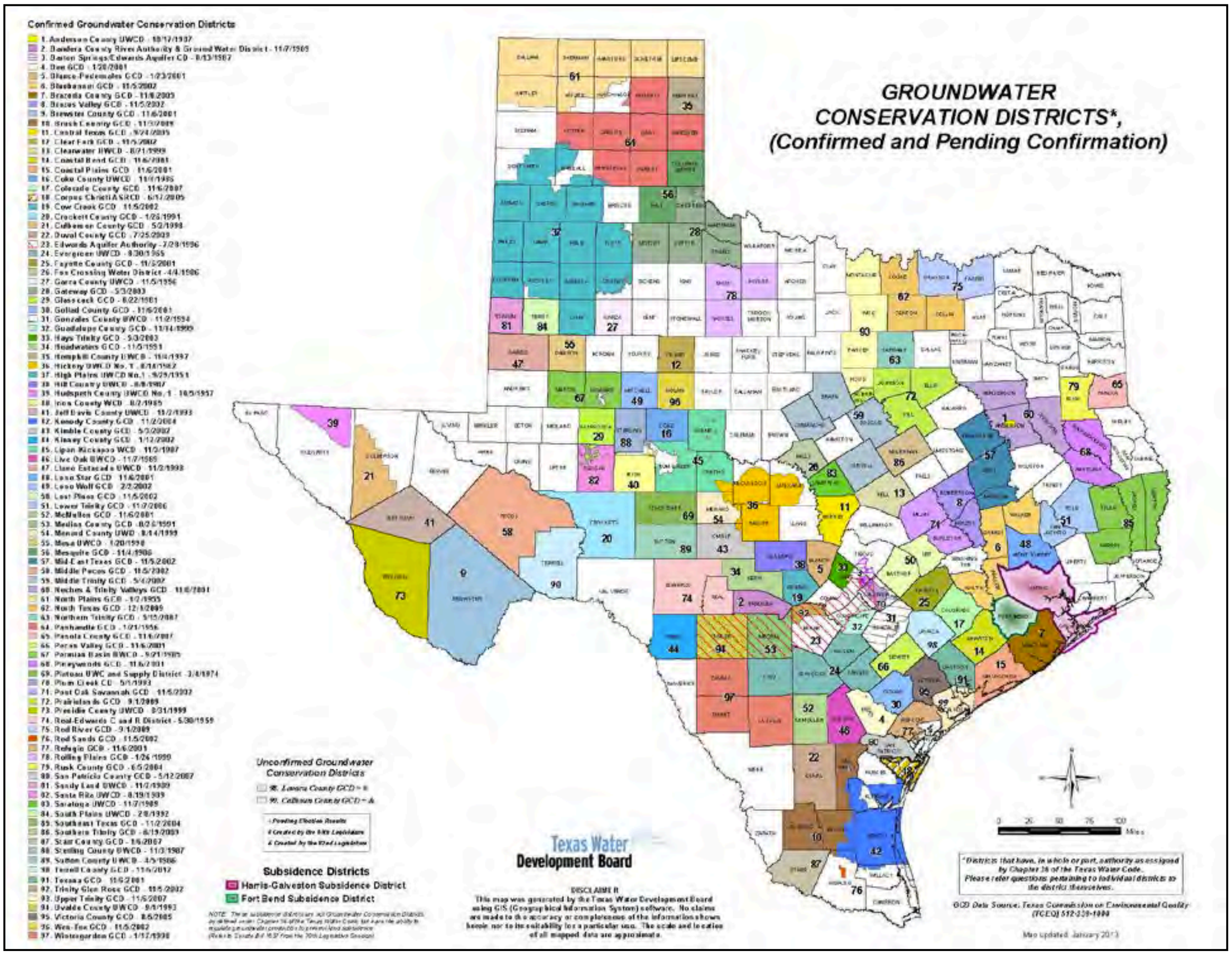

FIGURE 4: GROUNDWATER CONSERVATION DISTRICTS AS OF JANUARY 2013

Not all GMAs or even PMGAs have a GCD designated in their region, and even those that do cannot prevent groundwater from being pumped off-site. In most cases, GCDs do not follow the hydrological boundary of the aquifer, which increases the difficulty of effective management. However, GCDs can help to protect the groundwater for current and future generations of water users and are currently the most effective mechanism in place for doing so.

Edwards Aquifer Authority

The Edwards Aquifer Authority (EAA) was created as a result of the 1993 court case between Sierra Club and the U.S. Fish and Wildlife Service (USFWS). The findings of this case revealed that extreme over-pumping of the Edwards Aquifer resulted in the 'taking' of several endangered species endemic to the aquifer. The USFWS mandated that Texas regulate pumping of groundwater in the Edwards Aquifer despite rule of capture precedents. In order to accomplish this task the Texas Legislature passed Senate Bill 1477, which replaced the former managing entity with EAA. The EAA is the only managing entity in Texas that has a legal right to permit and manage groundwater for commercial and residential entities alike. Permitting for groundwater in the Edwards Aquifer has been in place since 2001. Today, it is required that all pumping be done sustainably in the Edwards Aquifer as mandated by federal statute to preserve adequate flows for endangered species living in the springs.[4] Over-allocation of water resources related to permitting leaves riparian and estuarine systems without sufficient freshwater resources to maintain a healthy habitat. This also protects local communities from over-pumping and depleting their primary water supply" (Veni, et al. 2001). In order to obtain an incidental take permit for the endangered species, the EAA is required to form a stakeholder group and create a Habitat Conservation Plan (HCP). The HCP was recently finalized and implementation has already begun.

Since the passage of Senate Bill 332 and the Texas Supreme Court ruling in the Edwards Aquifer Authority v. Day and McDaniel, landowners now have a vested interest in the groundwater as a property right while it is 'in-place' under the owned land. The result of this decision reaffirms the rule of capture[5] and has the potential to undermine pumping restrictions by holding groundwater managing entities responsible for potential 'taking' of groundwater property rights without adequate compensation to the landowner. There are many court cases currently in the litigation process that will clarify the true repercussions of these decisions.

[4] See section on Environmental Flows.
[5] See section on Groundwater Rights.

Texas Commission on Environmental Quality

In 1956, the "Big Valley Water Suit" resulted in the creation of the first Texas Water Master for the Falcon Dam, and reorganized the Texas Water Commission (TWC) to create the Texas Water Rights Commission in 1965[6]. Over the next 30 years, the TWC expanded to incorporate the Texas Well Drillers Board, the Board of Irrigators, the Water Hygiene Division, and the Solid Waste Bureau of Texas. By the final year of its operation, the TWC had a budget of $128 million and employed 1,800 workers (Hadley 2013). In 1991, the Texas Legislature ordered a consolidation the TWC and the Texas Air Control Board into the Texas Natural Resource Conservation Commission (TNRCC) by 1993. In doing this, TNRCC became effectively responsible for air quality, waste management, and water quality in Texas (Hadley 2013).

In 2002, the agency changed its name to the Texas Commission on Environmental Quality in 2002 (Texas Commission on Environmental Quality 2002). The TCEQ provides permitting for surface water, water quality, and wastewater. These permits are enforced via the 'watermaster' monitoring program (Texas Commission on Environmental Quality 2013).[7] Since the 2007 adoption of Senate Bill 3 regarding environmental flow standards, TCEQ is responsible for establishing appropriate environmental flow requirements for each river basin. TCEQ also plays a key role in intra-agency cooperation and coordination by engaging local, state, federal, and international groups in the water management process.

Today, the TCEQ is responsible for providing licenses and permits for water and wastewater operators, nonpoint source pollution (NPS) discharge permits, water quality, stormwater, and wastewater. The Office of Water within the TCEQ is responsible for handling the following programs:

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[6] The Texas Water Commission replaced the Board of Water Engineers in 1965 (Hadley 2013).
[7] See section on Surface Water Rights.

- Public Drinking Water
- Water Rights
- Interstate River Compacts
- Watermaster
- Districts and Utilities
- Groundwater Protection
- Texas Surface Water Quality Standards
- Nonpoint Source Program
- Wastewater, Storm Water, and Concentrated Animal Feeding Operation Permitting
- Surface Water Quality Monitoring
- Watershed Protection Plans and Total Maximum Daily Loads
- Galveston Bay Estuary Program[8]

Texas Parks and Wildlife Department

In 1895, the Texas Legislature created the Fish and Oyster Commission to regulate fishing, and in 1907, the Texas Game Department to was formed control hunting activities (Texas Parks and Wildlife Department 2004). Sixteen years later in 1923, the Texas Legislature created the State Parks Board as a separate entity. It was not until 1963 that these separate agencies merged to form the Texas Parks and Wildlife Department (TPWD). While TPWD has the "primary responsibility for protecting the state's fish and wildlife resources," it does not have any regulatory authority over the state's water resources (Texas Parks and Wildlife Department n.d.). The TPWD conducts natural resource evaluations for regional GMAs and environmental flow standards; orchestrates public outdoor education programs; and encourages private landowners to practice water conservation and land management techniques. This state agency also provides expertise on the sustainable management of the state's natural resources, both for state or local agencies and for the public.

[8] A complete list of sector responsibilities can be found on the TCEQ Water Office website: http://www.tceq.texas.gov/about/organization/water.html.

Texas General Land Office

When Texas first became a member of the United States, the Federal Government refused to accept land as payments for debt (Texas General Land Office 2012). Texas entered the Union owning its own public land and also owning 10.3 miles of submerged lands (tidelands) extending into the Gulf Coast of Mexico (Texas General Land Office 2012). In 1863, the Republic of Texas Congress created the GLO to manage all public land, issue titles, provide maps and surveys, and manage records.

In its organizational mission statement, the GLO is tasked with "preserving history, protecting the environment, expanding economic opportunity, and maximizing state revenue through innovative administration and prudent stewardship of state lands and resources" (Texas General Land Office 2013). Responsibilities of the GLO include the oversight of oil, gas, and mineral rights leasing of state properties, which also contains state-owned submerged lands in the Gulf of Mexico. The GLO is also able to provide financial and technical assistance to programs such as the Coastal Management Program (CMP) and the Oil Spill Prevention and Response Program. It is also primary state agency charged with regulating the coastal water programs in Texas.[9] Local and national non-governmental organizations NGOs, river authorities, and private organizations receive funding for coastal projects through partnerships or projects under the Texas CMP with the Texas GLO. The Texas CMP was established to help "ensure the long-term environmental and economic health of the Texas coast through management of the state's coastal natural resource areas". Once created, the CMP received approval to commence from the National Oceanic and Atmospheric Administration (NOAA) in 1996 and is chaired by the commissioner of the Texas GLO (Texas General Land Office 2012). Under this directive, annual funding for the Texas CMP from NOAA totals approximately $2.2 million (Texas General Land Office

[9] See section on Coastal Water Management

2013). Authority for the Texas CMP and other Coastal Programs stems from the 1972 Coastal Zone Management Act (Texas General Land Office 2013).

Conclusions and Analysis

As Texas' public responsibility becomes more complicated when dealing with water resources, regulatory agencies must adapt to the influx of policy reforms possibilities. In this section, we explored the responsibility of the various entities regulating Texas' water resources. State agencies such as TWDB, TCEQ, TPWD, and GLO are all designed to provide independent protection and allocation for surface water supply. Together, GMAs, PGMAs, GCDs and EAA are Texas agencies that tackle groundwater resource issues and management.

Some recent modifications, which have been discussed and could use further examination in how policy affects both our surface and groundwater. The primary functions of the TWDB is to act as an agency which coordinates the State Water Plan since the passage of Senate Bill 1, and also, maintains responsibility as a collector and depository for all water data for Texas. But, the arguably paramount function of the TWDB is to act as a distributer of loans and grants to be administered by the board for water projects in the state. Since 1957 the TWDB has successfully administered over $14 billion dollars throughout the state (Hunt 2013). Despite such success, the TWDB has experienced recent changes. With the passage of House Bill 4 by the Texas Legislature and encouragement from Governor Rick Perry, the previous six volunteer board members are now replaced by three appointed and paid commissioners. This change is expected to cost at least $1.2 million dollars annually (Hunt 2013).

The various GCDs and the EAA are an interesting concept for future groundwater management in Texas. Because of the absolute ownership of groundwater in Texas these entities are actually unable to limit production of groundwater. However, GCDs can regulate spacing of wells and production by tract size. Additionally, GCDs are unable to prohibit transfers outside of district, but can simply charge an increased fee for outside users (Lesikar 2002).

When discussing the policy surrounding groundwater management in Texas, the responsibility for prioritizing conservation of personal property maintains significant obstacles. Some future studies to be explored could provide information that will give the Texas Legislature and citizens a better understand of the implications of over allocated water resources in Texas. An examination of financial and political feasibility of increased regulatory power of current institutional actors will be helpful in defining the future of Texas' water issues and potential management objectives. Also, a possible reconfiguration of regional water management to recognize an interconnected hydrological system rather than arbitrary boarders will potentially provide a significant step in future management.

Above all, especially for the recent and future integration of an urban majority throughout Texas, a comprehensive and balanced approach to governing water resources in a drastically changing state is of primary importance. Generally speaking, the future of regulatory agencies and regional planning groups is unknown, but one can assume the need for effective management will provide security to a fragile and increasingly scarce resource.

Section 3: Geography of Resources

Take-away Points:

1. Statewide, nearly 11 million acre-feet of surface water are available for human use.
2. Nine major aquifers are in Texas: the Pecos Valley, Seymour, Gulf Coast, Carrizo-Wilcox, Hueco-Mesilla Bolson, Ogallala, Edwards-Trinity, Edwards, and Trinity.
3. Differential weather patterns and water distribution exist as a result of the geographic and climatic diversity of Texas.
4. With changing climate, the distribution of surface water is shifting and most of the water available for use is already allocated.
5. While it is possible to determine the capacity of aquifers, it is not yet possible to determine the exact amount of water. This lack of knowledge must be addressed in order to construct effective conservation legislation.

Background

Texas has a rich and varied landscape filled with resources that have provided much for its citizens. The diversity of geography is far reaching in scope; from the Great Plains in the northwest to the Coastal Plains in the Gulf of Mexico and even Mountains and Basins in the Trans-Pecos region shows the vast variety afforded to Texas (Maps of the World 2013). For all of its expansive beauty and progress, development in Texas has always been dependent on the availability of fresh water. As the purpose of this document is to explore water policy, the discussion in this and the following two sections will focus on exchange of rights and availability of water resources. This section provides only a brief overview of water systems in the state. Specific hydrogeology and river systems mapping in Texas will not be explored.

While groundwater and surface water are physically interrelated and part of the same sequence, Texas regulates each separately. For the purposes of clarity, this section will explore water resources available to Texas by separating them into these two groups, which better represents the policy realities of the Lone Star state. It is, however, essential to recognize the interaction between surface and groundwater. Groundwater depletion leads to a lack of freshwater flows and lack of freshwater recharge causes aquifer levels to become depleted and results in subsidence in many areas. While water may be in the ground at one moment, it can quickly move to the surface during its hydrological cycle. Groundwater and surface water are physically interrelated and are part of the same sequence. Underground flow from aquifers moves water, via springs, to sustain surface water, likewise, surface water, through recharge zones, fills underground sources. This interplay depends upon the geological conditions of the area (Hill Country Alliance Water Resource 2007).

Water is utilized for various purposes across the state that impacts every level of society. Rivers, lakes, streams, and wetlands are visible reminders of the available water but groundwater, stored in aquifers, is often a better indicator of available water. Existing water supplies state-wide are expected to decrease in the coming decades from roughly 17 million acre-feet in 2010 to 15.3 million acre-feet in 2060 a reduction of about 10%. The following will discuss the distribution and available resources in Texas for surface and groundwater.

Surface water

Surface water systems in Texas include rivers and streams, natural and anthropogenic lakes, springs, wetlands, and estuaries. Texas has very different climates depending upon the geography of the region (Figure 5). The water-rich east is humid and filled with pine woods, the Hill Country in central Texas is shaped by rivers and is home to coniferous and deciduous woods, the Northern Plans and Southern region are semi-arid and drought prone, and finally, the far west Trans Pecos region consists of the Chihuahuan Desert and is the driest location in the state (Bomar 1995). The state of Texas receives approximately 366 million acre-feet of rain annually that contributes to 191,228 miles of streams and rivers contained in 15 major river basins and eight coastal basins (UT Austin 1990). All told, nearly 11 million acre-feet of surface water are available for human use, and 65% of this is currently accessed (UT Austin 1990).

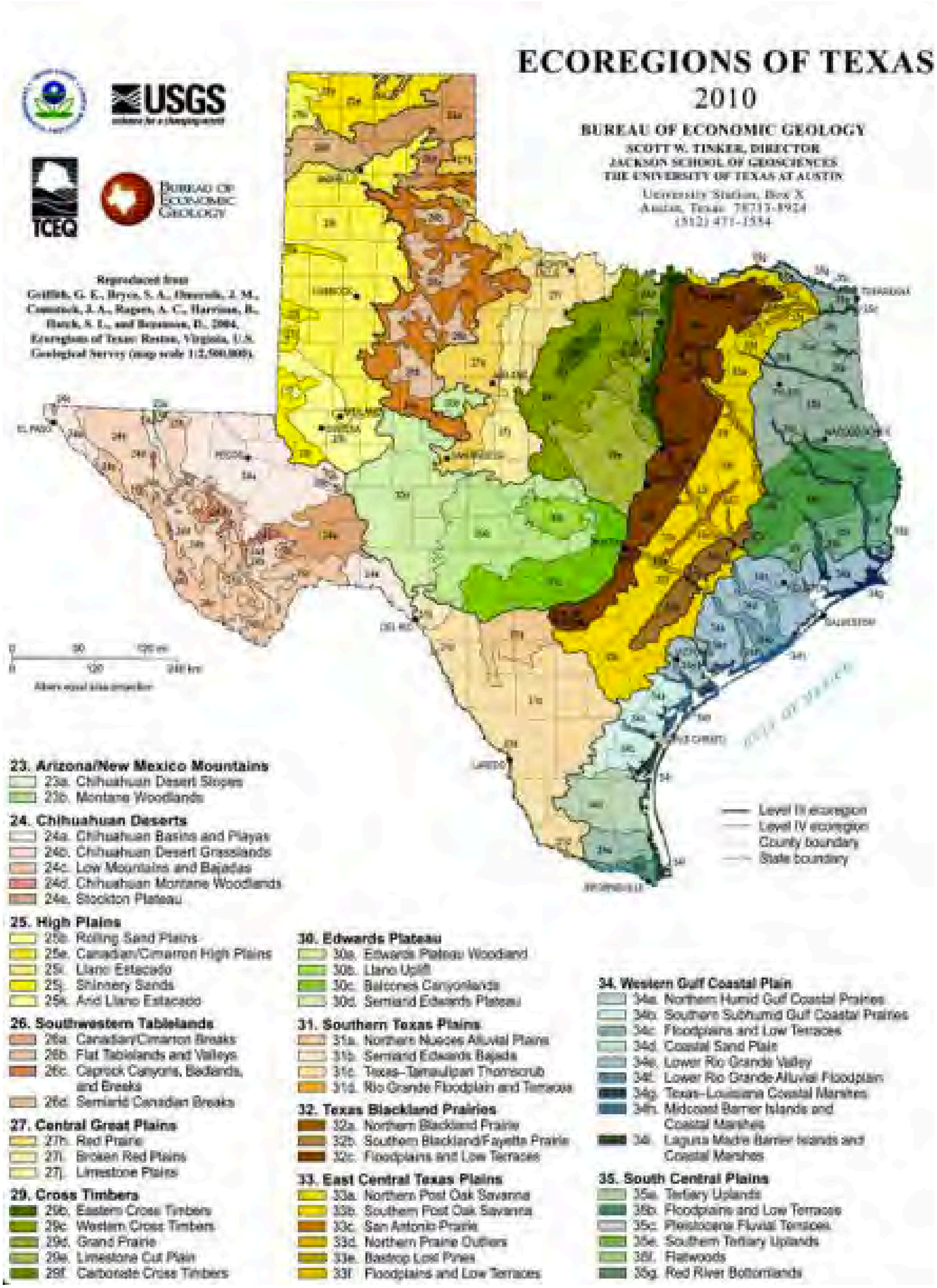


FIGURE 5: ECOREGIONS OF TEXAS (BUREAU OF ECONOMIC GEOLOGY 2010)

Surface water use comprises roughly 40% of the 16.1 million acre-feet put to use annually in the state. This comes from the states 15 major river basins and 8 costal basins, lakes, 191,000 miles of streams and rivers, and 7 major and 5 minor estuaries (Texas Water Development Board 2012).

The TPWD lists 177 locations that one would reasonable classify as a lake (Texas Parks and Wildlife Department 2013). Naturally occurring lakes do not occur in the state with the exception of Caddo Lake in East Texas, and even this location has had a permanent dam

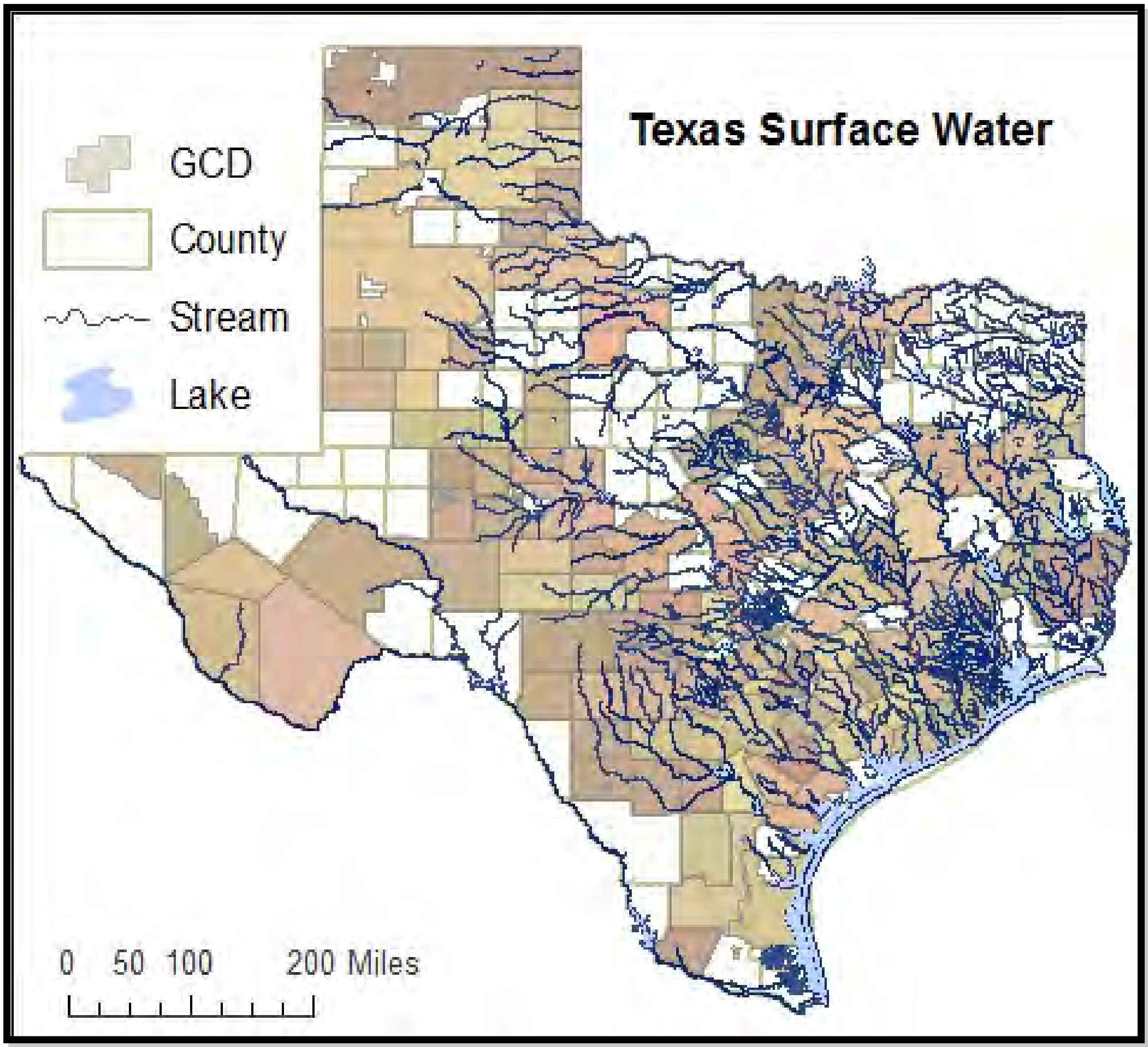


FIGURE 6: SURFACE WATER OF TEXAS (THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT 2013)

installed to prevent future difficulties. Due to the frequent, and often deadly, flooding that occurred around rivers in the 1930s and 1940s after rainfall the state officials began constructing dams in earnest. This created flood reservoirs that would collect overflow and offer other benefits in the coming decades (The Brazos River Authority 2013). While reservoirs were constructed to control damage from flooding they now play a major role with providing the state with a more robust water supply. More than half of the available surface water comes from anthropogenic lakes. These are capable of collecting water from storm run-off, rainfall, and floodwaters to be used during times of drought (Figure 7). Approximately 8.9 million acre-feet of the 13.3 million acre-feet captured from surface water come from these reservoirs. Even more dramatic structuring of dams and reservoirs was accomplished in the 1960s and 70s, but in recent decades the construction of new reservoirs has slowed (The Brazos River Authority 2013). Reservoirs play a pivotal role in surface water management in Texas because of highly variable streamflow and extreme weather patterns (Texas Water Development Board 2012). During times of drought or stress, water stored in these systems may provide relief from exceptionally dry conditions. A major reservoir is defined as having at least 5,000 acre-feet of storage capacity when at the normal operating level (Texas Water Development Board 2012). Reservoirs in Texas vary in size from 5,200 acre-feet (Upper Nueces Lake) to 4,472,900 acre-feet (Toledo-Bend Reservoir straddling Texas and Louisiana) (Texas Water Development Board 2012). There exist 15 major river basins, eight coastal basins, and approximately 191,000 miles of streams statewide (Figure 8). Surface water regulation has been evolving since Texas was first colonized, and modifications continue today.

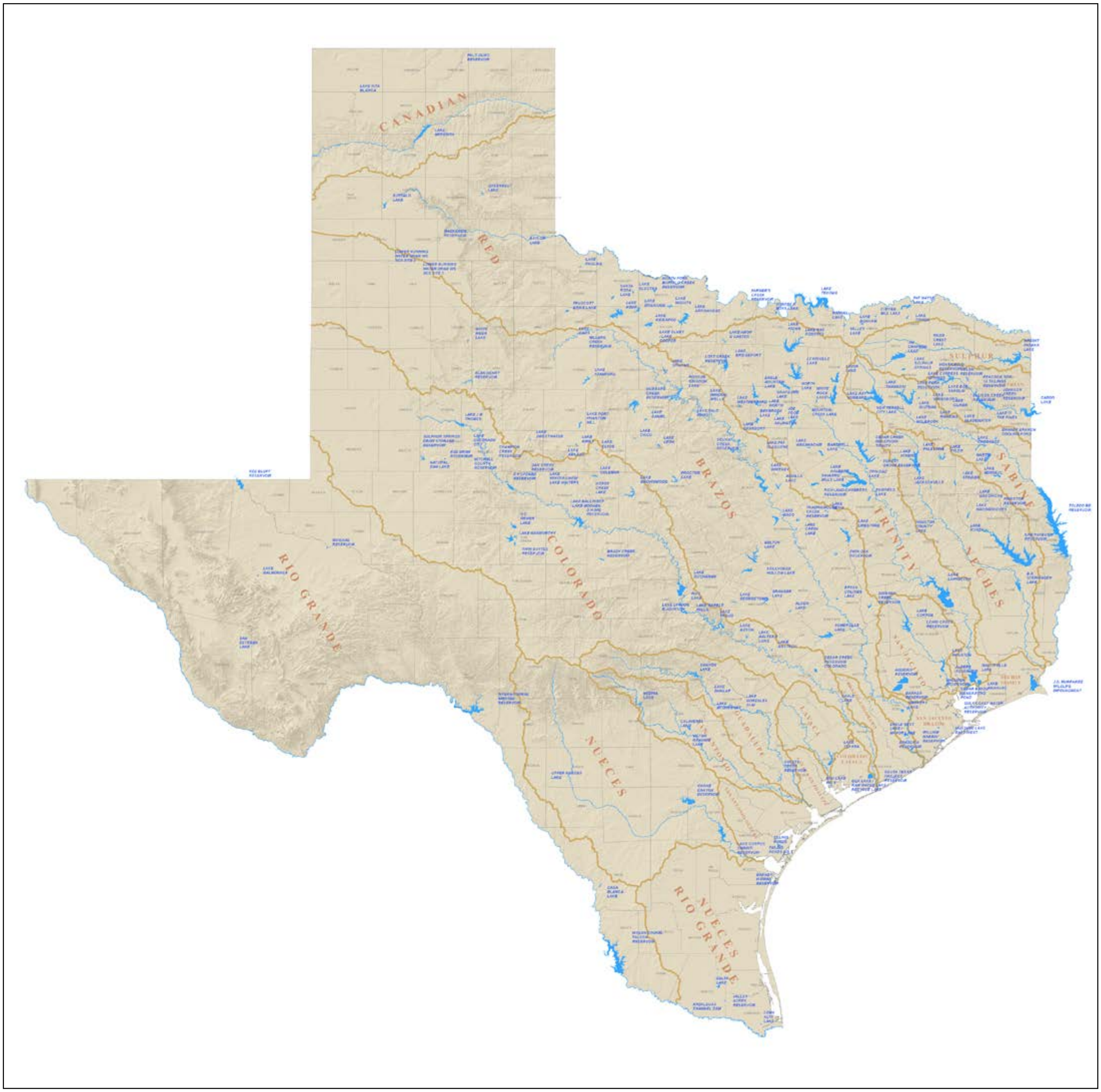


FIGURE 7: SURFACE WATER BODIES IN TEXAS (TEXAS WATER DEVELOPMENT BOARD 2013)

FIGURE 8: TEXAS RIVER SYSTEMS (TEXAS WATER DEVELOPMENT BOARD 2012)

Groundwater

Groundwater accounts for 60% of water-use and is a vital resource in all regions of the state (Figure 9). Groundwater is stored in nine major aquifers and 21 minor aquifers throughout the state and is greatly influenced by geological, anthropogenic, and weather patterns. Areas that have highly porous surfaces, such as sand and honeycomb karst limestone systems readily transfer water into aquifers and these areas are commonly known as recharge zones.

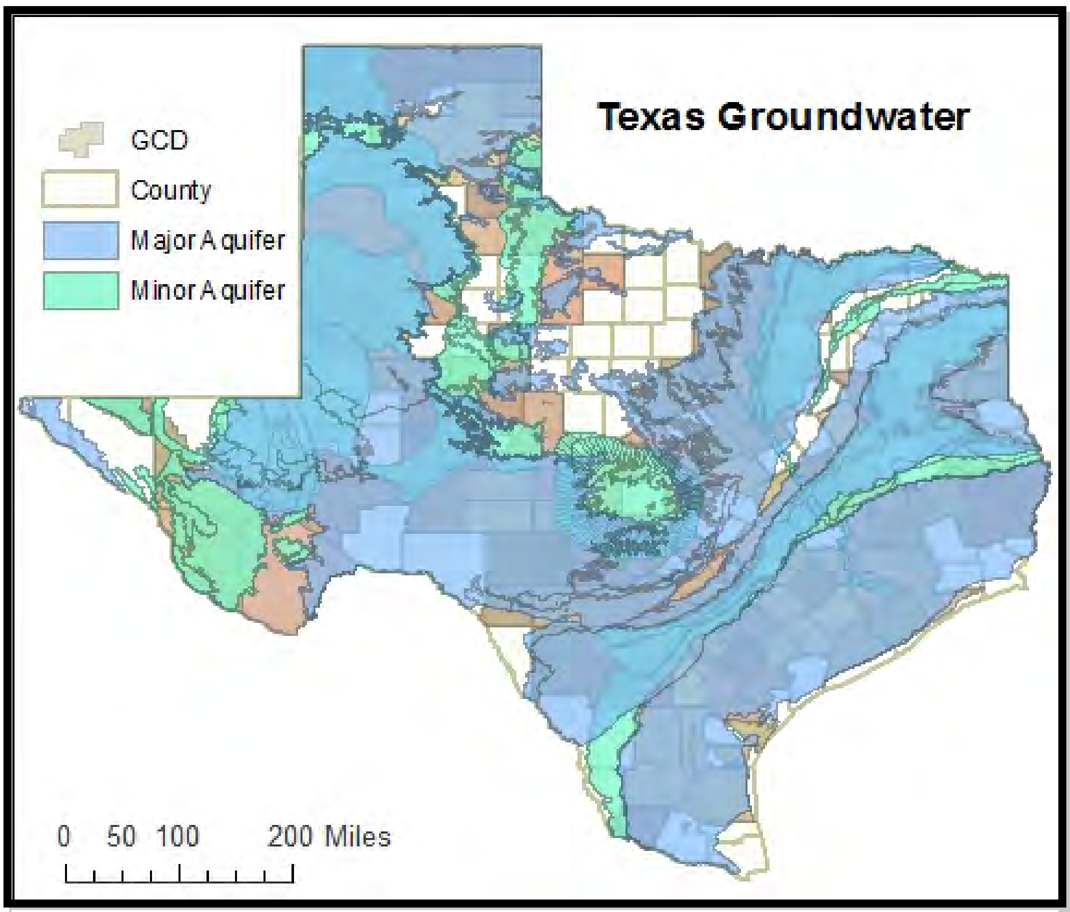


FIGURE 9 : TEXAS GROUNDWATER RESOURCES (THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT 2013)

Groundwater moves along flow paths of varying lengths from areas of recharge to areas of discharge (Winter, et al. 2002).

Monitoring subsurface resources is challenging not only because of the transient nature of its location, but also because of the large number of variables that come into play for recharge. Such matters affecting recharge include urban development (non-permeable surfaces), irrigation, weather and precipitation, and integrity of the area of the subsurface system (subsidence). Statistical modeling has been shown to be the most effective on assessing the quantity of underground sources. New methodology, such as those discussed in Appendix 2 of this document (equations 1 and 2), allow for a semi-comprehensive look at each aquifer and the effect that rivers, streams, precipitation, and pumping have on the short and long-term levels (Texas Water Development Board 2012).

The nine major aquifers in Texas are the Pecos Valley, Seymour, Gulf Coast, Carrizo-Wilcox, Hueco-Mesilla Bolson, Ogallala, Edwards-Trinity, Edwards, and Trinity (Figure 10). The three aquifers with the largest water supply are the Ogallala, Gulf Coast, and the Carrizo-Wilcox. The Ogallala Aquifer is the largest aquifer in the United States and spans several states and underlays much of the High Plains region of Texas. This system provides significantly more water for use than any other aquifer in the state and is vital for irrigating crops. Groundwater withdrawals in this region exceed recharge rates, and water levels have declined in most of the aquifer (Texas Center for Policy Studies 1995). All of these aquifers are vital for the longevity of the ecological conditions necessary to support a growing community in the state. Concerns have been expressed both currently and in past decades about pressures upon these systems including drought, population growth, and increased agriculture and industrial uses.

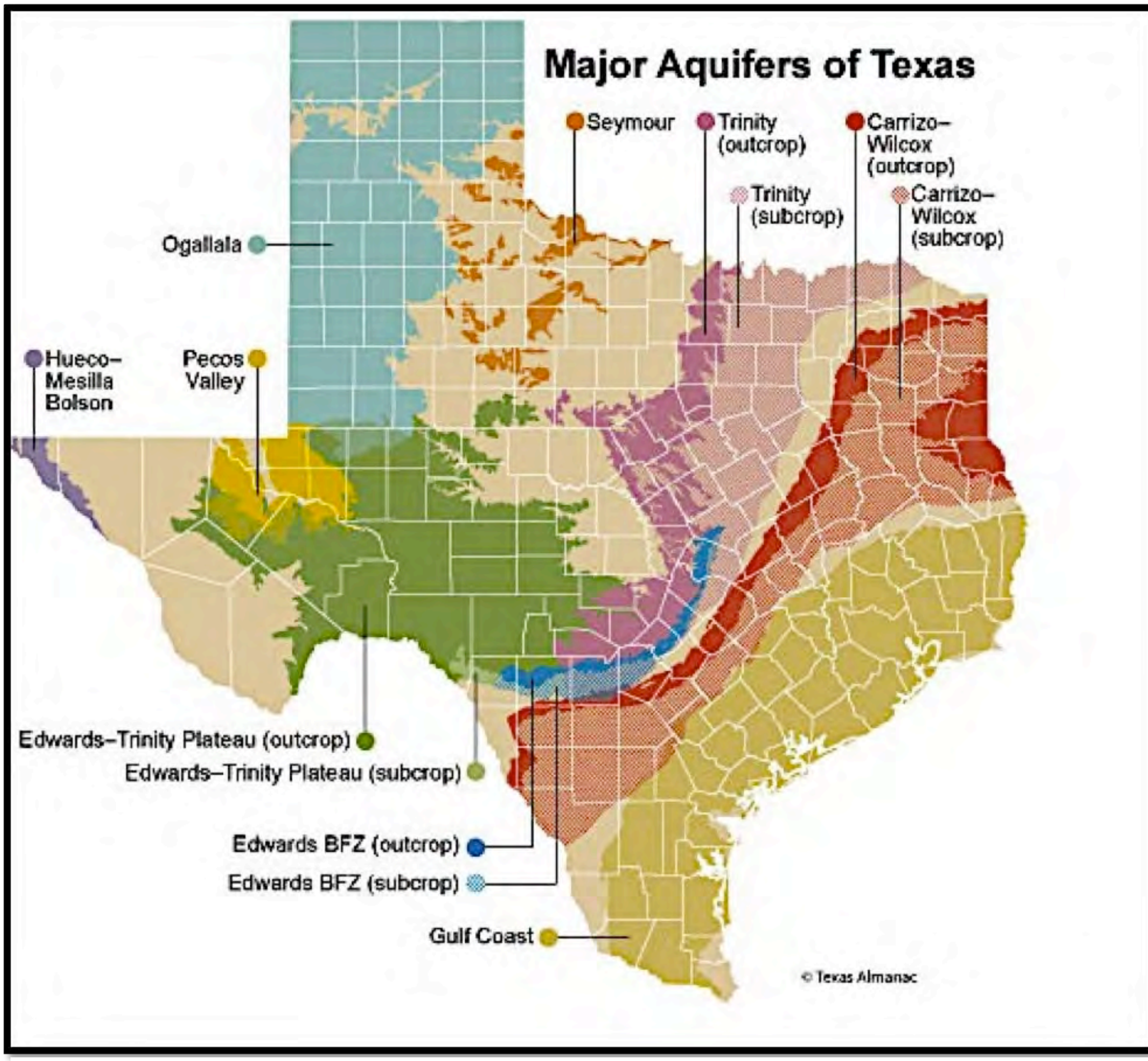


FIGURE 10: MAJOR AQUIFERS OF TEXAS (TEXAS HISTORICAL ASSOCIATION 2013)

The Gulf Coast aquifer is a system that extends from Florida to Mexico and lies beneath the entire Texas Coast. This is a culmination of several aquifers, including the Jasper, Evangeline, and Chicot aquifers, which are composed of discontinuous sand, silt, clay, and gravel beds. This aquifer has traditionally had pristine waters, but in recent years there have been declines in the quality and productivity. Large urban counties such as Harris, Galveston, Fort bend, and Jasper use this aquifer for municipal, industrial, and irrigation purposes and reports show historic drops in water levels by as much as 350 feet in these regions (Texas Water Development Board 2013).[10]

The Carrizo-Wilcox aquifer Extends from the Louisiana border to the border of Mexico. This aquifer is primarily composed of sand imbedded with gravel, silt, clay, and lignite. It is used primarily for irrigation but also serves municipal sources as well. Levels have declined for this aquifer in recent years as well, in large part due to municipal pumping from the northeastern parts of the aquifer. Although water pumped from this section of the Carrizo-Wilcox does contain mineral salts, the level of dissolved solids is not high enough to warrant concern (Mace and Petrossian 2011).

Conclusions and Analysis

Even though Texas has a wealth of sources of water from miles of rivers and streams, the large navigable lakes, and an immense display of underground aquifers they have all been placed under increased pressure over the last century (Texas Water Development Board 2012). Drawdowns in areas with increasing population and irrigation needs have been especially high, putting stress on the three largest aquifer systems in the state. The complex relationship between development and water present a challenge when developing appropriate policies to protect and utilize this resource. Surface water is owned by the state and is appropriated through a permit system based on prior appropriation; on the other hand, groundwater is owned by the private landowner and is based on rule of capture. Treating these two water entities as separate based on geographic location has been the traditional approach in the state.

The majority of subsurface water drawdowns occur in the Ogallala aquifer where more freshwater is available for use. Although current resources are plentiful, there is reason for

[10] Coastal Aquifer GAM report

concern as the amount diverted exceeds the reported amount available in this aquifer. The water management system in Texas does not support single-source monitoring techniques. Changes in both environmental and anthropogenic patterns across the state will increase the shift of surface water resources as climate changes and population increases and is redistributed. Groundwater stored in coastal areas is becoming increasingly salty as freshwater resources are pumped out to meet the demands of a growing coastal population. This problem is compounded by the amount of coastal agriculture taking place in the Texas Gulf Coast region. Coastal ranching and large operations inland require a large amount of water and runoff from farmland contributes to watershed eutrophication. While surface water is diverted and stored according to the way in which permits are received, this system appears to work well for water resources existing in a steady state. When resources are put under stress, water rights holders are forced to make sacrifices based on a first-come, first-serve system.

What we don't know

In order for legislators to develop effective policy for groundwater management strategies, it is vital that techniques for determining the existing amount of water in subsurface systems. Understanding how much groundwater is available will give landowners an idea of how much water should be conserved and where sensitive areas exist. The TWDB has been tasked with developing models to estimate the storage capacity of the aquifers across the state. Current efforts are in action for estimating both the capacity and the resources currently contained in the Hill Country (Appendix 2).

Take-away Points:

1. Unlike surface water, monitoring and regulation of groundwater by institutional actors is limited.
2. GMAs and GCDs are local zones in which groundwater management for specific watersheds is monitored. These and GCDs are established through the Texas Legislature and supported administratively by the TWDB.
3. The TCEQ has the ability to create PGMAs if an aquifer is in danger of overuse.
4. Agricultural irrigation uses groundwater resources very heavily.
5. Enhanced conservation and aquifer protection is provided through HB-2 and SB-1.
6. Maintaining quality of groundwater resources is also of concern with increased mining activity.

Section 4: Evolution of Groundwater Policy

History and Background

In 1904, the Texas Supreme Court set the precedent for groundwater rights by ruling in favor of the English common law system of ownership (often called the rule of capture or law of the biggest pump) in the *Houston and Texas Central Railroad Co. v. East* case (Houston and Texas Central Railroad Co. 1904). The High Court ruled that it was up to the State Legislature to pass groundwater legislation that would inform state policy. Historical rulings of the Courts on groundwater matters expressed the opinion that it is up to the Legislature to act in order to preserve the natural resources of Texas, and the Courts have continued to rule in favor of property rights in the absence of such regulation.

The rule of capture has been consistently upheld in court since 1904, with few exceptions. The first exception to this rule was the *Beckendorff v. Harris-Galveston Coastal Subsidence District*

(1977) case. In this court case, the Texas Supreme Court ruled to protect public welfare by limiting harmful pumping, which was causing ground subsidence of the land resulting in flooding. Up until the formation of the EAA, this was the only case that resulted in a ruling where protecting public welfare superseded the rule of capture (Beckendorff v. Harris-Galveston Coastal Subsidence District 1977). In 1993, the Texas Legislature passed Senate Bill 1477, creating the EAA. The purpose of this body includes data gathering, issuing permits for groundwater, managing withdrawals, and implementing drought management practices (The Supreme Court of Texas 2013). The formation of the EAA was necessary to prevent federal government interference and was tasked with protecting groundwater in the Edwards Aquifer. The EAA has the additional benefit of protecting the sustainability of the region's springs and, by proxy, the drinking water for nearly 2 million Central Texans.

Texas is the last western state that continues to use the rule of capture. However, the Texas Legislature has a long history of groundwater management regulation[11]. As previously mentioned, the Texas Legislature has created a system of 16 locally represented GMAs across the state. These GMAs create and implement regional groundwater management plans (Armbrister 1993). If an aquifer is in danger of overuse, the TCEQ has the authority to create a PGMA (Texas Water Development Board 2013). In addition to GMAs and PGMAs, the Texas Legislature has authorized nearly a hundred locally created and elected GCDs, which have the authority to oversee pumping and enact limits necessary for aquifer protection (Texas Commission on Environmental Quality 2013). Texas has several regulatory and planning agencies, commissions, and boards that oversee the finance, management, and enforcement of the laws and rules relating to the use of groundwater. The TWDB provides management,

[11] See section on Institutional Actors

oversight, and financial support to GMAs, GCDs, and others. The TCEQ is the enforcement arm of water quality and quantity concerns, and the Texas Railroad Commission oversees all waters used in mining and petroleum extraction (The Railroad Commission of Texas 2013). While there are policy conditions that need to be met state wide across all facets of water usage, irrigation, municipal and industrial uses makeup the vast majority of water used in the state and require special mention.

Irrigation

As a drought-prone state, crop irrigation is an absolutely necessary tool for agricultural production in Texas. Farmers can use irrigation to mitigate the effects of prolonged drought by pumping groundwater to improved crops. Improvements in technology and irrigation methods have resulted in groundwater utilized for irrigation is highly efficient compared to other applications. Texas agricultural irrigation use averages less than 18 inches per acre annually, compared to household applications that average twenty-two inches per acre. Furthermore, as can be seen in Figure 11, irrigated water use has remained near constant since the 1970's, while corn yields has increased 62%, and cotton yields have nearly doubled (Texas Water Resource Institute 2012).

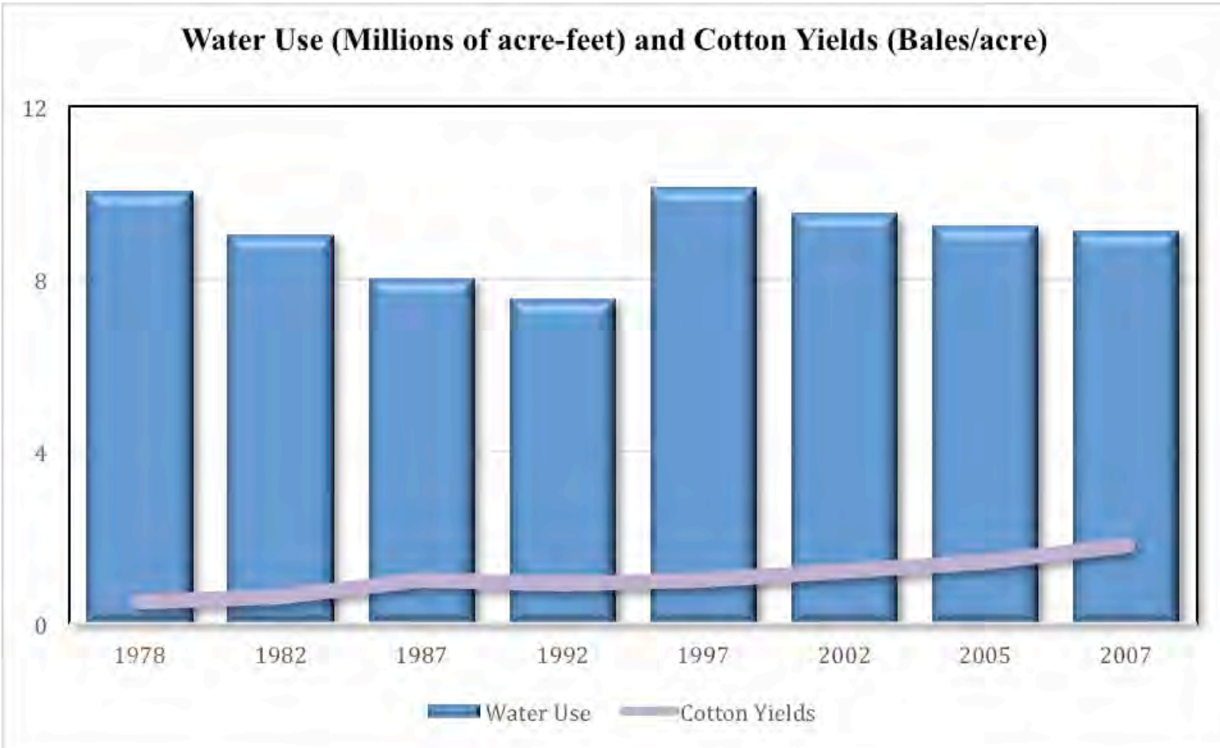


FIGURE 11: WATER USE AND COTTON PRODUCTION 1978-2007 (TEXAS WATER RESOURCE INSTITUTE 2012)

The economic value of irrigating crops cannot be underestimated. In 2007 an estimated $4.7 billion in value was attributed directly to agricultural irrigation. Over the years, the shift to increasingly water- efficient systems, such as center pivot sprinkler systems and subsurface drip irrigation, has reduced water consumption compared to output but it still uses roughly 57% of all water utilized in the state.

Municipal

Municipal water use is of particular concern for policymakers and citizens alike, as Texas' population is growing at a rate that far exceeds the national average (Weissmann 2012). Growth in municipal water-use is expected to almost double from 4.9 million acre-feet in 2010 to 8.4 million acre-feet in 2060 (Texas Water Development Board 2012). Water projections for municipal use have been of concern for over a decade and as a result of this, the 75th Texas Legislature passed a comprehensive statute that attempts to address statewide water concerns. The first attempt was House Bill 2 (HB-2) in 1985, which stated in broad terms that water conservation planning could be required from the Texas Water Commission; Senate Bill 1 (SB-1) took effect on September of 1997[12]. SB-1 began the foundation for effective monitoring and developing of future plans to ensure quality and quantity of water resources by mandating conservation plans that are designated and overseen by the TWDB.

With the implementation of SB-1 certain provisions for giving permits for transferring groundwater out of a district were put in place. These include certain variables to be considered such as; the availability of water in the district, how the water is to be used, projected effect on the aquifer and alternative import proposals. Although these individual policies affect water districts, there is no overarching state rule regarding groundwater use and extraction (Hardberger 2008). In many parts of the state to meet the increasing demand of water consumption municipalities engage in groundwater marketing[13].

Industrial Water Use

Industrial water use, and the potential for conservation techniques, varies by the nature of the industrial pursuits. This is due to the variation in the purpose for water usage by industrial processes[14]. Furthermore, it is unclear what the law requires for certain activities such as hydraulic fracturing that both uses groundwater as well as pumps water solutions into the ground. Certain permits may or may not be required for these types of endeavors. Examples of

[12] See section on Environmental Flows
[13] See section on Water Marketing.
[14] See section on Energy-Water Nexus.

industrial and manufacturing uses include petroleum refining, paper production, metal manufacturing, and chemical production. The use of groundwater is often utilized alongside surface water (Texas Water Matter 2013).

This variation underscores the importance of implementing and developing Best Management Practices (BMPs). Experts in various branches of water resource conservation, including irrigation, commercial and municipal water, and commercial use supply recommendations for conservation practices to Regional Water Planning Groups (RWPGs), water users, and water providers. The TWDB, TCEQ, and the state maintained Texas Water Advisory Council work with stakeholders to maintain updated lists of BMPs for local stakeholders. Identified BMPs bring together the best available data on what reduces water use and also decreases the chances of water contamination. TCEQ recommends certain BMPs for specific point and nonpoint sources of water pollution that can be adopted by players utilizing the water source (Texas Commission on Environmental Quality 2013).

Recent Policy Developments

In 2011, during the 82nd session, the Texas State Legislature passed, SB- 332, which states that landowners have a vested ownership interest in the groundwater beneath their property. This bill affirms that landowners have a vested interest in the groundwater under their land, and therefore they have certain constitutional protections from unreasonable regulations or ‘takings’. Previous to this, the right of ownership was realized when the water was actually captured. The first court case to test this new law was the *Edwards Aquifer Authority (EAA) v. Day and McDaniel* case, and while it was determined that landowners do have a vested interest in groundwater under their land, the court has yet to decide if a constitutional taking occurred in this particular case. With these changes, landowners now have ownership of subsurface groundwater and do not have to pump in order to acquire ownership. This seemingly subtle change in the language of the law could potentially hinder GCDs from creating adequate pumping restrictions, which could greatly alter the ability to preserve future supplies. The ramifications of this legislative action are still being sorted out in court cases across the state.

Conclusions and Analysis

The history of court precedents in defining groundwater rights has established the reasoning for Texas to remain the last western state to adhere to the rule of capture. Water use, particularly groundwater use, and policy is manifested in three fundamentally different venues; irrigation, municipal or urban use, and industry. All told, Texas' groundwater is stored in 32 aquifer systems, yet 97% of that is from only nine, supplying the three users (Texas A&M 2013). Irrigation, the largest user of water in Texas, has experienced great efficiency standards reducing its volume of water per acre while simultaneously increasing crop production. Because many Texas irrigators use groundwater, contributing to the estimated 80% of groundwater use in the state, such practices are increasingly important in future water resource supply (Texas A&M 2013). An interesting point on water policy and irrigated agriculture is the fact that most farmers are utilizing such increased efficiency without policy mandates (Kalisek 2013). This type of use generally influences the economics of farmer's business as well as conserves our most precious resource.

In municipal use the general issues are those seen with increased population. Texas is seeing a surge in new residence construction, and according to the 2012 State Water Plan, municipal water use will almost double by 2060 (TWDB). An interesting case with urban water use is the availability for incentivized and or mandated conservation practices. Unlike an irrigated field, a homeowner uses water at a limited rate. Yet, the number of homes and other buildings found in a concentrated area provide municipalities with an increased level of water demand per acre.

Thus, expectations for adopting progressive conservation methods is not bound by and economic bottom-line as it is for farmers and ranchers, but rather requires specific strategies to be successful. In the City of San Antonio, a city fully reliant on groundwater for municipal use, the San Antonio Water Service (SAWS) has demonstrated the success of conservation initiatives. Although the population doubled between 1987 and 2007, total city water use remained relatively unchanged (Opp 2010).

Of concern regarding water use and contamination is hydraulic fracturing, a specific industry reliant on groundwater availability. Currently, the Texas Water Code exempts oil and gas exploration in the permitting process. Concerns for future water availability and unknown factors surrounding this booming industry magnify the suggestion that such activities are currently unpermitted and relatively unmonitored. Yet, despite the massive volume of water these sites pump, the relative percentage of overall use remains low. Despite this, a growing concern for regional safety and water security could suggest further exploration into potential overall withdraws industrial use of water in mining natural resources could have on the states groundwater supply.

Through the various ways in which Texas groundwater is being removed and used, governing structures have yet defined a way to properly manage such a “mysterious and occult” (East v. Houston) resource. Despite recent measures to establish conservation based governing bodies, a long-lasting and effective measure will be left to the people of the state to decide.

Section 5: Evolution of Surface Water Rights in Texas

Take-away Points:

1. The State is responsible for regulating and allocating surface water rights
2. Texas surface water rights policy functions through the Prior Appropriations doctrine and riparian rights
3. Senior water rights holders in a river basin have priority for use during times of stress over junior rights holders.
4. The TCEQ OW is the office responsible for enforcing compliance regarding water use.
5. There exist three watermaster programs in Texas that maintain water rights management.

Background

Water law has changed multiple times over the years since Texas became a state, which has led to numerous conflicts between the competing legal systems and approaches across the United States. Texas manages surface water as a dual-doctrine state, utilizing Spanish water law and English riparian rights (Templer 2001). The state is responsible for surface water management allocation. In contrast with views held by the scientific community that water is a single entity within a continuous cycle; the Texas legislative system divides water into classes through which the resource can be regulated. Groundwater management, as has been previously discussed in this document, is not nearly as broad or complex as surface water regulation. Intricate water marketing management, interbasin transfers, and a complicated appropriations process managed through regulatory agencies results in a multi-faceted management system.

History of Water Rights in Texas

Prior to adoption of the English system of riparian rights, surface water doctrine in Texas was based on the Spanish riparian rights system that granted use of water to those who owned land through which a surface water system flowed (Templer 2001). Spain had sovereignty in Texas until 1821. Surface water legislation under this system was first enacted in 1889, but extends back to the conquest of Mexico in 1519 (Brown n.d.). Under Spanish law, land was classified and priced according to its prescribed use: irrigation, dryland farming, or pasture land. Irrigable land was also granted a measure of water with its sale; so naturally, this was the most expensive land available for purchase while pastureland was the cheapest. In order to have land classified as irrigable, a landowner was required to pay a significantly higher price for it. Thus, after the revolution, few established irrigation water rights were found in Texas (Brown n.d.).

The system in use now that has replaced Spanish riparian rights is based on English common law and ties the rights to use surface water to land ownership. Riparian water rights holders may use water flowing through a river as long as they own the land adjacent to the water. The prior appropriation doctrine is controlled by statute and is more often recognized in the western states. In this doctrine, surface water use is not tied to land ownership, but can only be used by complying with statutory requirements (Kaiser 2005).

In 1967, the Texas Legislature merged the riparian rights into the prior appropriation doctrine with the passage of the Water Rights Adjudication Act. This required anyone seeking riparian ownership of surface water to apply for it before 1969 or it would be converted to prior appropriation. Consolidation of rights requires permission from the state to utilize surface water even on your own property in the form of a water right. These rights are given out in the form of permits and are reviewed by the TCEQ. The state owns all surface water, including every river, natural stream, lake, bay, and the arm of the Gulf of Mexico (Kaiser 2005).

Water Rights Permitting

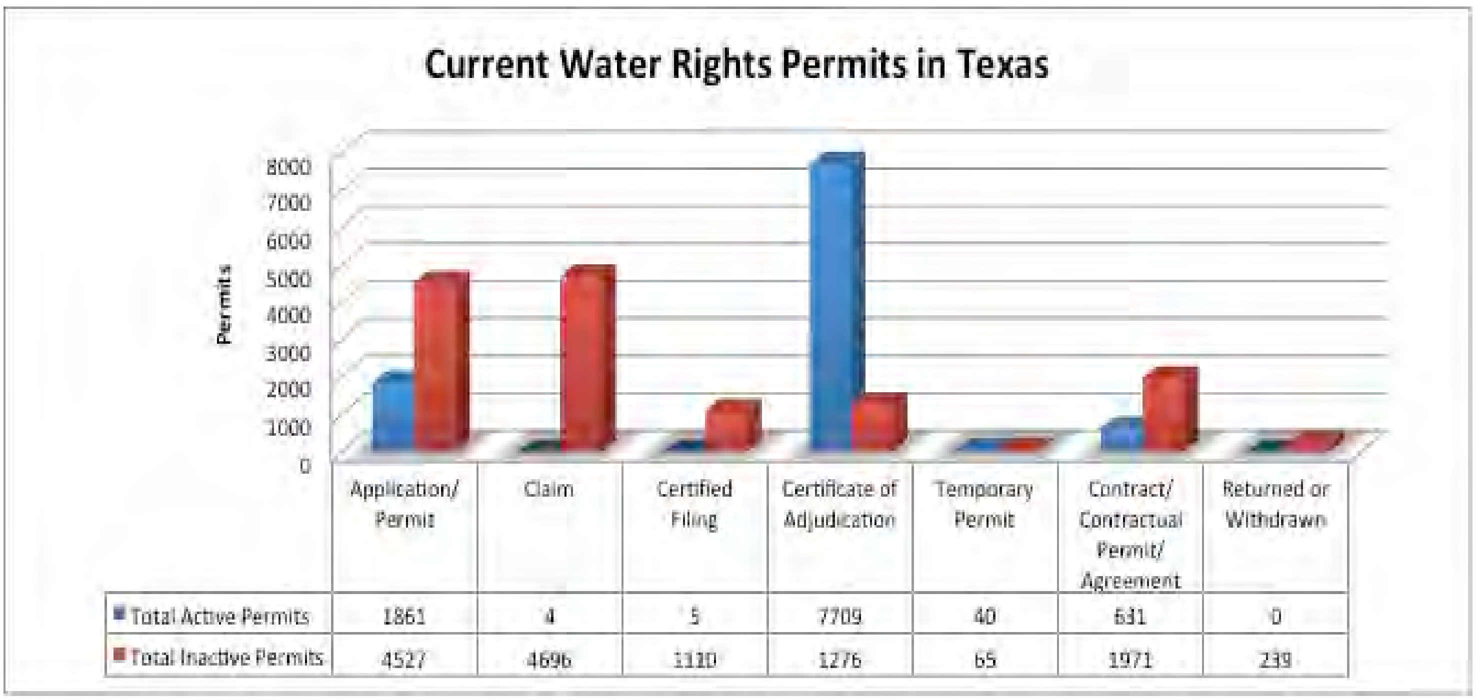
During Texas' history, conflicting surface laws that were still in existence from the Spanish system often led to confusion regarding resource rights. In 1967, the TWC (predecessor of the TCEQ) attempted to ameliorate the confusion by issuing certificates of adjudication for approved claims of existing rights (Texas Commission on Environmental Quality 2009). Claimants had to show the following in order to be approved for use of an existing surface water right:

- "That they had used a certain amount of water at a specified rate, for certain purposes from the stretch of a river, stream, or reservoir; and
- The date that they had first used the volume of water" (Texas Commission on Environmental Quality 2009)

Each certificate was assigned a priority date that depended on when the water use first occurred. This process is nearly complete[15] with Texas courts having awarded 10,000 claims since 1967. Texas Water Law[16] states that new permits may only be issued "only if water is available to satisfy other water rights and still meet new demand" (Texas Commission on Environmental Quality 2009).

[15] Water rights in the Upper Rio Grande Basin have not all been adjudicated.
[16] Texas Water Code, 11.134(b)(2).

Today, surface water rights are acquired through permits and do not require judicial review, but it is permitted. An appropriated water right is one that has been documented and is on-file with the TCEQ (Texas Commission on Environmental Quality 2009). Once water rights are received it can be lawfully acquired, allocated, or used, even if it diverts the flow from its natural channels. Surface water rights can be given out in either a perpetual manner, meaning the use has no time limit, or a limited-term right, which includes seasonal or temporary usage. Over 10,250 water rights are currently active statewide and another 13,645 are listed as inactive permits (Figure 12 and Figure 13).



	Application/ Permit	Claim	Certified Filing	Certificate of Adjudication	Temporary Permit	Contract/ Contractual Permit/ Agreement	Returned or Withdrawn
Total Active Permits	1861	4	5	7709	40	631	0
Total Inactive Permits	4527	4696	1110	1276	65	1971	239

FIGURE 11: ACTIVE WATER RIGHTS IN TEXAS (TEXAS COMMISSION ON ENVIRONMENTAL QUALITY 2013)

Surface water supplies available as of 2010 equal nearly 8.4 million acre-feet and are projected to increase to nearly 9.0 million acre-feet in 2060 (Texas Water Resources Institute 2011). This is the amount of surface water remaining after the current 45 million acre-feet that have been adjudicated and appropriated to water rights holders in Texas[17]. The increase in resources projected by the TWDB is a result of new plans to add contract expansions to existing supplies

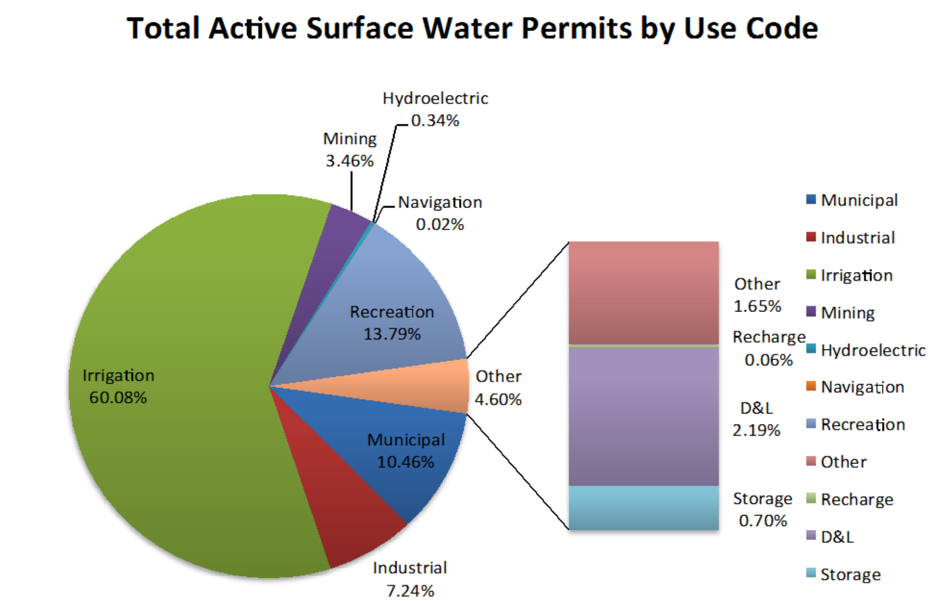


FIGURE 12: WATER RIGHTS BY USE (TEXAS COMMISSION ON ENVIRONMENTAL QUALITY 2013)

only when needed and to offset sedimentation in reservoirs (Texas Water Development Board 2012). Water rights sold in the form of a temporary contract by a water rights holder to another entity may be counted twice – once for the owner, and once for the temporary permit holder (Texas Commission on Environmental Quality 2009). Also, the use of water allocated depends on the amount available for use.

[17] The Adjudication Act of 1967 merged riparian and appropriation systems together on a statewide basis. This Act consolidated all previously existing surface water permits into a unified system (Texas Water Development Board 2003).

Statewide, irrigation is the single greatest use of water equaling more than 10 million acre-feet of total water, or 60% of all water use (Figure 13). However in active surface water permits, irrigation only accounts for less than 5 million acre-feet while municipal permits, although fewer in number, account for more than 16 million total acre-feet (Figure 14).

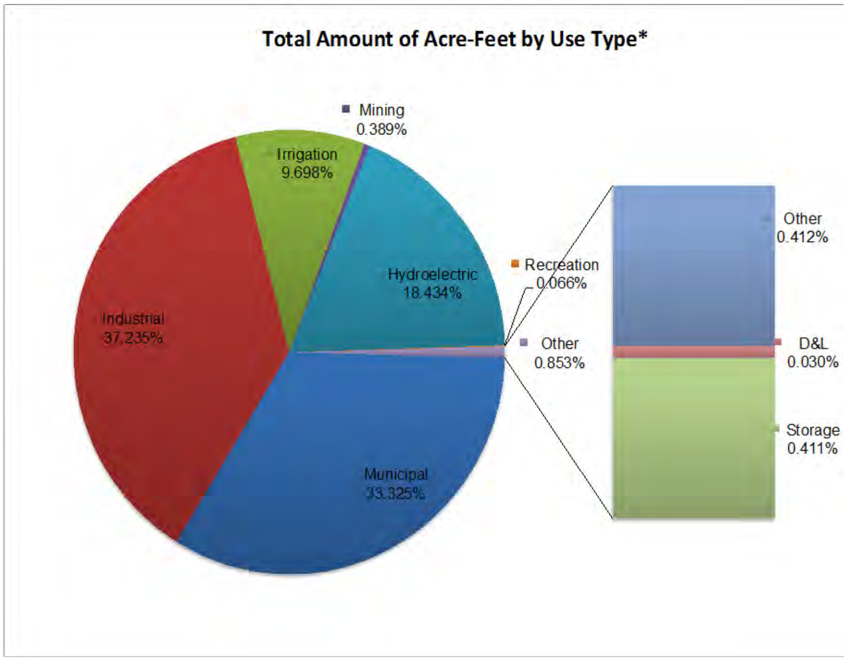


FIGURE 13: ACRE FEET BY USE CODE FOR ACTIVE PERMITS AS OF AUGUST 2013 (TEXAS COMMISSION ON ENVIRONMENTAL QUALITY 2013)

*Note: Acre-feet for recharge and recreation uses is negligible. See Appendix 1.

Priority During Water Shortages

Although it is commonly believed that type of use determines when water may be cut off during a shortage, this is most often not the case. Priority of use is only determined by type in the Middle and Lower Rio Grande Basin for resources stored in the Amistad and Falcon reservoirs

(Texas Commission on Environmental Quality 2009)[18]. During a shortage, municipal and industrial rights users drawing water from these reservoirs take precedence over irrigation rights.

In other areas, water stored in a reservoir upstream can provide relief for water users in a river basin during times of shortage. However, water legally stored by reservoirs belongs to the holder and is theirs to do keep. If a reservoir does choose to release that water during a water shortage, they may choose to do so under a *bed-and-banks authorization*[19] from the TCEQ (Texas Commission on Environmental Quality 2009). Water rights holders downstream from a large reservoir that receive flow once it is released may legally receive water from the inflow if the following criteria are met (Texas Commission on Environmental Quality 2009):

1. A user is not receiving appropriated flow;
2. The reservoir impoundment right is junior to a downstream water holder right;
3. Flow coming into the reservoir is greater than the flow passing through the dam;
4. Water can reach the rights holder under current stream conditions if permitted to pass; and
5. Other users with senior rights in the basin can receive their appropriated amount of water.

Water rights distributed in the form of contracts or permit agreements are rights held by another party that are temporarily given to another individual or company. This is the total amount of water permitted for diversion in acre-feet per year for the state of Texas. Each month, changes to the list of water rights are made and new rights are added or statuses of current rights are updated.

All water rights have a priority date for use that is assigned **when a right becomes active**. Senior water rights holders have priority for water diversion than those with junior rights and so it is necessary for all water rights holders to know who is located where in a river basin. An

[18] See section on Transboundary Water
[19] A bed-and-banks authorization is a permit that allows the use of a river, creek, or other type of watercourse to transport water without losing the right to it (Texas Commission on Environmental Quality 2009).

individual with a senior diversion rights must be assured their appropriated water. Junior water rights holders in a river basin must be familiar with all existing senior rights holders downstream so that they may ensure that enough water reaches other rights holders (Texas Commission on Environmental Quality 2009). Senior water rights holders may insist on junior rights holders reducing the water that they divert. Limited-term rights holders are at the very end of the line regarding diversion rights behind all perpetual and exempt use water users.

Limited-term Rights - Limited-term rights are permits that may be issued to maximize use of state waters in basins where the water supply is fully appropriated but not used. These rights may be useful to a municipality in order to ensure that enough water is available for future development. Limited-term rights are also some of the first to be lost during times of drought and environmental stress.

Temporary Permits - The TCEQ issues nearly 200 temporary permits each year. Temporary permits are issued by the TCEQ for up to three years and are usually released for road-construction projects. Water is used to “suppress dust, to compact soils, and to start the growth of new vegetation” (Texas Commission on Environmental Quality 2009).

Generally speaking, all surface water use requires permission in order to use it, except in very specific circumstances (Texas Commission on Environmental Quality 2012). The exempt uses, according to the Texas Water Code, include four categories. First, Domestic and Livestock (D&L) use, which includes irrigation and watering livestock, is acceptable without state permission as long as it utilizes 200 acre-feet or less of water in a consecutive twelve-month period. Second, wildlife management programs may take surface water for use in a dam or reservoir for the purposes of wildlife betterment, as long as it does not exceed 200 acre-feet of water. Third, emergency use is permitted for fire departments to utilize the water during wildfires or a similar event. Lastly, there are many items that fall under specified uses, such as water in fish or shrimp farming or retaining water with spreader dams or terraced contours. Under these conditions, a permit is generally not needed. However, if an activity such as terracing or shrimp farming may add contaminants or sediment to a water body, a water permit may be needed (Texas Commission on Environmental Quality 2009). The TCEQ does not currently keep track of the amount of acre-feet for exempt uses (See Appendix 1).

Water Rights Permitting Based on Availability - Although the purpose and nature of appropriated water rights may differ, all of these have some basic features in common.[20] Whether or not a surface water right is issued depends on whether or not a stream or reservoir has sufficient supplies to meet an increase in demand. The TCEQ has general guidelines that are used to determine whether or not a right may be issued[21]:

1. Generally, if the historical record shows that water in a body is expected to be available 75% of the time, the right will most likely be issued.
2. Municipalities will usually only be issued a permit if historical records show that water is expected to be available 100% of the time, unless a backup source is available.
3. If a water user has access to a back-up supply of water, the TCEQ may issue a permit to use water expected to be available less frequently (Texas Commission on Environmental Quality 2009).

All perpetual water rights are assigned a *priority date* that determines their place in line for that water right. This differs from the definition of priority date given to existing water rights. When dealing with new permits, the priority date is the day when an application is administratively complete. This means all of the necessary information focusing on water availability is ready for review (Texas Commission on Environmental Quality 2009). There is a common misconception

[20] Specific legal information on water rights can be found in the Texas Water Code (especially Chapter 11) and Title 30, Texas Administrative Code, Chapters 295 and 297.

[21] This process applies to applications for new permits only.

that priority for water use is based on type of use, but this is not necessarily the case. The purpose of use determines priority only in the Middle and Lower Rio Grande Basin, but only for water stored in the Falcon and Amistad Reservoirs. In this case, municipal use has a higher

Water Rights Permitting by River Basin - Water rights uses vary greatly depending on the geography and variation of industry in river basins statewide (Figure 15). The majority of surface water permits are clustered in areas with high amounts of industrial activity, municipal centers,

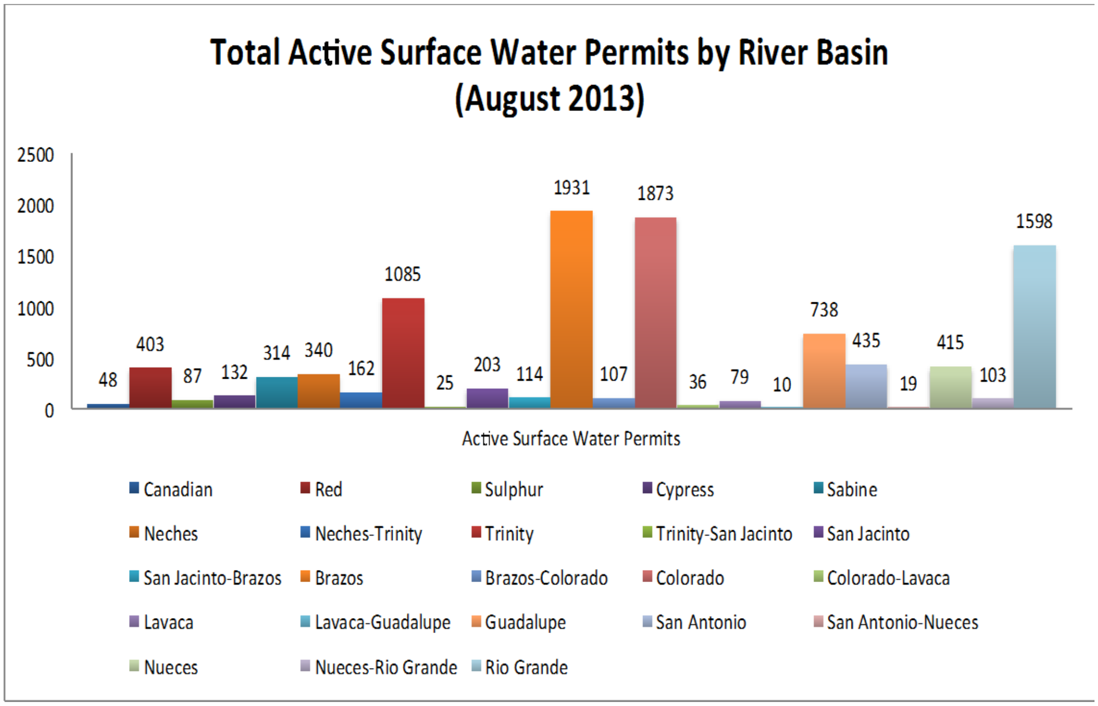


FIGURE 14: ACTIVE WATER PERMITS BY RIVER BASIN (TEXAS COMMISSION ON ENVIRONMENTAL QUALITY 2013)

and agriculture. In many river basins with growing populations and an increase in drought, the over allocation of water resources results in a reduction of water resources that contribute to the ongoing existing of riparian species, many of which are endangered or threatened. [22]

[22] See section on Environmental Flows.

As expected, the majority of acre-feet associated with active water rights are allocated in Regional Water Planning Areas (RWPAs) containing major metropolitan centers, advanced industry, and agricultural activity (Figure 16). Counties located in river basins that run through

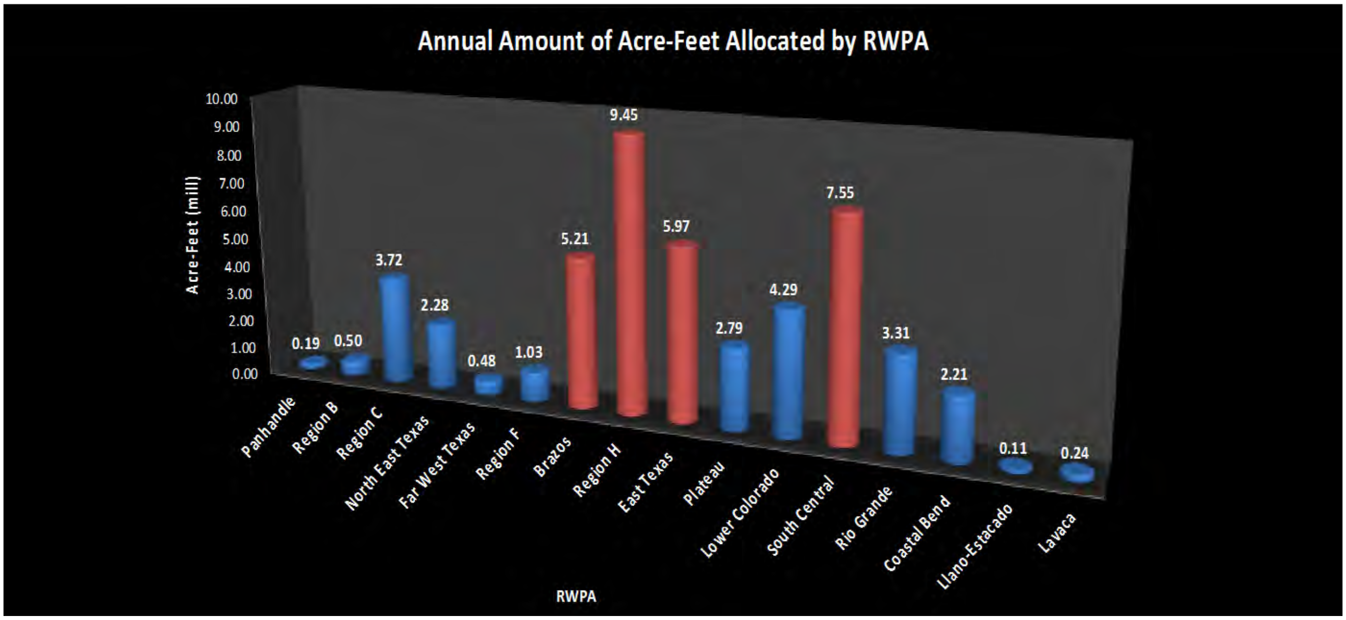


FIGURE 15: RWPA WITH HIGHEST AMOUNT OF ACRE-FEET DIVERTED (TEXAS COMMISSION ON ENVIRONMENTAL QUALITY 2013)

these regions contain a majority of the population including some of the fastest growing cities both state and nationwide (U.S. Census Bureau 2013). Texas contains eight of the 15 fastest growing cities in America (Table 1) and nearly all of them, with the exception of Midland, are located in central or east Texas. Houston, Texas, located in Region H along with Galveston experienced the second largest increase in population next to New York City from 2011-2012 and is expected to continue growing (U.S. Census Bureau 2012).

Although the actual number of surface water permits actually active in the San Jacinto, Trinity-San Jacinto, and Neches-Trinity river basins are not as many as those in the Brazos, Colorado, and Trinity river basins, the actual amount of acre-feet being diverted in Region H is the highest out of all RWPAs. In the humid coastal plain region, the majority of water diverted is for recreational purposes to support water-related activities. In central and west Texas, surface water permits within the Colorado and Brazos river basins are mostly purposed for irrigation and industrial uses.

TABLE 1: FASTEST GROWING CITIES IN TEXAS

Rank	Area Name	State Name	Percent Increase	2012 Total Population
1	San Marcos city	Texas	4.91	50,001
3	Midland city	Texas	4.87	119,385
4	Cedar Park city	Texas	4.67	57,957
7	Georgetown city	Texas	4.21	52,303
10	Conroe city	Texas	4.01	61,533
11	McKinney city	Texas	3.95	143,223
12	Frisco city	Texas	3.92	128,176
13	Odessa city	Texas	3.83	106,102

Water Rights Enforcement

The TCEQ Office of Water (TCEQ OW) contains four divisions: 1) The Water Quality Planning Division, 2) The Water Quality Division, 3) The Water Availability Division, and 4) The Water Supply Division (Texas Commission on Environmental Quality 2013). The TCEQ requires that all water rights holders be in compliance with regulations. It is important for water permit holders to keep in mind that the state of Texas prohibits wasteful water use, and that such conduct can result in a lawsuit. Any water rights holder who is not in compliance is subject to investigation from the Office of Compliance and Enforcement (OCE). This office is responsible for ensuring that all water rights holders remain within the boundary of responsible water and legal water use. If a water rights holder is not receiving the amount of water that they have been appropriated, they may request that water users upstream decrease their diversion.

Each water user with an appropriated water right may determine whether surface water is available to them at any given time by determining what other water users exist within their river basin. All D&L users with senior division rights in a basin are entitled to their share of allocated water. If, for example, a senior D&L rights holder living downstream from a junior holder is not receiving his share of water, he may then request that the junior rights holder decrease his use (Texas Commission on Environmental Quality 2009). This seniority is determined by when rights are distributed (priority dates). Texas' waters are protected in two different ways: the honor system and via the TCEQ watermaster program (Figure 17).[23]

The Honor System

The "honor system" promotes the idea that individuals holding surface water rights in a basin without a water master will obey the conditions of their water rights. This is advantageous because it does not require constant vigilance on the part of the state, which reduces costs and paperwork. Typically, in areas or times of the year when water is plentiful, the honor system seems to be adequate for most parties involved. Individuals who abuse and misuse their water without seeking out permission from the state or who violate the permits already obtained for overuse or diversion of flows are the most obvious and challenging disadvantage to this system. This is especially pronounced in drier areas or during times of drought. Unfortunately, the honor system can at times end up costing the state and other users access to surface water (Texas Water

[23] Refer to the section on Coastal Water Policy.

Development Board 2012). Perpetual appropriated water rights are property rights; therefore those who hold them can enforce them in court.

Obtaining proof of misuse of rights and water appropriation is often difficult to do. Common complaints filed with the TCEQ for rights holders operating under the honor system are that upstream junior-right holders are diverting and impounding water that should be released to downstream holders, and that purchased water flowing from a seller's reservoir is being diverted by other users instead of making it to the buyer's diversion point (Texas Commission on Environmental Quality 2013). Legal action and enforcement of water rights is easier to do in river basins with a watermaster.

Texas Watermaster Program - Under section 11.325 of the Texas Water Code, a water division can be created to protect water rights holders that may be overseen by a watermaster (Texas Commission on Environmental Quality 2013). Texas currently has three watermaster programs in operation: the South Texas watermaster area, the Concho River area, and the Rio Grande area (Figure 17). The two older programs, Rio Grande Watermaster (established in 1956) and the South Texas Watermaster Program that was created in the late 1980's have been responsible for coordinating diversions and regulating reservoir release. In 2005, a Watermaster Advisory Committee was appointed for a third area, the Concho River watershed. Such programs are established through the executive director of the TCEQ who is responsible for establishing a Watermaster Advisory Committee for each watermaster program in the state. These programs have been founded under amendments made to the Texas Water Code[24] in 1997, which resulted in the creation of Watermaster Advisory Committees for the two existing watermaster areas in 1998: the Rio Grande Watermaster Committee and the South Texas Watermaster Committee.

[24] Texas Water Code Section 11.326-11.3291

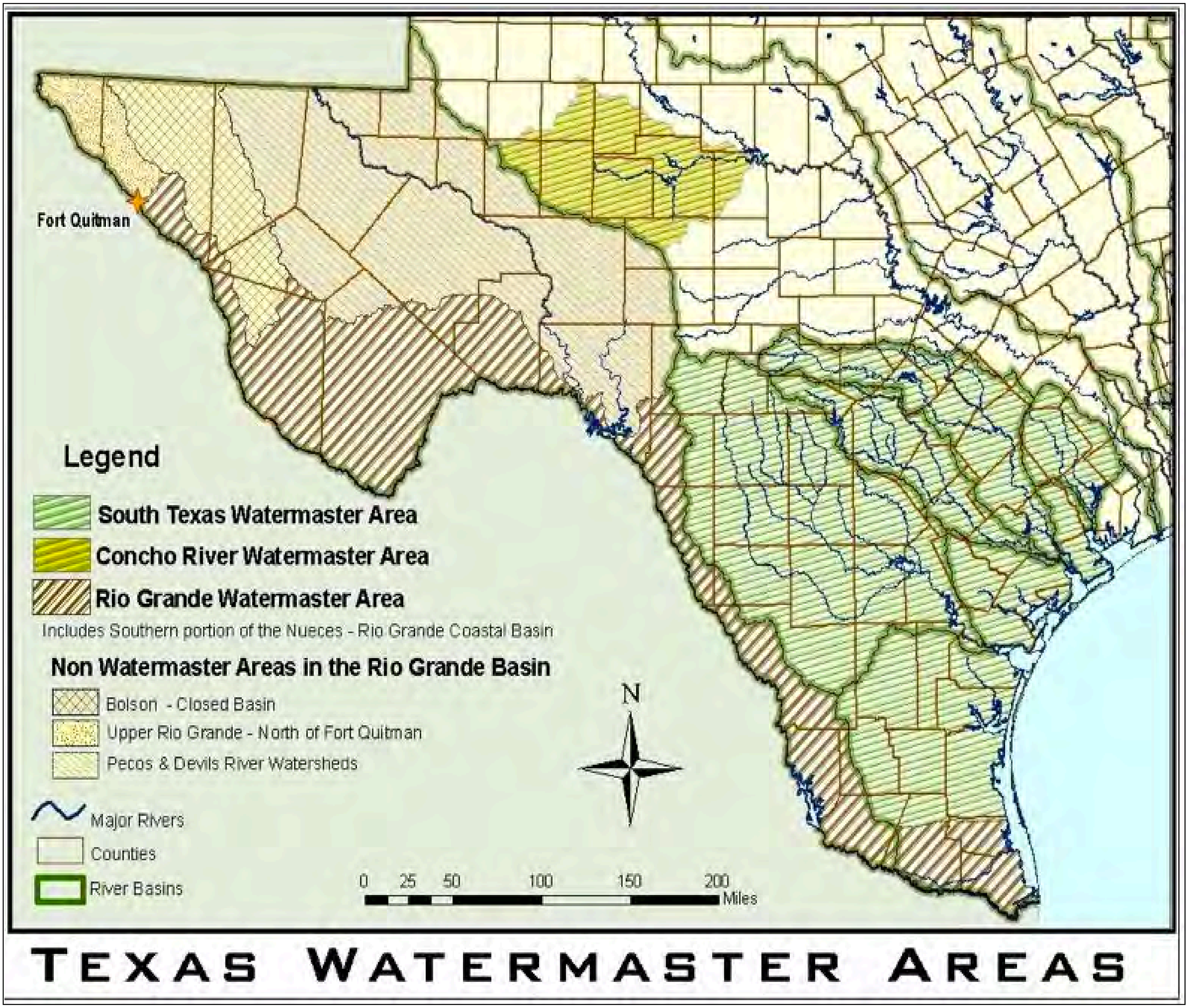


FIGURE 16: TEXAS WATERMASTER AREA (TEXAS COMMISSION ON ENVIRONMENTAL QUALITY 2013)

Each committee may contain anywhere between nine and 15 members who hold water rights (or are representative of rights holders) within a particular watershed. A watermaster is an officer working through a regional office appointed by TCEQ and is responsible for monitoring water usage. Continuous monitoring of stream flows and reservoir levels in a river basin allows for an accurate assessment of water use. This approach is used less often than the honor system, but has been employed in several specific locations. The main advantage of this system is better assurance of state law compliance, as well as the data retrieved through monitoring. Watermasters provide the following services to water rights holders in basins with this program:

Diversion coordination in basins ensures “best overall value” for water rights holders and the water available to them (Texas Commission on Environmental Quality 2009). An example of this is planning during the year for junior rights holders to divert water when senior rights holders may not be diverting water. During droughts the watermaster may be able to alert officials about water loss before it becomes a serious problem. Watermasters also provide a long-term solution for managing water and ensures that priority is respected. In basins without a watermaster, rights holders may make a “priority call” if their appropriated water is not received (Settemeyer and Ramos 2013). Priority calls are then subject to inspection by the TCEQ, which will determine whether or not suspended water rights will provide enough water for beneficial use. If it is determined that suspension of some rights will indeed provide water for some beneficial use, then junior rights that are up for suspension in accordance with their place in line will be suspended temporarily.

In basins without a watermaster program, the TCEQ-OCE is responsible for responding and investigating priority calls. As the state agency accountable for responding to a variety of environmental complaints and compliance issues, the TCEQ-OCE may not be as familiar with the unique problems within every river basin statewide. Watermaster areas with personnel working solely in one basin are able to resolve local problems as entities answerable directly to local rights holders.

The major areas of contention around instituting a watermaster area arise around the costs associated with a watermaster; by law the water-right holders in the area served by the watermaster pay for this service through a fee. Statutory requirements state that rights holders must pay an annual fee. Additionally, administrative costs for the program also include a base fee for each account and a fee based on permitted amounts and types of use (Settemeyer and Ramos 2013). Some argue that this affects the autonomy of an operation and contributes unduly to paperwork and expenses (Cambell 2006).

Watermasters in Texas are not only responsible for managing water and enforcing rights during times of shortage; they are also responsible for monitoring streamflows, preventing resource waste or use in excess of allocations made to permit holders, and to ensure that seniority of right is respected (Texas Commission on Environmental Quality 2013). In 2011, the 82nd Legislature passed a report filed by the Sunset Commission[25] through House Bill 2694 requesting that the TCEQ do the following:

1. "Evaluate each river basin or coastal basin that does not have a watermaster;
2. Assess whether or not there is a need to appoint a watermaster in that basin;
3. Report findings to the Legislature; and

[25] Created in 1977, the Sunset Advisory Commission is a 12-member legislative body responsible for reviewing more than 150 government policies and programs every 12 years (The Sunset Advisory Commission n.d.).

4. At least once every five years, repeat this assessment in each basin" (Texas Commission on Environmental Quality 2013)

The TCEQ evaluates the current state of water rights holders and resource availability in basins across the state to determine if a watermaster program should be implemented. Any history of threatened senior water rights or water storages, besides cities being on water restrictions due to enacting drought contingency plans[26], could result in the need for a watermaster.

As of August 2013, four river basins have been recommended for evaluation: the Trinity basin, the Trinity-San Jacinto Coastal basin, the San Jacinto basin, and the San Jacinto Brazos Coastal basin (Texas Commission on Environmental Quality 2013). According to the TCEQ, the estimated costs of implementing a watermaster program in all four basins would be approximately $548,962.85 for the first year, and then drop to $409, 770.59 for each year afterwards.

If water rights holders within these basins face stress from rights over-allocation during drought, a permanent watermaster may be able to ease tensions by acting as a mediator and constant monitor and of water conditions when resources become scarce. The four river basins that are under consideration for a watermaster program have some of the highest concentrations of population in the state. Also, a majority of acre-feet allocated through surface water permits are in RWPAs within the basins in question. The predicted recurrence of drought and associated resource-stress is expected to add pressure on current rights holders to increase water conservation and storage, especially in highly populated areas.

Conclusions and Analysis

Much progress has been over the last 100 years regarding how Texans view surface water. Surface water flowing into the Gulf of Mexico is no longer regarded as "uncaptured" resources

[26] See section on drought.

and freshwater flows required by riparian and coastal ecosystems is now, at least, recognized (Ward 2000). However, Texas is reaching a pivotal moment where management will have to take environmental and climatic factors into account. The majority of surface water use is confined to urban centers that require water be stored for public use and during times of drought. If unappropriated water is available in a stored supply, the TCEQ may distribute new permits for water use[27]. When the surface water rights permitting system does not work properly in that water rights holders do not receive the amount of water they are allotted, a watermaster may advise individuals based on the problem at hand. However, watermaster programs are limited because many rights holders in other basins do not want to pay for the services associated with a watermaster. In these cases, the TCEQ is responsible for water rights management and litigation cases can be lengthy and expensive.

There is concern about water rights allocation in urban areas increasing to meet the demands of a growing population. The 2012 Water Plan for Texas estimates that nearly $45.8 billion will be needed to fund municipal water projects including dam building and infrastructure development (Texas Water Development Board 2012). There also must be methods for addressing unmet irrigation needs totaling $2 billion that regional planning groups were unable to find. Ensuring that enough water is held in reserve to meet with demand during periods of drought is also vital. The TWDB estimates that economic losses could equal approximately $11.9 billion annually if current effects drought mirror those of the drought of record (Texas Water Development Board 2012). Surface water supply is expected to increase with the finalization of water projects to increase storage capacity.

[27] Section 11.134(b)(2) of the Texas Water Code allows for distribution of unappropriated resources.

The geographical region comprising Texas has always had large hydroclimatology. Although there are, at present, enough resources to meet the needs of the existing population, the rate of change necessitates action to plan for the future of resources in river basins facing the most stress. The growing concern that most individuals have regarding water resource allocation stems from a conflict between the agricultural sector in Texas and growing municipal needs. Existing policy still provides individuals with a choice regarding water management in river basins; rights holders can either employ a watermaster or depend on the TCEQ to manage disputes. Under the regulations designed and enforced through the TCEQ, water rights holders diverting water for irrigation purposes must yield appropriated resources to municipalities during times of drought. Current legislation that will be up for vote in November of 2013 including Proposition 6 is designed to create a permanent source of funding for water project plans and address those that are most dire.

What we don't know

Over the past 50 years, water resources have been redistributed across river basins, and the need to effectively manage disputes regarding seniority must be addressed. In order to alleviate stress on existing groundwater resources, a major shift has been made in regard to surface water use over the last century. Conversion of water resources from irrigation to municipal uses will result in agricultural losses across the state (Ward 2000). Although the water needs of cities and industry are relatively small, compared with the needs of irrigated agriculture in Texas, this situation may very well change over the next 60 years. Conversion of irrigation water rights into municipal rights is projected to continue in the Rio Grande River basin and central Texas as cities expand. It is difficult to predict how these changes will affect water resource management, and how the agricultural industry will adapt to resource loss. However, such changes affecting the important agricultural industry in Texas are easier to speculate about than implement. Currently, Texas ranks number four in agriculture behind California, Iowa, and Illinois. As irrigated agriculture makes crop and livestock production viable in drier portions of the state, this is one problem that many argue cannot be solved with a single action. It will take time and research to navigate Texas policy and insure that in state agriculture remains viable. Is it realistic to suggest eliminating irrigated agriculture in a state where one out of every seven Texans is involved in an agriculturally related occupation? There are many complications that must be addressed through study and science in order to address this enigma.

Additional research also must continue regarding runoff, recharge and the mechanics of how surface water pollutants directly affect specific aquifers. There is general information present about aquifer systems that informs state and local policy, but comprehending how pollution levels vary in terms of drought is not something that is communicated effectively to the public. This is a function of community-level environmental literacy that must be improved to make surface water quality and quantity management strategies easy to implement and translate for stakeholders and decision-makers. In order to properly manage this information, surface water education must be formalized in the TEKS for K-12 students in Texas, and campaigns for environmental education supported by local government. Materials for communicating these ideals have already been developed, but strategies for proper implementation have yet to be recognized.

Section 6: Coastal Water Management

Take-away Points:

1. The Texas CMP is responsible for overseeing coastal industry and projects.
2. NPS and water quality in coastal ecosystems is of especial concern to the Texas CMP, the TCEQ, and the GLO.
3. Lack of instream flows affects coastal agricultural industry, such as rice production. This issue also extends to coastal systems in Mexico.
4. Important legislative Acts enacted for coastal management include the Texas Open Beaches Act (TOBA), the Dune Protection Act, and the Coastal Erosion Planning and Response Act (CEPRA)

Background

The Texas Gulf Coast covers more than 3,300 miles of estuaries and bays and 367 miles of beach (Texas General Land Office 2013). Maintaining coastal water quality and quantity in Texas is vital to insuring the longevity of key industries such as fisheries management, recreation and tourism, and coastal agriculture. Fluctuations in water quality parameters resulting from NPS pollution can adversely affect estuarine ecosystems, putting wildlife populations and coastal industry at risk.

Maintaining sufficient water quantity for coastal watersheds has also inspired debate and speculation in recent years. Over-allocation of water rights for agricultural, municipal, and industrial purposes may limit freshwater flow to coastal wetlands. As the population of major Texas cities continues to rise and state drought rates restrict instream flows and aquifer recharge, the coastal ecosystems, where endangered species such as the Whooping Crane feed and breed, will face major water reductions and habitat loss (United States Fish and Wildlife Services 2013).

According to the Texas Almanac, the coastal vegetation area, gulf prairies and marshes, covers 10 million acres and is made-up by two subunits; marsh and salt grasses, located at tidewater, and a strip of bluestem and tall grasses farther inland (Texas State Historical Association 2013). Much of the prairies make fertile farmland and excellent grazing for cattle. In the Gulf Coast region, agricultural production reported $1.69 billion in goods in 2008. Wharton, Colorado and Matagorda counties, making up 79% of the total rice acreage in Texas, produced 963.4 million pounds of rice, 81% of the state's total rice production in 2008. Additionally, these agriculturally important counties along the Texas Coast produced 45% of the state's catfish sales and 40% of the state's total aquaculture sales (Window on State Government 2013).

Evolution and Driving Factors of Policy Change

As population and economic development throughout the Texas Coast increase, environmental degradation of sensitive coastal ecosystems becomes a more pressing reality. In addition, increased economic importance and population along coastal regions mean increased human proximity to coastal flooding, storm surges, and wind damage resulting in increased landscape management and habitat alterations. Due to Texas' economic and environmental need for a comprehensive approach to addressing these issues, the state has developed a Coastal Management Program (CMP). The Texas CMP is based on the Coastal Coordination Act of 1991 as amended by House Bill 3226 (1995). Ultimately this requires establishment of procedures that comply with local, state, and federal policy on coastal regulations.

In order to maintain coastal development, the Coastal Coordination Council (CCC) was founded in 1991 through the Texas Coastal Program under the General Land Office (GLO)[28]. Until 2010,

[28] See section on Institutional Actors.

the CCC was responsible for distributing federal funding through the CMP to regional and statewide projects designed to maintain coastal health and stewardship. A review of the CCC conducted by the Texas Sunset Commission in 2010 led to the abolishment of the Council. Responsibilities formerly associated with the CCC were given to the CMP under the GLO as of January 1, 2012 (Texas General Land Office, Coastal Coordination 2013). The GLO is the primary state agency charged with regulating the coastal water programs in Texas. Water quality standards, wildlife and fisheries management for water associated estuarine environments, and wetlands are regulated through the TCEQ and the TPWD. The TPWD is the agency responsible for managing boating, fishing, hunting, recreational use of the natural resources on the coast.

Current Coastal Water Policy

A combination of federal and state laws has improved policy towards protecting the Texas coast. Federally, the Coastal Zone Management Act (CZMA) and the Coastal Barriers Resource Act (CBRA) have provided tools to improve the quality of these sensitive environments nationwide. The CZMA, enacted in 1972 and managed by NOAA's office of Ocean and Coastal Resource Management to balance an overall goal to "preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone" (U.S. Department of Commerce 2013). Additionally, the CBRA of 1982 was established in light of Congress' recognition of the significant encouragement federal support had given development projects along the coast, spending millions in tax dollars and ultimately harming sensitive ecosystems, and endangering human life and property. This law put in place restrictions for federal expenditures, specifically flood insurance, to help conserve natural resources along the hurricane prone coastal regions of our country (United States Fish and Wildlife Service 2013).

State regulations, such as the Texas Open Beaches Act (TOBA), the Dune Protection Act, and the Coastal Erosion Planning and Response Act (CEPRA) are all state initiatives to establish accessibility and protection of the Texas coast. The TOBA provides unrestricted access to all Texas beaches as defined as mean low-tide to the vegetation line. The goals of this law are to protect the constitutional rights of Texas citizens and also to maintain, protect, and enhance the Texas coast. The Dune Protection Act[29], defining the dune line up to 1,000 feet landward of mean high tide, requires a permit for any activities within the protected dune area. This law preserves the natural barrier that protects inland areas from storm surges, and maintains significant nesting grounds for sea turtles. The CEPRA is a result of 1999 Texas Legislation to provide, at minimum, a 15% in-kind match of grants to fund coastal community projects to help dune restoration as well as prevent coastal and shoreline erosion (Texas Coastal Erosion Network 2013).

State organization partnership with the National Oceanic and Atmospheric Administration (NOAA) allows Texas regulatory agencies to provide monitoring data in water level, temperature, and coastal integrity to maintain maritime trade and general public and environmental health. Many public and private entities are involved in coastal management and water resource protection in Texas. Local and national NGOs, river authorities, and private organizations receive funding for coastal projects through partnerships or projects under the CMP with the GLO. The CMP received approval from NOAA in 1996 and is chaired by the commissioner of the Texas GLO. Under this directive, annual funding for the CMP from NOAA totals approximately $2.2 million (Texas General Land Office 2013). The authority for CMP and

[29] Texas Natural Resource Code Sections 63.001-63.181.

other coastal programs is within the 1972 Coastal Zone Management Act (Texas General Land Office 2013).

In order to maximize efforts and supplement as many projects as possible along the coast, the GLO manages to increase state-funding for coastal and water conservation projects by matching dedicated capital with federal and local partnership opportunities. These funds are then distributed to state and local entities to fund projects in the following areas:

1. Coastal Natural Hazards Response
2. Critical Areas Enhancement
3. Public Access
4. Waterfront Revitalization and Ecotourism Development
5. Permit Streamlining/Assistance, Governmental Coordination and Local Government Planning Assistance
6. Water Sediment Quantity and Quality Improvements

Since 2003, nearly 500 coastal projects have received funding through the CMP, 45 of which have been specifically for water quality improvement. Funded projects are very diverse, ranging from water resource management through experiential learning and environmental education[30] to modeling beach erosion and shifting coastal morphology (Texas General Land Office 2013). Every award cycle, potential grantees must register with the GLO to submit an application for one of the six approved project areas. Coastal projects funded through the CMP focus on water quality improvement and do not necessarily mention freshwater or environmental needs to restore coastal habitat. Wetlands and ecosystem recovery projects that are funded through the Texas Coastal Watershed Program (TCWP) may involve water and sediment quantity management.

Stipulations for management require implementation of water quality monitoring due to the level of inland river basins making up the basis in which coastal ecosystems survive. As of 1997

[30] See section on Environmental Education.

Texas' approach to appropriately managing their sensitive water supply passed SB-1 that divided water-planning authority among the 16 RWPGs. These RWPG's boundaries were drawn to reflect major river basins and communities within RWPG to submit their water plan assessing water demand and supply predictions to appropriately implement water management strategies for the future (Window on State Government 2013).

Water Quality Management Plans (WQMPs) focusing on NPS pollution are laid out in Senate Bill 503. This bill enacted by the Texas State Legislature in 1993 outlines NPS pollution control and soil conservation measures relating to coastal zone management. An education-based program established through the GLO to monitor water quality of Texas' recreational beaches during the summer months, the Texas Beach Watch Program is tasked with collecting water samples weekly from 65 recreational and high-traffic beaches along the Texas Coast. As a measure to track water quality, this data is then added to an interactive map where website patrons can observe shifting water conditions and areas with elevated amounts of bacteria.

Coastal programs that include a water quantity component focus on ecosystem recovery and restoration. Maintaining the health of coastal habitat and ecosystems requires a sufficient supply of freshwater. Wetlands and ecosystem recovery projects that are funded through the TCWP involve water management and water sediment quantity management.

Coastal estuaries and marshes are dependent on freshwater flows from Texas Rivers. Ninety-five percent of the Gulf's important commercial fish rely on healthy estuaries at some part of their life cycle. Without healthy freshwater flows upstream, water quality would decline inside these sensitive estuaries and many species would be unable to reproduce and grow (National Wildlife Federation 2004). With increasing periods of drought and Texas' growing population, freshwater inflows to coastal estuaries are plummeting below sustainable levels. As a measure to better conserve these valuable ecosystems the National Wildlife Federation suggests reserving unallocated freshwater flows to meet required levels to maintain aquatic life. [31]

Currently, a direct association of limited water supply in period of intensive drought, and the population increase in areas all around the state, water allocation is monitored strictly for the attempted longevity of current resources. An example of policy implemented in relation to the coast is the Lower Colorado River Authority (LCRA) cutting off irrigation water for a second year in a row to rice farmer in Matagorda, Wharton and Colorado counties. Such measures will have an extensive impact on economic development in those communities and overall agricultural production for the state of Texas (Lower Colorado River Authority 2013).

The Future of Freshwater and the Texas Coast

Estimated within the TWDB-developed State Water Plan for 2012, the state population is to expect in increase 82% in 50 years (2010-2060) resulting in an increase from 25.4 million to 46.3 million with no additional water availability. This increase is 4.5 million short of a doubling of population, and is mostly concentrated in urbanized metropolitan areas. A region with a large amount of economic influence on the Texas coast is Regional Water Planning Area H, which is comprised of all or parts of 15 counties and portions of five different river basins. Additionally, the Houston metropolitan area, which is one of the most heavily populated regions in the country, produces two-thirds of the petrochemical production for the United States. With 89% population growth predicted by 2060 for Region H alone, water demands will increase in the coastal zone from a 2010 rate of 290,890 acre-feet per year to over 1.2 million acre-feet per year. Currently, municipal demand is measured at 19% compared to 52% for irrigated agriculture. Projections are expected to increase municipal needs to 61% and irrigated agriculture to 12% (TWDB). This shift in demand is a combination of water right allocation and conservation

[31] See section on Environmental Flows

practices allocating a higher percentage of our available water supply to municipal use rather than irrigated agriculture.

Conclusions and Analysis

In coastal water management, Texas' main priority is to maintain adequate freshwater flows into the estuaries and bays. Without such flows many industries and coastal wildlife will suffer. The major reason for this drop in instream flows is the over allocated surface water upstream in major Texas Rivers. A particularly recent industry suffering from the lack of waters flowing to the coast is the Texas rice farmers. Nearly 81% of the state's rice production in 2008 came out of three coastal counties that have recently experienced a cut off from upstream the Lower Colorado River Authority (LCRA) (Window on State Government 2013). In addition, the prolific aquaculture throughout this region has a particular interest in maintaining the essential flows to provide appropriate habitat for the species in coastal shores. As for wildlife, the endangered whooping crane maintains essential habitat along coastal Texas. Without adequate protection of this area and the inland waters, an already stressed species may not be found in the wild.

Additional issues surround coastal waters include NPS pollution and increased flood and wind risks in growing populations. As the country's major petro-chemical producer, the Texas Coast experiences elevated amounts of pollutants as well as an increasing rise in urban population. Both issues can have an effect on the fragile ecosystem. In addition, with a growing population in and around coastal areas, the likelihood of more costly property damages to homes and businesses during extreme weather events increases. The result of this growing threat to Texas' gulf coast was the creation of the Texas CMP a program based off the Coastal Coordination Act of 1991 and House Bill 3226 (1995). What's missing in Texas' coastal water management is a clear definition of what constitutes sufficient freshwater flows into the gulf region in order to maintain adequate habitat and resources for the various industries.

It is suggested that further research be completed to analyze the economic value of freshwater inflows for coastal regions. This will be of use in designing appropriate steps to take in managing water resources for agriculture and other various industries, including recreation and tourism. Through such a study more informed decision-making would be supported to manage Texas' surface water flows for all ecosystems and viable industries.

Take-away Points:

1. Federal standards for water quality management provide guidance for standards enforced through the TCEQ at the state-level.
2. Impaired water segments are listed on the 303(d) list in accordance with the CWA section 319.
3. The TSSWCB provides guidance for WPP and TMDL implementation.
4. The new PGP under the TCEQ developed to address NPS pollution management associated with pesticide control is effective only for large-scale programs.

Section 7: Water Quality Management

Water quality management is ensured through various federal and state agencies that assess, monitor, and take legal action to clean and preserve water in Texas. Water quality has been a growing issue with individuals as well as representative bodies over the past several decades. Historic conditions of water nationwide reached such poor quality in the 1960's and 70's, due to raw sewage discharge and heavy pollution from industrial practices that waters certain waters, like Ohio's Cuyahoga River, caught fire. In light of such devastating pollution, many private and public agencies rallied behind legislative changes to reduce and prevent future water quality issues (Salzman 2012). There has been a movement at the federal and state level to address both nationwide regulations as well as local ones more in tune with native political, cultural, and environmental needs and demands.

Federal Approaches

While some preliminary attempts were made to protect United States waters in the form of the 1899 Rives and Harbors Act[32], which limited dumping of refuse into waterways, these were largely ignored and not actively enforced. This was the only law of the land for water-related legislation until 1948 with the Federal Water Pollution Act placed responsibility of the quality of water to the states to govern themselves and also informed states about the active treatment protocol for sewage wastes. The first comprehensive and meaningful legislation was passed after the event of the Cuyahoga River fire in 1972 with amendments to the Federal Pollution Control Act. Together, these amendments are commonly known as the Clean Water Act (CWA) (Migliaccio and Obreza 2011).

The CWA is the primary federal law that regulates water pollution. The purpose of this legislation is to restore and maintain ecological and biological conditions that ensure the integrity of our nation's water. Primary elements of this legislation, including regulating point and nonpoint pollution sources, provide assistance to treatment facilities and maintain wetlands. The CWA consists of two major components: one being given the authority to offer financial and education assistance for municipal sewage treatment plant construction; and the other being the enforcement of regulatory requirements that apply to industrial and municipal water discharges. Various programs are put in place into the act to give different aspects of water quality, the two largest distinctions between them depend on if the pollution is from point or nonpoint sources (Copeland 2010).

National Point Source Pollution Program

[32] See section on Valuation of Natural Resources

The National Pollutant Discharge Elimination System (NPDES) is the program under section 402 of the CWA that controls point source pollution. Point source pollution occurs when there is a single identifiable source of a pollutant. This type of pollution typically occurs with direct discharge from pipes and sewers that are put into the environment from one facility. The NPDES issues permits after an entity completes an application. The permit requires that a facility intending to discharge waste into the nation's waters provide quantitative analytical data identifying the type and quantity of the pollutant to be discharged (U.S. Environmental Protection Agency 2013).

When issuing NPDES permits, local water quality criteria will be taken into account. Water quality criteria differ from state to state and also each specific body of water. Certain aspects must be taken into consideration such as local aquatic wildlife, the uses of the water, and overall ecological conditions of the site. These standards do not take into account technological or financial limitations of the area and must adhere more strictly to environmental concerns (U.S. Environmental Protection Agency 2013).

Nonpoint Source Pollution

Nonpoint source pollution (NPS) results from land runoff, atmospheric deposition, and hydrologic modification, and other unknown sources, that ultimately collect and move pollutants into bodies of water. Nonpoint source pollution is more challenging to identify because it comes from several different sources within a large geographic region. Commonly, NPS pollution can occur due to excess fertilizers, herbicides and insecticides, bacteria from livestock, pets, and faulty septic systems.

At the federal level, the CWA addresses NPS pollution issues to mitigate effects on drinking water supplies, recreation and, fish and wildlife. The 1987 amendments authorize measures to address such pollution by directing states to implements NPS pollution management programs that are informed by federal guidelines and through, in part, by federal means. Under section 319 of the CWA all states are encouraged to pursue groundwater pollution programs by preventing nonpoint source pollutants. Federal grants associated with this program may cover up to 60% of program implementation costs to states. The NPS pollution program is not subject to the CWA permits or other regulatory requirements under federal law; they are administered by state programs for the management of runoff on watersheds (Copeland 2010).

State Approaches in Texas

Preserving Quantity and Ensuring Quality

Because of specific Texas laws that govern surface and groundwater separately, the state has an active role to play in maintaining the surface water integrity. Surface water quality is managed through the TCEQ.[33] In order to develop a meaningful program to promote pristine water conditions, the specific chemical, physical, and hydrological characteristics of every surface water system in Texas must be known. In order to address this need, segments are classified to categorize waterways on the basis of relatively homogenous characteristics. They are then given identifying numbers that correspond to the major river basin in which they are located.

Maintenance of acceptable water quality standards denotes the foundational process that the TCEQ utilizes to manage surface water quality in the state. These standards consist of two parts: first, what the purpose for which the surface water will be used, of which there are five that can be seen in Table 2, and second, what indicators will be used to determine if the use is met. There

[33] See section on surface water.

are different requirements for water quality depending upon how the water is to be used. For instance, an aquatic life standard may focus on the diversity of organisms in the sample, while a contact recreation standard may focus on *Escherichia coli* (E. coli) and fecal coliform levels. Total coliform is an indicator of fecal contamination and drinkable water may not contain fecal coliform per state and federal standards. When measurement of standards in a water body is complete, the TCEQ carries out planning reviews with partner agencies to create the overall water quality management plan; that includes monitoring actions, restoration plans, and administration reviews. This allows for regular monitoring, assessment, and targeted approaches for quality improvement (Texas Commission on Environmental Quality 2012). In 2012, the Pesticide General Permit (PGP) authorizing point source discharge relating to pesticide use for areas larger than 6,400 acres was made available through the TCEQ (Texas Commission on Environmental Quality 2013). Pesticide users spraying over large areas in watersheds contribute to degradation of water quality and pollution in sensitive systems. Clearly, because of the acreage required for a PGP, most pesticide users are not required to apply for a permit. Other operators who use pesticides and herbicides for what is known as "restricted use" must apply for a Pesticide Commercial/Noncommercial Applicator License or a Pesticide Private Applicator

TABLE 2: TEXAS SURFACE WATER QUALITY STANDARDS

Texas Surface Quality Standards
1. AQUATIC LIFE 2. CONTACT RECREATION 3. PUBLIC WATER SUPPLY 4. FISH CONSUMPTION 5. GENERAL USE

License through the Texas Department of Agriculture (TDA) depending on the purpose and method of dispersal (Texas Department of Agriculture 2013). Pesticides applied for agricultural or municipal purposes in Texas that are not regulated may flow unchecked into water systems that recharge aquifers, or pollute surface water systems bringing nutrient and pathogen levels above maximum amounts. Although applied pesticides do end up in Texas waterways eventually, management of application through a permitting system is expected to keep water parameters within state and federally approved levels.

Upon completion of monitoring, an Integrated Report is created for every water body segment. This report is used to indicate the water quality status and management activities. This is also provided to the public, the EPA, and internal agency programs. There are five main categories with subsections, which can be seen in Table 3. The higher the category number, the more challenging the effort is to manage water quality. For example, the water quality of segments in category 5 (the highest level) indicates that the state must take action to remediate and restore water quality. This requires the development of a Total Maximum Daily Load (TMDL). The TMDL is the maximum amount of a particular pollutant that a segment can receive and still attain desired water quality standards; this takes into consideration point and nonpoint sources (Texas Commission on Environmental Quality 2012).

TABLE 3: CATEGORIES OF USE IN INTEGRATED REPORTS

CATEGORIES	DESCRIPTION
Category 1	Attaining the water quality standard and no use is threatened.
Category 2	Attaining some of the designated uses, no use is threatened, and insufficient information (or none) is available to determine if the remaining uses are attained or threatened.

Category 3	Insufficient information (or none) is available to determine if any designated use is attained.
Category 4	The standard is not supported or is threatened for one or more designated uses but this does not require the development of a TMDL.
Category 4a	A TMDL has been completed and approved by USEPA.
Category 4b	Other pollution-control requirements are reasonably expected to result in the attainment of the water quality standard in the near future.
Category 4c	A pollutant does not cause nonsupport of the water quality standard.
Category 5	Category 5 is the 303(d) list. The segment does not meet applicable water quality standards or is threatened for one or more designated uses by one or more pollutants.
Category 5a	A TMDL is under way or scheduled, or will be scheduled.
Category 5b	A review of the water quality standards will be conducted before a TMDL is scheduled.
Category 5c	Additional data and information will be collected before a TMDL or review of the water quality standard is scheduled.

State Plans and Programs

There are numerous public and private approaches for water quality management. The Water Quality Management Plan (WQMP) for Texas is a treatment plan that is required under the Texas Water Code[34] and satisfies the requirements put forward in the federal CWA. While numerous private and public efforts have begun to implement self-imposed management practices on land in the last several decades, statewide plans are ongoing projects that are continually locating and implementing best practices in this field. Under the TCEQ WQMP is a planning and permitting program that protects the water quality and addresses water quality problems under the Texas Pollutant Discharge Elimination System (TPDES). This is part of the state's priority assessment program for water quality issues (Texas Commission on Environmental Quality 2011).

[34] Texas Water Code, Subtitle D Chapter 26, Subchapter A: WQMP. Effective 2001.

The WQMP through the TCEQ is updated quarterly and encourages public comment during the process. Many different limitations and management practices may be put in place with the WQMP. These include effluent limitations of wastewater facilities, nonpoint source controls, identification of designed management agencies, and ground water protection planning. These elements require separate and specific protocol for each region. Once an area has received an appropriate plan it goes through public comment, TCEQ certification and ultimately is approved through the EPA; once this is accomplished it becomes a part of the state's ongoing WQMP (Texas Commission on Environmental Quality 2011).

With the Passage of Texas Senate Bill 503 in 1993, the Texas State Soil and Water Conservation Board (TSSWCB) was directed to implement water quality management plans across the state. Water Quality Management Plans are site specific, so they take into account water use, the ecological conditions of the watershed, and the needs of the flora and fauns in the region. Thus far the TSSWCB has implemented over 8,000 plans in Texas (Texas State Soil and Water Conservation Board 2013).

Currently, the TSSWCB offers WQMP development at no costs to the location but does require that an individual requests planning assistance through the local TSSWCB district. The WQMP is certified after the development of an appropriate plan. When managing such a plan with resources flowing through private land, the landowner implements the program. Annual reviews are necessary through the state and the TSSWCB offer reviews of land management plans in place (Texas State Soil and Water Conservation Board 2013).

As previously mentioned, the TMDL is a vital step for the TCEQ to reduce pollution in impaired or threatened bodies of water. The TMDL Program is the process of gathering stakeholders and other state agencies together to begin developing an implementation plan to improve water quality after monitoring and analysis of the body of water is complete. Section 303(d) of the CWA requires implementation to improve water quality the TMDL program satisfies this requirement. The program outlines specific steps necessary to reduce the pollutant load through regulatory as well as voluntary activities. Each program is specific to the quality standard of the region and requires scientifically sound approaches and techniques. This program is ongoing and many projects are in action across the state at any given time (Texas Commission on Environmental Quality 2011).

The Watershed Approach

The watershed approach to water quality management is often considered the most comprehensive for controlling unwanted pollutants in the states waters. A watershed is the geographic surface region draining into a steam, river, or lake. Watersheds include surface water and groundwater, soils, vegetation and animals as well as human activities within its region. The watershed approach includes planning, data, collection, assessment targeting, strategy development, and ultimately, implementation of holistic methods designed to benefit all members (human and non-human) living within a watershed. Applying a TMDL for an entire watershed allows for a far greater control of the pollutant level by attempting stopping nonpoint source runoff. This approach takes into account voluntary and regulatory activities in order to have comprehensive and positive changes in the state of water quality in the state (Russell, Griffin and Williams 2013).

One such program is provided by the TSSWCB with the Watershed Protection Plan (WPP) Program that provides guidance and technical assistance for environmental groups, stakeholders, and private entities to implement a WPP. By providing a framework and guidance that is in compliance with the EPAs suggestive approaches, the TSSWCB offers a holistic and comprehensive approach for bettering the water quality. In addition to technical, logistic, and practical guidance on implementing a WPP, the TSSWCB along with the TCEQ, can provide financial assistance to stakeholders wishing to pursue a WPP. Funding for such programs is made possible through section 319(h) of the CWA in 1987, which establishes WPPs to control nonpoint source water pollution. Federal funding for related endeavors in Texas is provided annually through the EPA and is split evenly between the TSSWCB and the TCEQ (Texas State Soil and Water Conservation Board 2013). Both of these agencies collaborate on programs and projects for the betterment of Texas' waters.

Citizen Engagement

Watershed Protection Plans sponsored through TSSWCB are all funded through Clean Water Act 319(h) Nonpoint Source Grants and address water quality concerns relating to agricultural or silvicultural practices (Texas State Soil and Water Conservation Board 2013). Watershed Protection Plans sponsored by the TCEQ may develop to address water quality as it relates to urban or rural development, however, usually they also address problems associated with agriculture and silviculture. Plans developed through a thrid party may or may not meet the nine-elements sanctioned by the EPA for Watershed Protection Planning. Total Maximum Daily Loads (TMDLs) established for impaired water bodies also require an education and outreach component and some may incorporate "citizen science" measures (see Involvement in Watershed Protection Planning). Watershed protection planning is an example of coordinated watershed planning that consists of two locally-driven efforts: 1) establishment of a mechanism to protect unimpaired water bodies; and 2) rehabilitation of polluted water bodies (Texas State Soil and Water Conservation Board 2013). A WPP may be submitted as a pre-emptive measure to protect fragile water segments in lieu of a TMDL. Public participation is mandatory under the 1992 guidelines for both TMDL and WPP implementation in U.S. watersheds (Environmental Protection Agency 2013). Case studies involving TMDL and WPP programs in the Texas Hill Country are found in Appendix 4.

Involvement in Watershed Protection Planning

As of 2013, there are 34 established WPPs and 26 TMDLs either implemented or in the planning process in Texas (Figures 18 and 19) (Texas Commission on Environmental Quality 2013). As a measure to support nonpoint source pollution prevention efforts, Texas AgriLife Extension offers a Texas Watershed Steward workshop sponsored through section 319(h) of the Clean Water Act for active community members. Established and proposed WPPs integrate a science-based method for maintaining data on water quality involving monitoring and strategy evaluation with community interaction and educational programs (Texas State Soil and Water Conservation Board 2013).

The EPA requires that an information and educational component be present in all WPPs and TMDLs as a measure to enhance public understanding of the project (U.S. Environmental Protection Agency 2004). This stipulates that plans must include methods for encouraging citizen participation at every stage of the project, thereby increasing and holding public interest in local environmental issues. Additionally, community members may be involved as “citizen scientist” during sampling for nonpoint source pollution. This involves training the public in water chemistry, bacteriology, or other pertinent methods and data collection.

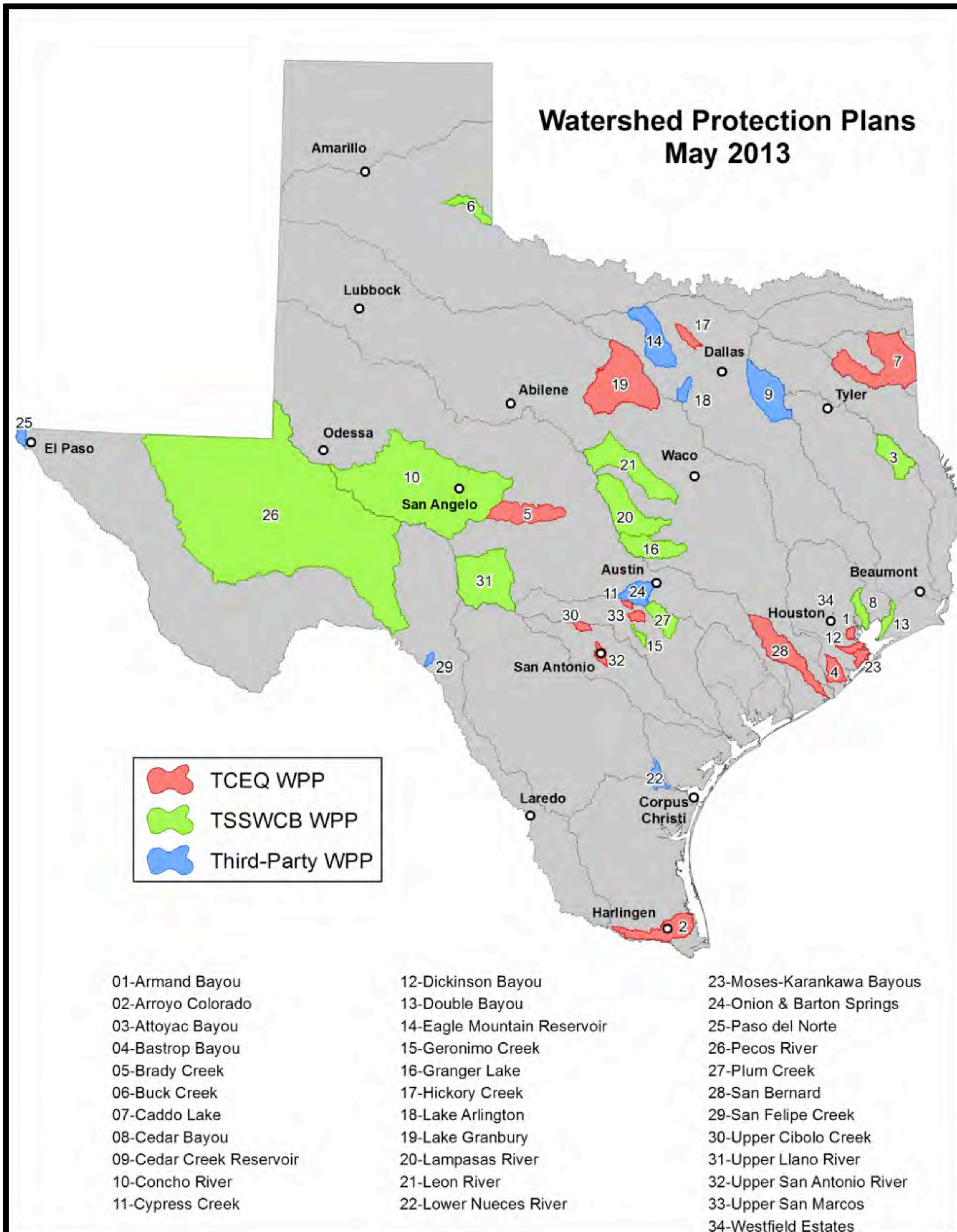


FIGURE 17: ESTABLISHED WPPS IN TEXAS (2013)

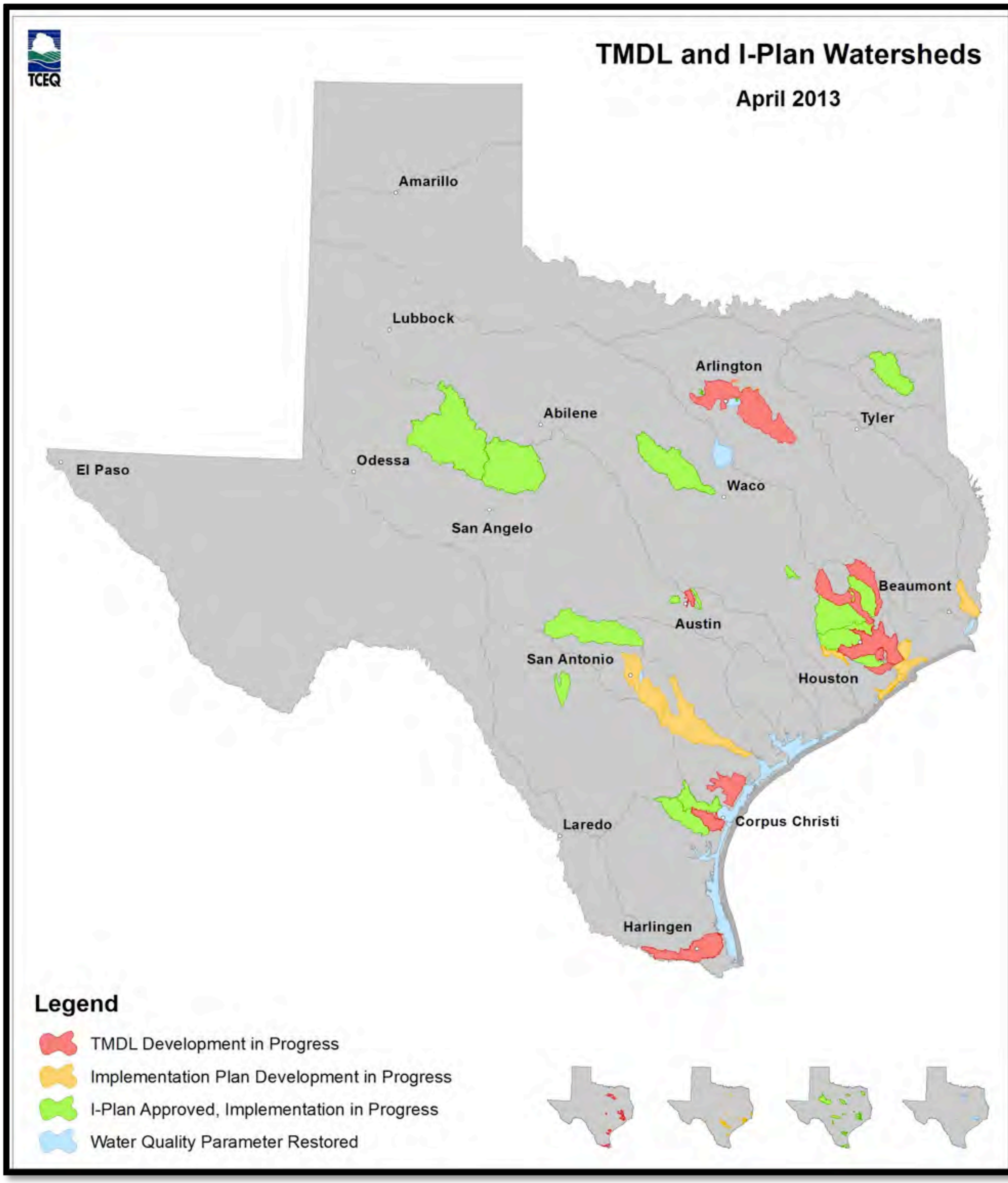


FIGURE 19: TMDL PROGRAMS IN TEXAS (2013)

Conclusions and Analysis

Point-source pollution management regulated through the TCEQ - TPDES program requires that business owners, developers, manufacturers and all other companies that may discharge sediment or pollution into a water segment comply with regulations by applying for a permit.

Geographically discernible points of pollution are easier to identify and, therefore, regulate. Pesticide licenses for applicators are available through the TDA, and farmers or municipalities expecting to spray pesticides over a large area (6400 acres or greater) must submit for a PGP through the TCEQ. Over the last 30 years, citizen engagement, education, and sound scientific methods have been developed to address the condition of polluted waterways and create sustainable environmental management at the local level. Formally, 50 plans statewide are currently approved by regulatory agencies to address water quality. Water quality and contamination analyzed at the watershed level provides a comprehensive review of water needs for all members of an ecosystem, not just the human element. Citizen involvement and stakeholder education promotes program sustainability and enhances environmental awareness at the community level.

It is possible to see that the methods for identifying and addressing immediate concerns with regard to water quality in Texas is addressed, at least in theory, by programs sponsored through the TTCEQ and the TSSWCB. It is an effective and somewhat lucrative business for regulatory agencies and third-party project sponsors both in fiscal and social terms. However, the methods that are employed by institutional actors to distribute permits and oversee regulation are handled in ways that are not in keeping with the traditional role of a regulator. The TCEQ refers to applicants for permits as “customers”, which can blur the line between an agency enforcing a required regulation, and a for-profit entity. The permitting rules and established methods of regulation are especially lax regarding NPS management and pesticide management.

Recommendations for Future Research

As a measure to determine the effectiveness of WQMPs, WPPs, and TMDLs, a comprehensive analysis of state programs should be made. This includes, but is not limited to, comparative investigation of 303(d) lists from the program's inception to the present date; types and sources of pollution that required attention; parties involved and the amount of funding received per project; and the current state of all water quality programs. Within this document, information pertinent to policy and regulation is discussed. Separate studies that may improve the knowledge base are discussed in these sections.

The purpose of this proposed study would to create a better framework for implementation methods that produce the greatest sustainable result. Developing this knowledge will also allow stakeholders living in watershed with compromised water quality to adopt plans that have been shown to be most effective under parties that produce results with the greatest benefit and lowest cost.

Take-away Points:

1. The Texas Water Bank administered by the TWDB provides buyers and sellers of water rights with a secure platform on which to do business.
2. Water held for an environmental purpose by the state is handled through the Texas Water Trust, however this mechanism has not generated much business.
3. The TCEQ and TWDB oversee water rights transfers.
4. It is expected that water right transfers (between agriculture, commerce, municipalities, and industrial holders) for most municipal or economic use will be leased rather than sold out right.

Section 8: Texas Water Marketing

Introduction

As the nature of water policy evolves, transfers of existing water rights by way of water marketing will be an important aspect of proper water allocation. Water marketing refers to the transfer of surface and groundwater rights from one party to another. This includes the sale or lease of water rights, water banking, dry-year option contracts, and redirecting conserved water (Kelley 2009). Water marketing is an important measure when addressing four main points of interest: over-allocated surface water in a region; growing urban areas demanding more resources; increase in irrigation practices associated with a rise high value crop production; and governmental and non-governmental interest in protecting instream flows (Kelley 2009). The right to use water in Texas depends on whether or not it originates above or below the ground. Changing demand patterns may be met, in part, through voluntary market transfers of water rights (Texas Water Development Board 2013).

Texas Water Bank

In 1993, the Texas Legislature created the Texas Water Bank to enable the transfer of surface and groundwater rights between buyers and sellers administered through the TWDB (Texas

Water Development Board 2013). Use of the Water Bank is optional and marketing can be done outside of the bank. Though the bank helps with negotiations and facilitate the transactions, they do require a 1% administration fee (Texas Water Development Board 2013). The TWDB keeps a listing of all water deposits statewide and a registry of water rights for potential buyers and sellers (Texas Water Development Board 2013). Once the water rights are administered through the bank, a 10-year protection from cancellation is provided. Additionally, the Water Bank implements water conservation measures for irrigation and deposit the additional supply. This conserved water is then transferred to municipalities, industry, or other irrigators through leasing or purchase agreements.

Texas Water Trust

Established in the Texas Water Code in 1997, the Texas Water Trust is an entity within the Texas Water Bank, administered by the TWDB, which may hold water rights designated for an environmental purpose. Established in the 76th Texas Legislature, a water trust is "a repository where water rights can be transferred during periods of non-off-stream use in order to provide a measure of security that the water will remain instream" (Texas Water Development Board 2013). The purpose of a water trust is to hold rights to maintain environmental flows, estuarine health or fish and wildlife habitat. All rights to be transferred to the trust must be approved by the TCEQ with special consultation by Texas Parks and Wildlife and TWDB. Water rights held in the trust are not subject to cancelation or forfeiture through contract or perpetuity. Unfortunately, education on the water trust option is not well known. Only two water trusts to date are on record with the TWDB. Potentially with increased concern on sensitive waterways and fragile ecosystems, more preservation measures will be taken.

Current Water Marketing Policy

Water marketing involves transactions between a willing buyer and a willing seller of either temporary or permanent transfer of water rights and ownership. In Texas there is no state permit required to pump groundwater and therefore the state cannot review groundwater sales or leases. Outside of water districts the rule of capture allows for unrestricted water pumping and selling to municipalities, this transfer of rural to urban use is seen throughout the state. Within groundwater districts certain pumping will be limited and may include fees and requirements. This is only enacted, however, if the aquifer where pumping is occurring is completely covered by a district (Kelley 2004). By 2001, 87 groundwater conservation districts covered roughly half of the state, managing and protecting the water table. In water marketing, many transfer types are possible (Table 4).

TABLE 4: WATER RIGHTS TRANSFER TYPES

Type of Transfer	Description	Requirements
Sale	A direct transfer of a surface right between two parties. Traditionally, transfers of surface water rights permits have involved change in use or location.	If a change in use or location accompanies the sale, amendments must be approved through the TCEQ. Otherwise, a change of ownership may be filed with the TCEQ.
Wholesale Contract Sale	One entity develops a water supply (reservoirs, etc.) and sells the use of that water to another party. This is the most common type of water marketing in the state of Texas.	The contract terms must identify: 1. "A per unit cost of water; 2. Effective date and termination date; 3. Allowable diversion rate; annual average quantity of water to be furnished; 4. Location of purchaser's diversion point; and 5. A general statement of compliance with applicable rules and statutes."
Lease	The temporary lease of a surface water right for	If the lease involves a change in use, amount of water location, an amendment to the water permit

	financial considerations. The lease is returned at the end of the agreement.	must be authorized by the TCEQ.
Interbasin Transfer	The transfer of water from one river basin to another	These transfers may only occur: "to the extent that detriments to the basin are less than the benefits of the receiving basin, and the applicant has prepared drought and water conservation plans" for water use efficiency." Through Senate Bill 1, interbasin transfers must contain environmental, water rights, and economic analysis.
Dry-Year Option Contracts	The option to secure additional reliable sources of water during times of drought. This generally occurs between municipalities and irrigators.	A change in water use from what is in the original right necessitates an amendment.
Transfers of Conserved Water (Ground or Surface Water)	The transfer of water that has been saved through conservation.	

Source: (Texas Water Development Board 2013)

Regulations

The TCEQ and the Texas Water Development Board (TWDB) are the regulatory agencies that oversee surface water rights exchanges and contracts. The contract rules set by the TCEQ require that the following be laid out during a permit exchange:

1. Contract terms specifying a per unit cost of water
2. An effective date and termination date
3. Allowable diversion rate
4. Annual average quantity of water to be furnished
5. Location of purchaser's diversion point

6. A general statement of compliance with applicable rules and statutes (Texas Water Development Board 2013).

Water rights permits in Texas may be granted through Section 11.134 of the Texas Water Code. There are two types of appropriated water rights: perpetual and limited term rights. Perpetual rights are distributed as certifications or adjudicated rights, whereas limited term water rights may be seasonal, temporary, contractual, or emergency permits (Texas Water Development Board 2013). Transference or sale of a water right can occur in many different ways, depending on the circumstances (Table 4). The selling of surface water rights can take place between a willing buyer and seller and can involve a change in type of use (i.e. irrigation to municipal) or location. Water marketing with resources in the Rio Grande is different from general surface water marketing, which is managed by the prior appropriations doctrine (Characklis 2002). Rio Grande water transfers are managed through the Rio Grande Watermasters Program Office under the TCEQ. Above the Amistad Reservoir water rights are managed in the same “first in time, first in right” fashion as the rest of Texas. However, in and below the reservoir water rights administration is the responsibility of the Rio Grande Watermasters Program. This organization controls water rights accounts for primarily municipal and irrigation activities. Transfers of rights within the middle and lower section of the Rio Grande Basin are relatively unrestricted. The majority of rights movement has been from agricultural use (irrigation) to municipal use as population expands in the basin.

Groundwater marketing is limited in Texas partly due to the amount of infrastructure required to move underground resources from one area to another. There are also areas without established groundwater districts where regulation is difficult, and the reliability of the source cannot be guaranteed. Rights to groundwater may be purchased separately from the land; however it is usually simpler to purchase the land itself than water rights from the existing owner (Texas

Water Development Board 2013). Pumping and water rights transfers in the Edwards Aquifer region differ from the general rule and are controlled through the EAA. The porous limestone (karst) nature of the aquifer necessitates limitations on groundwater pumping both for the protection of endangered species within the basin, integrity of the landscape, and to ensure that enough water is available for urban centers in the region like San Antonio that depend on the aquifer as a primary source of water (Texas Water Development Board 2013).

Future Policy

As a measure to conserve the region's most precious resource, the TWDB has designated a combination of potential methods in maintaining adequate water resources for the future. Water marketing is one of the several strategies that municipalities, irrigators, industry, and Texas citizens have adopted in order to meet the growing demand. Water marketing has a potential to provide much needed water resources from relatively high abundance in some areas of the state, to the highly concentrated urban areas where water resources are scarce (Texas Water Development Board 2013). According to the Environmental Defense Fund, Texas' water marketing policy must undergo several adjustments in order to properly protect both ground and surface water resources (Kelley 2004). Five major recommendations were provided to assist future policy adjustments in this area:

1. The legislature should replace the rule of capture for groundwater with a system based on principles of reasonable use.
2. State law should be revised to require that groundwater districts adopt rules setting sustainable pumping caps, and districts should be authorized to place a moratorium on large export proposals until such rules are in place.
3. State law should be changed to provide that market transfers of existing surface water rights be authorized in a manner that protects the environment, downstream water users and other statutorily recognized interests.
4. Funding should be provided for sufficient real-time stream gauging and to ensure that water rights are properly enforced.

5. The Texas Water Trust should be reformed to make it a more effective tool for protecting instream flows (Kelley 2004).

Conclusions and Analysis

Providing financing assistance for water projects throughout the state is the primary responsibility of the TWDB. An area of concern with both of these options is the tendency for water marketing initiatives to underserve the public good (Giffin 2002). Individuals and business entities have two options providing different benefits in securing future water: economic and social support offered through the Water Banks and ecological health and recreational use afforded through Water Trusts. Aside from the two Water Trusts recorded with the TWDB, such transactions ignore instream flow management and the effect that lack of freshwater has on natural systems or recreation-related industry.

Transfers and sales of water rights are often between agriculture, commerce, municipalities, and industry. It is reasonable to suspect that the bulk of future water right transfers, for most municipal or economic use will be leased rather than sold out right. This, like many cases in the western United States, will result in the allocation of any unused water supply stored in large projects without extensive state oversight. Some structural challenges must be resolved in order to make these transfers more effective. This includes minimizing transaction costs and uncertainties as well as providing public information to include a wider range of buyers and sellers.

The National Parks Service has compiled an annotated bibliography containing resources that provide valuable information about the economic benefits of conservation of rivers[35]. In these reports, conservation for recreation and tourism is identified as a major topic. In the eight reports

[35] *An Annotated Bibliography: Rivers, Trails & Conservation Assistance Program*. http://www.nps.gov/ncrc/portals/rivers/fulabib.pdf

containing recommendations for approaching conservation, discussion regarding Texas rivers, and the impacts recreation and tourism has on the river-community's economy are absent. An interesting, and valuable research opportunity would be to investigate the economic benefits of allotting surface water flows for specifically ecological and recreational benefit with the established Water Trust system. Such a report will assist communities that may benefit from contributions to the Water Trust providing detailed evidence to the economic importance of such rivers continued flows.

Section 9: Instream and Environmental Flow Policy

Take-away Points:

1. Policy for instream and environmental flows is enacted through SB-2, SB-3, and HB-3.
2. Energy production requires a large amount of water resources (nearly 40% of available resources statewide).
3. The environmental flows process does not always function as a result of scientific findings. Conflict of Interest involving surface water rights sales and river authorities creates confusion.

Background of Environmental Flows

Since the 1970s, legislative developments for ensuring freshwater inflows into major bay and river systems in Texas has been developed with the purpose of protecting marine life, water quality, and fish habitat (Roach 2013).[36] Prior to the environmental flows program, the instream flow program, enacted in 2001 through SB-2 by the 77th Texas Legislation, was established to generate scientific and engineering studies in order to "determine flow conditions necessary for supporting a sound ecological environment in the river basins of Texas" (Texas Water Development Board 2008). Instream flows are defined as the amount of water flowing through a river during a specified amount of time (Texas Water Development Board 2008). In 2007, the 80th Texas Legislature passed SB-3 and HB-3 requiring that the TCEQ adopt environmental flows for every river basin in the state (Texas Commission on Environmental Quality 2013). Environmental flows were established in Texas through Article 1 of SB 3 and stipulate that recommendations for maintaining adequate freshwater in river basins be based on the best science available (Roach 2013). The purpose of environmental flows management is to establish

[36] *Instream flows* refer to the amount of water flowing through a channel of a stream that is required to maintain acceptable levels of streamflow. This includes freshwater required for maintaining biodiversity, recreation, maintenance for riparian habitats, and waste assimilation for water quality purposes (Kaiser and Binion 1998).

a flow regime to support healthy ecosystems. This water allocation process attempts to address the trend of over-allocation, maintaining healthy coastal estuaries and rivers in Texas, and how to protect water sources (Texas Water Matters 2010).

Rivers must carry a certain amount of water in order to maintain healthy riparian systems and aquatic biota in beds, banks, bays, and estuaries (UNESCO-IHE Institute for Water Education n.d.). In Texas, the over-allocation of surface water rights has necessitated legislation to define, quantify, and provide adequate environmental flows (Texas Water Development Board 2013). When managing watersheds with resources that are already over-allocated, permit cutbacks do not necessarily apply. The purpose of SB-3 bill is to strike a balance between surface water extraction rights and healthy rivers and bays. The ability of river basin and bay systems in Texas to perform valuable functions for maintaining the health and well-being of wetland and riparian ecosystems depends on adequate freshwater flows. Additionally, with adequate flow, rivers, bays, and estuaries provide valuable ecological services in the form of aquifer recharge, storm surge buffers, and as natural waste treatment facilities for NPS pollution.

Rivers also provide surface water for agriculture, industry, energy production, and municipal and recreational users. Statewide, power plants consume nearly 40% of state water supply resources and also create impoundments to ensure adequate supply for plant cooling (Roach 2013). These actions can have huge repercussions on wildlife habitats and migration patterns. Large reservoirs disrupt the natural rate, frequency, and timing of flow into river ecosystems, and the damage that this does to wetlands has been well documented through observation of the ecological limits of hydrologic alteration (Poff, et al. 2009). Although some water is returned after the cooling process, the actual water lost through power generation is estimated to be around 3%. The relationship between water resource use and energy production has been, and is currently being, explored in order to explain just how much the two industries are linked.

Economic Impact of Environmental Flows Management

Healthy bays contribute billions of dollars to the state economy through the fishing industry, wildlife protection, tourism, and recreation. Estuarine ecosystems support industries totaling a combined $3.5 billion per year (1994 dollars). This includes seafood, sport fishing, and recreational industries (Texas Water Development Board 2013). Inadequate freshwater discharge into Texas' bays leads to increased salinity, poor biological health, and economic loss.

Recognizing that each river and bay system in Texas has unique properties, the state is divided into regions in order to adopt legal standards that best fit the unique environmental conditions in different river basins (Figure 19) (Texas Water Matters 2010). These standards are adopted

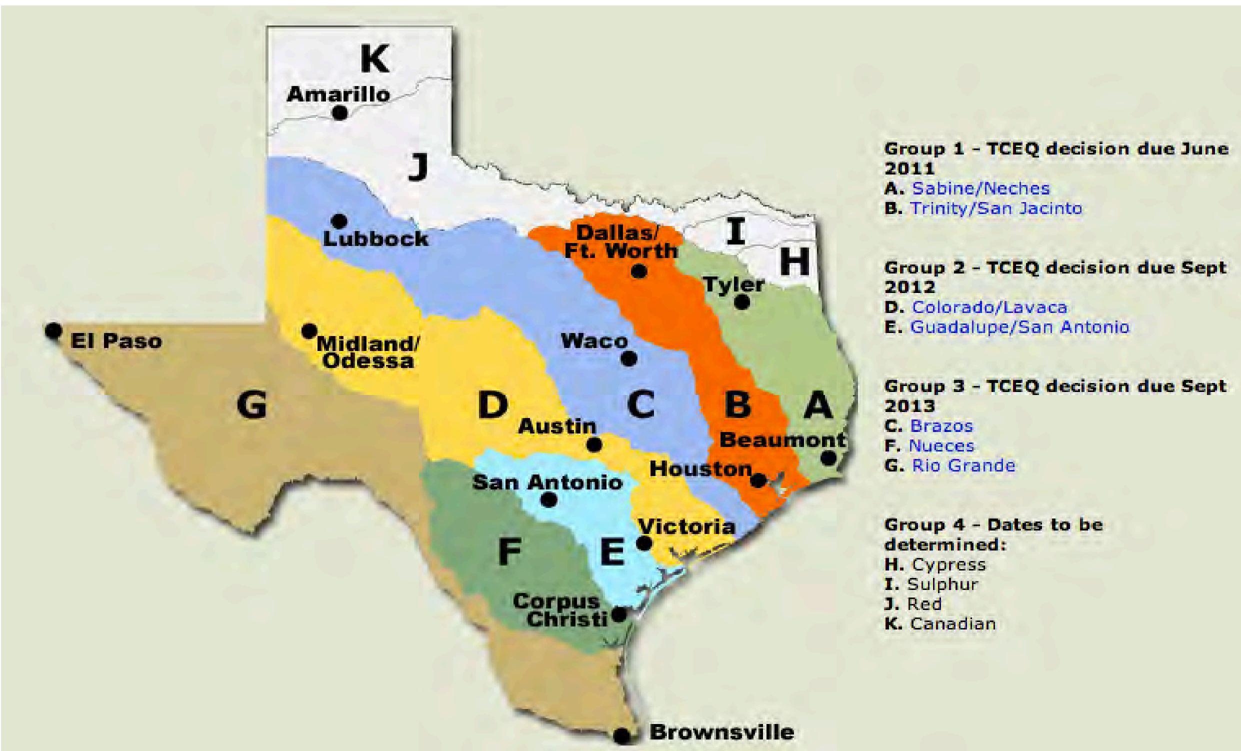


FIGURE 18: RIVER BASIN REGIONS OF TEXAS

through a public process through which information about the region is gathered from local individuals with the most knowledge about local basin information (Texas Water Matters 2010).

Establishing Environmental Flows

The Environmental Flows Advisory Group (EFAG) is made up of three state senators, three state representatives, and one representative from each of the following state agencies: the TWDB, TPWD, and the (TCEQ) (Texas Water Matters 2010). This group is responsible for appointing members to regional committees across the state.

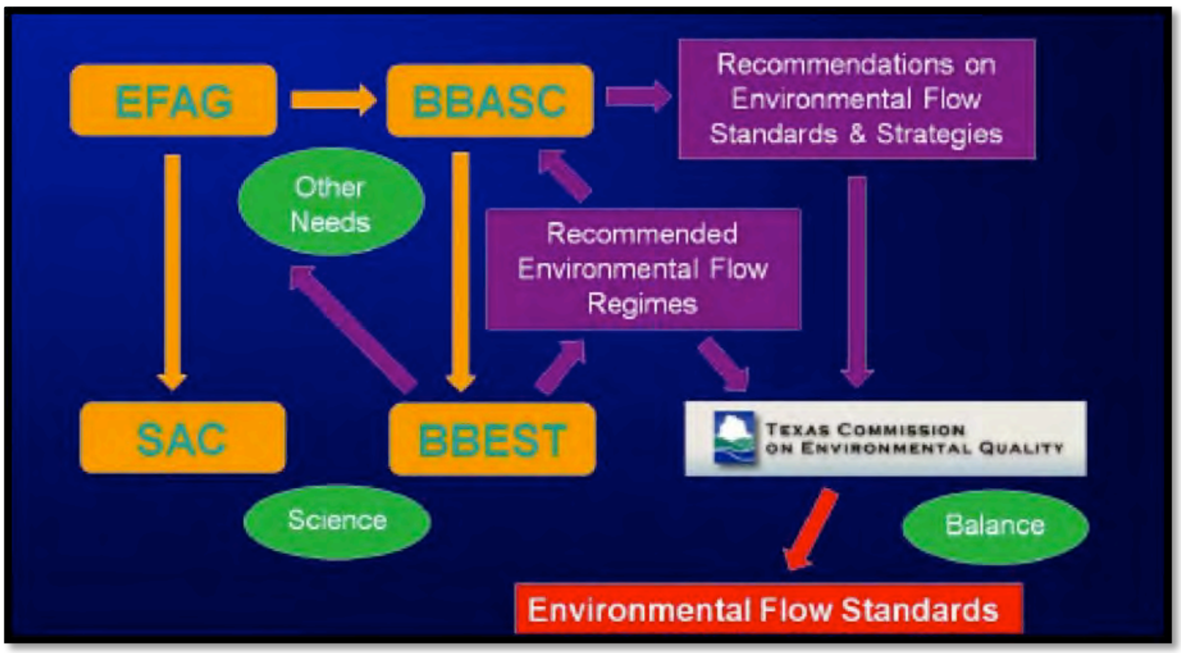


Figure 19: Representation of Environmental Flows Process (Texas Water Develoment Board 2012)

The different regions of the state each have a Bay/Basin Expert Science Team (BBEST) and a designated Bay/Basin Stakeholder Committee (BBASC) composed of people with different backgrounds and interest groups (Texas Water Matters 2010). A nine-member Science Advisory Committee (SAC) provides BBEST groups with guidance and "consistent application of scientific principles" during this process (Texas Water Matters 2010). The BBEST makes recommendations based on scientific observations and study of local basin water requirements to the BBASC. After considering BBEST suggestions, the BBASC then will add policy recommendations to the suggested flow regime and develop strategies for implementing BBEST flow recommendations. Once the BBASC has finalized their recommendations, the TCEQ has one year to adopt the BBASC proposed actions and “set aside” water that has not yet been allocated (Texas Water Matters 2010).

The Future of Environmental Flows

The importance of water conservation for environmental habitats is enhanced by the projected increase in population in metropolitan centers across the state and the observable rise in drought events. River basins containing endangered species must ensure that enough freshwater is available to maintain future populations. Introduction of new species with added critical habitat may potentially add more economic stress to water rights holders in the commercial, industrial, municipal, and agricultural sectors. However, as previously discussed, ensuring that riparian and coastal wetlands habitats are maintained is vital to ensuring the health of the overall ecology of Texas and tourism and fisheries.

A study performed by Wolaver et al. published in 2013 focuses on the potential shift in water distribution that would occur to sustain habitat for endangered species. In central Texas, the U.S. Fish and Wildlife Service has identified five freshwater mussel species that may be up for inclusion in the federal endangered species list (Wolaver, et al. 2013). If these species do become listed as through the ESA, habitat preservation may necessitate the assurance of environmental flows in certain basins. Of particular concern to water rights holders are the changes to existing allocated water supplies in basins containing endangered species. The overall results of this study showed that in worst-case drought scenarios, Texans living in the central region could expect environmental flows to have a moderate effect on the economy relating to the new environmental flows standards imposed by TCEQ for the protection of endangered species of mussels (Wolaver, et al. 2013). Methods suggested to alleviate economic stress resulting from mandated environmental flows are to create new and expand existing water markets.[37]

Permitting for Recreational Use

In Texas, many types of water-related recreation activities are regulated through the Texas Parks and Wildlife Department (TPWD). Texas has numerous navigable waterways that are open for public use (TCEQ 2013). These rivers, streams, creeks and lakes add to the character of the state, and increase tourism, economic growth and environmental stewardship. The TCEQ is the agency responsible for setting water quality standards for navigable streams, waterways and issuing permits for surface water rights.

Permits for Individuals

Permits serve as a means to protect the environment, communities, certain species of plants and animals, as well as to garner funding for the state. The TPWD offers permitting and license sales for state citizens that allow individuals to engage in certain activities or use their land in a way to promote recreational or conservational use. A license provided though TPWD is required to engage in hunting, fishing, and boating in the state. Permits are also required if an individual wishes own or transport exotic species which have caused extreme environmental damage when placed into native waters in the past. Furthermore, if a landowner wishes to disturb a streambed

[37] See section on Water Marketing

by taking materials from it, either in wet or dry conditions, this may also require a permit from TPWD (Texas Parks and Wildlife Department 2011).

Surface water is owned by the state and requires specific water rights permits in order to be utilized. Prior to 1969 the adjudication act applied to permit claims; however, a more standard procedure is followed with modern water rights permit applications. The TCEQ accepts, reviews, and issues permits for surface water rights in the state. The criteria to receive a permit are different depending upon the conditions of the area and the needs of the community. In general, if the applicant for the permit intends to use the water in a fashion that is not detrimental to the public welfare, does not impair vested water rights, and they intend to practice conservation management, then the permit may be granted. Taking of surface water for recreational purposes on private property is still under the auspices of the TCEQ and requires permitting (Recreational Use Attainability Analyses 2013).

Water Permits for Industrial Uses Promote Quality Assurance

State regulatory agencies like the TCEQ offer guidance or regulations to assure that recreational waters in the United States meet certain standards to reduce the risk of adverse health outcomes associated with waterborne pathogens and pollution. The CWA is the primary federal law that governs water pollution of any kind in the United States. Section 303(d) of the CWA requires each state to set water quality standards (WQS) which are site-specific standards for allowable pollutant levels depending on the type of body of water, such as recreational water. The Environmental Protection Agency (EPA) offers oversight on many rivers, lakes and bays and drafts a report that outlines criteria that each state can follow to effectively set WQS (Texas A&M and Texas Water Resource Institute 2013).

The EPA released the Recreational Water Quality Criteria (RWQC) in 2012 that had been updated from the 1986 recommendations, and offers information pertinent to human health. The RWQC gives up-to-date information reflecting modern epidemiological findings and toxicological studies that aim to reduce the risk of illness associate with recreational water use. The recommendations are intended as guidance to states, territories, and authorized tribes in developing water quality standards to protect swimmers from exposure to water that contains organisms that indicate the presence of fecal contamination (Environmental Protection Agency 2012).

The TCEQ sets the state water quality standards under the authority of the CWA and the Texas Water Code authorized by the state. The Texas Surface Water Quality Standards (TSWQS) established explicit goals for water quality throughout the state. These TSWQS are developed to maintain the quality of surface waters in Texas in order to support public health and enjoyment, and to protect aquatic life. Each of the four categories is assigned to a body of water based on a Recreational Use Attainability Analyses that helps protect Texans from utilizing bodies of water in an unsuitable fashion (Recreational Use Attainability Analyses 2013).

If a body of water has established a recreation standard, additional criteria are needed to issue a permit for effluent discharge. In these areas the TCEQ may consider odor as a water quality criteria when assessing the permit application. Furthermore, if the body of water crosses or abuts any park, playground, or schoolyard within one mile of the point of discharge than any unpleasant qualities can be taken into consideration. In the event that any likelihood of damage to the recreational value of the park, playground, or schoolyard will occur then the permit may be declined (Texas Statutes 2012).

Revenue Generated Through Water Recreation

Many resources for water-related recreation are available through the TPWD website, including information about paddling trails, swimming in state parks, and coastal activities. Within the TPWD, the Administrative Resources Division is responsible for distributing boat licenses and Inland Fisheries Division and the Coastal Fisheries Division manage licensing for fishing activities. Funds received from the sale of boating and fishing licenses and permits are deposited into the Game, Fish and Water Safety Account, also known as Account No. 9, created by the 64th Texas Legislature in 1975. Account No. 9 is a General Revenue-Dedicated Account established to receive revenue from hunting and fishing licenses. Over the last year, an estimated $253 million in revenue has been deposited into Account No. 9. Such revenue is used to "fund the administration and enforcement of game, fish, and water safety laws" as well as other conservation activities (Legislative Budget Board 2012). During the 2012-2013 biennium, nearly 75% of the revenue deposited into Account 9 had been generated from the sale of hunting and fishing licenses. Funds deposited into this account also come from boat registration, penalties involving conservation or water safety violations, and titling fees. Revenue for recreation and parks management for the TPWD is also generated through specialty stamp sales, and the use of these funds is limited to certain programs and activities within the TPWD. Section 11.032 of the Texas Parks and Wildlife Code states that 15% of all boat registration and title fees must be transferred annually to the General Revenue-Dedicated State Parks Account No. 64 in order to support park operations.

Water recreation provides economic benefit for a variety of private businesses from the purchasing of boats, clothing, sunscreen, and other water recreation related merchandise. Furthermore, individuals travelling from different states and communities help promote business;

from restaurants, and travel-related expenses, to local attractions. Each year, an estimated $646 billion is spent in consumer purchases on outdoor recreation, which amounts to $39.7 billion in state tax revenue.

Maintaining water quality is imperative to ensure that water-based recreation activities remain viable. The economic benefits of having clean water more than compensate for the cost of maintaining it. As an example of such benefits, a 2002 report regarding the cost and benefit of surface water quality performed by the TCEQ determined the annual revenue generated from sport fishing in Texas to be at least $6 billion. Yet the average annual capital investment into maintaining water quality to support this industry is only $500 million.[38]

Importance of Permits

Issuing permits for water capture, recreational use, and waste discharge is a process that benefits the state as a whole. Historically in this country waste discharge in our waters were under regulated and rarely enforced, in the 1960's conditions became so poor that the Cuyahoga River caught the country's attention when it burst into flames due to the extremely poor water quality (Hartig 2011). Permits are part of the solution to reduce the amount of hazardous chemicals present in our water, as they help to ensure both the quality of water and protection for recreational uses. Furthermore, permits are necessary to safeguard against excessive and unscrupulous water uses.

Conclusions and Analysis

Concerns Regarding Conflict of Interest

The Water Rights Adjudication Act of As stated previously, Article 1 of SB-3 mandates that establishment of environmental flows be based on sound science. The purpose of this is to ensure

[38] These numbers are taken directly from the TCEQ Report: Benefits and Costs of Surface Water Quality Programs.

that physiological and chemical needs of existing species are met and that coastal industry remains stable. There is some evidence, however, that the existing process is not carried out as recommended. The River Authorities responsible for managing surface water under their jurisdiction obtain a large portion of their funding from surface water sales and this presents a conflict of interest (Roach 2013). Similarly, scientists also contracted to determine what measures should be adopted also often work for consultant firms in business with river authorities (Roach 2013). This represents another conflict of interest. This is of especial concern not only for the future health of ecosystems, but also for the present condition of estuarine and river systems in Texas. Many of the river systems in Texas are fully appropriated, meaning that resources are longer available for diversion (Kaiser and Binion 1998). Concerns about maintaining environmental flows and ecological health in the future are expanding because, unlike an individual capable of defending a water right, the environment has no ability to express what is required to maintain health systems.

Recommendations for Environmental Flow Program

Disagreements about how much water is needed to sustain environmental flows for a particular river basin have also impeded program progress. The first two basins for which environmental flows[39] have been mandated did not receive enough water to mimic a natural flow regime (Roach 2013). In order to ensure that the environmental flows program is effective, it is recommended that an independent regulatory body be established to ensure that ecosystems receive the freshwater required for maximum ecological health. Allowing the same agency that profits from surface water rights sales to determine how much water is required for riparian health is not economically or environmentally prudent. Riparian and coastal water bodies supply

[39] Sabine and Neches River Basin and Sabine Lake Bay.

significant resources to various industries in Texas. Without the insurance of water resources for these systems, the industries that depend upon these resources will suffer or may perish.

Recommendations for Future Studies

Successful environmental flows require an in-depth understanding of river hydrology, linkages in flow events, biotic responses and geomorphic responses (Shafroth, et al. 2010). In order for this program to be managed properly in Texas, a consensus must be reached regarding how much water is sufficient for maintaining the health of coastal ecosystems. Examples of program success have already been implemented in many nations, and such progress has always been an interdisciplinary endeavor (Kendy and Le Quesne 2010).

Support for environmental flows implementation in Texas river systems requires that the science behind the program be sound, and also that decision-makers at all levels support implementation. Once methods for determining how much water is required for environmental flows in every river basin in Texas is established, attention should be given to educational efforts and policy development. We must determine how to best disseminate scientific information, adaptive management practices, and limit situations involving conflict of interest.

Section 10: Habitat Conservation

Take-away Points:

1. Section 10 of the Endangered Species Act sets the processes for creating HCPs.
2. There are 80 HCPs currently established in Texas.
3. HCPs can be negotiated directly with the landowner and the U.S FWS, or through state and local governments, environmental groups, or business organizations.
4. Methods for enforcement of economic valuation of resources in Texas are currently limited to remediation programs.

Background on Habitat Conservation Planning

Habitat conservation planning and techniques have changed throughout the history of the United States. Perhaps the first example of habitat conservation at the federal level was the funding for Yellowstone National Park in 1872. Concerns over the influence development was having on the ecological conditions of the country were voiced as early as the 1830s as America's westward expansion was underway. These concerns resulted in the creation of National Parks Service to preserve habitat for the public good as well as for the benefit of the flora and fauna of the land. Over the years, the approach to conservation has evolved, and each state's approach to habitat conservation is different depending upon the local needs, politics, and environmental conditions of the region. Conservation issues have traditionally followed an atomistic approach in the United States, but as increasingly sophisticate data is presented and the public becomes better informed on environmental concerns, a more holistic method has been proposed to tackle current and future problems (Welcomme and Petr 2003).

The connection between habitat conservation, water management, quality assurance programs, and drought protocol are gradually being realized. As has been covered earlier in this document, the quality and quantity of surface water relies on groundwater that of groundwater, as they are part of the same hydrological cycle[40]. Certain species living in diminishing environments rely upon a healthy habitat, watershed, and water quantity to survive. The connection between the land, water, plants, and animals simply underscores the importance of appropriate and comprehensive tactics in the coming years.

Habitat Conservation Plans

Established and passed by Congress in 1973, the Endangered Species Act (ESA) states that endangered species "are of esthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people.” The purpose of the ESA is to provide protection for ecosystem preservation in which endangered and threatened species can rely upon, and to provide a conservation program for those species. Species of plants and animals may be designated as endangered if certain conditions are met (U.S. Fish & Wildlife Service 2013).

Habitat Conservation Plans (HCPs) are a preemptive measure used to protect at-risk species. Section 10 of the Endangered Species Act sets the processes for creating HCPs. This helps assure that measures for “adequately minimizing and mitigating of the take” are in place to limit harm to endangered species. When non-federal activities result in the taking of a threatened or endangered species, an HCP accompanies an incidental take permit. The term “take” is used broadly to mean any action that will harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct of a species that has been identified as being endangered (U.S. Fish & Wildlife Service 2013).

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[40] See section on Surface Water Rights.

Put simply, HCPs are tools that aim to balance the needs of non-federal landowners and threatened or endangered species. The permit granted by the HCP allows landowners to the incidental take and the landowner, in turn, agrees to pursue the specific management protections for the area. Established HCPs vary in breadth and purpose depending upon the conditions of the region, the specific species or group of species being protected, and the geographic size of the property. All HCPs can be negotiated directly with the landowner and the U.S FWS, or through state and local governments, environmental groups, or business organizations. Furthermore, the approach to management can range from predator control, preserving key habitat, or various other mitigating measures prescribed by the HCP (Aengst, et al. 1997).

Once a plan is enacted, non-federal landowners may be protected from future changes to the plan if the need to adjust arises. The government gives these landowners assurance of no additional need to commit or restrict additional land, water, and financial resources to the HCP without consent of the permit holder through the so-called No Surprise policy. This policy change was adopted by the Clinton Administration in 1994 to offer further incentive for landowners enact an HCP, and it assures the landowner that if unforeseen events reduce the likelihood that a species covered by the HCP will survive the agency agrees to bear all responsibility both financially and logistically. In short, this requires that the agency be accountable beyond the original requirements of the HCP instead of the owner (Aengst, et al. 1997).

Currently, there are more than 80 HCPs in Texas alone. The majority of these plans are developed to conserve resources in rapidly developing areas where habitat for indigenous species like the golden-cheeked warbler and the Texas Blind Salamander is diminishing (U.S. Fish & Wildlife Service 2013). Larger regional and countywide HCPs for the Hill Country are also in effect or in development (Hill Country Alliance 2011). This area of special interest because of the large amount of urban expansion projected over the next 50 years and the development currently underway. Progressive legislation in this area has been introduced to the 83rd Legislative Session and included in plans for establishing environmental flows[41].

Conjunctive Use

The environmental quality of a region, the availability of clean water, and the outcome of endangered and threatened species are all connected. Healthy habitats require that watersheds be of good quality in order to sustain life. There are several examples of watershed HCPs in which efforts for species conservation are tied to managing water resources within a watershed. Habitat Conservation Plans like the Edwards Aquifer Habitat Conservation Plan, or the Edwards Aquifer Recovery Implementation Program (EARIP), sustain the health of the fragile karst aquifer and endangered species in the system by limiting human activity in sensitive areas (Edwards Aquifer Authority 2013). During times of drought, species living within the protected area may suffer when existing water resources are further diminished by human activities. One mitigation technique to help reduce the negative impacts of drought in Texas is an approach called conjunctive use.

Within the complex world of water resources there are numerous management structures available. Conjunctive use is a management strategy that falls under the Integrated Water Resource Management (IWRM) framework, a global paradigm that is aimed at managing water in a holistic fashion by encouraging institutional cooperation, extensive stakeholder involvement, and efficient water resource management. By recognizing the innate physical connection between groundwater and surface water, conjunctive use is a strategy that attempts to offer a

[41] See the section on water –related legislation in the 83rd session.

flexible and cost-efficient management framework. It is excellent for long-term planning, is often utilized in arid to semi-arid environments, and is particularly effective in addressing over-allocation and general water-stress. Conjunctive use is a management system that takes four primary components into account: physical water systems, economics, water law, and societal issues. In considering all four of these components, conjunctive use insures a more comprehensive approach to water use (Roberts 2010). Drought has become a serious concern in Texas as the projections for future water shortages, and increased population growth become realized. The state was reminded of the severe cost that drought can cause during the 2011 drought. According to the Texas Forest Service, "an estimated 5.6 million trees that once shaded homes, streets and parks in communities across Texas now are dead as a result of last year's (2011) unrelenting drought" (Texas A&M Forest Service 2012) Furthermore, habitat and species were threatened by the reduction in both access to water, as well as the decrease in habitable landscape. The cost of drought is incredible and, unfortunately, the only way to mitigate those costs is to be prepared. Conjunctive use is a strategy serving the land, species, and communities in Texas.

Conjunctive use manages surface water and groundwater supplies by taking into consideration that the two states occupy different stations within one same cycle. Employing active conjunctive involves capturing and storing surface water into a groundwater basin or aquifer during wet years. This helps bolster the groundwater supply through withdrawing water supply from the basin during dry years when surface water levels may be low. Such practice also utilizes the natural hydrologic cycle and places a focus on the optimal use of one resource while the other resource is being replenished, thus using the natural hydrological environment for storage and transportation. An example of this is a river or canal functioning as a transport system or an underground aquifer that serves as a repository (Fetter 2000).

The TWDB has recommended conjunctive use as a major water management strategy in Texas. Conjunctive use is estimated to have produced 26,505 acre-feet of water in 2010 with capital costs of $140 million. If recommended strategies be adopted to increase conjunctive use, this water supply volume is projected to increase to 136,351 acre-feet by 2050. This has quickly become one of the prime approaches for Texas conservation efforts in the state (Texas Water Development Board 2012).

Economic Valuation of Ecological Services

Ascribing an economic value to the environment has been explored extensively as a philosophy; however putting into practice in a capitalist society has many challenges. A price for a good or a service may be obtained based on the market value of said item or service, but the value of nature is difficult to calculate. In economic terms, *value* is the price that an individual is willing to pay for a service or a good (NOAA Coastal Ocean Program 1995). Whether it is a market good or the health of the environment that is at stake, the notion of value and its measure remain constant (NOAA Coastal Ocean Program 1995). However, ecologists and environmental scientists understand that the value of an ecosystem may fluctuate depending upon human preference unlike other market goods. If, for example, a water body becomes polluted and is no longer able to support recreational activity, then the value of that water body goes down. Conversely, some individuals living in a watershed may not care very much if a polluted stream or river is unable to support as much wildlife as it did when the system was less polluted.

There are social and economic differences that can potentially be problematic when determining the value of natural resources. Simply defining terms is the first obstacle that stakeholders and decision makers must address before any regulatory or social action is taken. Questions associated with this problem include determining the economic worth of a “healthy watershed” and ascribing a quantifiable value to water. Can ecosystem health be incentivized in the same manner as oil and natural gas, and what policy measures will the public respond to most favorably? These are questions that we will need to answer in the future in order to preserve ecosystem health and ensure that resource integrity will be maintained for generations to come.

The accepted method: cost-benefit analysis

Professionals and decision makers responsible for legislative developments must take into consideration the cost for proposed action affecting the integrity of a watershed. The most widely acceptable method of determining the environmental effect and making decisions regarding natural resources of a prescribed action is to apply a cost-benefit analysis (NOAA Coastal Ocean Program 1995). Generally speaking, a cost-benefit analysis identifies all possible major costs and benefits and detects the consequences of legislative action that may be taken (NOAA Coastal Ocean Program 1995). The primary benefit of this method is not necessarily the predicted outcome, but rather through the use of process rooted in scientific reasoning (NOAA Coastal Ocean Program 1995).

However, precisely defining the *economic value* of nature is not a cut-and-dry procedure. Quantifying the benefits and costs of actions impacting environmental assets is difficult when dealing with assets that are not normally exchanged in the marketplace. There is also the issue of intrinsic worth and other less-concrete sources of value for which applying an associated cost has been historically difficult. When a watershed experiences a disturbance from mining or other industrial activities that affect the integrity of the system, the altered value of that ecosystem is often unaccounted for in the equation. Establishing methods for employing ecosystem valuation is difficult in part because it involves compensation for a “non-service” that is paying a regulatory agency or community for the use of resources provided by nature, not a business or other entity.

History of Valuation in America

Creation of an accounting system for economic loss or gain relating to ecosystem growth or destruction has been in consistent development in the United States since passage of The River and Harbor Act of 1902 (NOAA Coastal Ocean Program 1995). This first Act required that a group of engineers report on the “desirability,” that is the benefits and costs to commerce, of river and harbor projects executed through the Army Corps of Engineers. During the 1930’s, advanced ideas regarding social justification for federal projects began to inform program development. An example of this is the 1936 Flood Control Act, which stated that action by the government relating to flood-control schemes during flood events is permissible if the benefits of such action outweigh the costs. Recognizing the “intangible” costs associated with hazards also informed the development of post-World War II federal programs that focused on accounting for secondary, indirect, and the environmental (intangible) costs and benefits (NOAA Coastal Ocean Program 1995).

A precursor to the environmental movement of the 1960s, the language of welfare-economics was formally introduced into legislation in the form of The Green Book published in the 1950s. After The Green Book was published, pollution control became a highlighted concern for federal project justification in the 1960s and 1970s. The National Environmental Policy Act (NEPA) established in 1969 and then amended in 1982 did require the use of cost-benefit analyses, but actual valuation of environmental resources did not progress until the 1980s. Prior to this change, the Clean Air Act of 1970 and the Clean Water Act of 1972 were established and remain the two cornerstone pieces of legislation on pollution control (NOAA Coastal Ocean Program 1995). However, the creation of these two acts was not centered on the economic balance of environmental standards, but rather was based on public health criteria (NOAA Coastal Ocean Program 1995).

In 1981, Executive Order 12291 also known as the Regulatory Impact Analysis Requirement was passed as a measure to "decrease the burden of existing and future regulations increase agency accountability for regulatory actions, provide for presidential oversight of the regulatory process, minimize duplication and conflict of regulations, and insure well-reasoned regulations" (U.S. National Archives 1981). Other key environmental legislation passed in the 1980s includes the Environmental Response, Compensation and Liability Act of 1980 (CERCLA). The passage of CERCLA permitted trustees holding natural resources the right to claim damages for harm done to natural resources such as publicly owned estuaries, water bodies, or terrestrial habitat due to chemicals or oils released into the environment (NOAA Coastal Ocean Program 1995). Subsequently following the Exxon Valdez incident, the Oil Pollution Act (OPA) of 1990 required that regulatory agencies develop specific Area Contingency Plans to provide insurance for environmental protection efforts (U.S. Environmental Protection Agency 2011). The creation of OPA also resulted in the establishment of the Oil Spill Liability Trust Fund that is able to provide up to $1 billion in the event of an oil spill (U.S. Environmental Protection Agency 2011).

As was previously mentioned, valuation of resources in the ecological sense is in part related to the measure of welfare that individuals ascribe to environmental attributes. This concept is referred to as *willingness-to-pay*. A basic understanding of this principal can be summed by stating that the lost value resulting from a degraded environment is the maximum amount individuals are willing to pay to keep that same area free of pollution (NOAA Coastal Ocean Program 1995).

Economic Valuation of Resources in Texas

In Texas, natural resource valuation is often determined by analyzing the amount of damage an ecosystem sustains in response to industrial activity. Under the TCEQ, the Remediation Division oversees a variety of activities that require remediation to restore environmental health. Programs available through this division are the following:

1. Brownfields Program – Provides site assessment for brownfields and provides cleanup assistance for government and non-profit organizations not responsible for damages.
2. Drycleaner Remediation – Implements standards set forth by House Bill 1366[42]
3. Innocent Owner/Operator Program (IOP) – Allows business owners and operators to be free of responsibility when contamination to property comes from an off-site source.
4. Municipal Settings Designations (MSDs) – An MSD is given when groundwater within a municipality or an external jurisdiction is contaminated and no longer potable.
5. Natural Resource Trustee Program (NRTP) – Evaluates damage done to natural resources due to a release of hazardous materials and seeks restoration appropriately.
6. Petroleum Storage Tanks – Oversees the cleanup of petroleum released from underground and above ground storage tanks.
7. PST State-Lead Program – Directs contractors to address leaving petroleum tanks.
8. RCRA and Industrial Hazardous Waste Sites – Oversees cleanup of soil and groundwater contamination from industrial waste.
9. Superfund Site Assessment, Discovery, and Cleanup Program
10. Voluntary Cleanup Program – Encourages cleanup of contaminated sites in Texas.

Through the OSPA and CERCLA, state agencies are able to establish methods for preventing natural resource destruction in the wake of mining or industrial activities. The Natural Resource Trustee Program in association with the Remediation Division through TCEQ is tasked with acting as the state trustee responsible for both evaluating the damage done to natural resources as a result of an oil or chemical spill; and seeking restoration of those resources (Texas Commission on Environmental Quality 2013). Through these programs, regulators and acting trustees are able

[42] House Bill 1366 was passed September 1, 2003 and establishes environmental standards for operators and assistance with clean up involving solvents used in dry cleaning (Texas Commission on Environmental Quality 2013)

to determine the value lost to these natural resources by assessing the damage. However, there is no standing economic value for healthy watersheds and ecosystems in the state of Texas. Indeed, the legislative orders for ecological valuation mechanisms discussed in this section do not include methods for valuation of environmental attributes in current cost-benefit analysis models.

The programs available through the TCEQ Remediation Division do indeed work toward ameliorating damages done; but the actual valuation of ecological resources is arguably still lacking in Texas and nationwide. The instate programs that exist are remediation programs, meaning that action is taken after damages are done and have been assessed. This implies that there is no defined economic value that the state of Texas currently gives to natural resources. Section 23.51 of the Texas Tax Code does state that "open-space land" devoted to farm or ranching may be used as an 'ecological laboratory' by public or private universities. This can be taken to mean that such private land may be preserved for 'natural' purposes as such preservation has scientific and economic value. However, this idea is not the same as valuing nature for nature's sake.

Conclusions and Analysis

With weather variability in Texas becoming more frequent and having serious economic and environmental repercussions, methods to maintain healthy ecological systems within sensitive areas of growth are of increased importance. Diagnosing the significance of successful habitat conservation plans by integrating conjunctive use and environmental valuation provides a pathway to meet concerns in the physical water system, the economy, water policy and societal issues throughout the state[43]. According to the State Water Plan 2012, the TWDB projects conjunctive use to increase almost 20% by 2060 (Texas Water Devolvement Board 2012). This

[43] See four primary components of conjunctive use (Roberts 2010)

suggests that of our various strategies to manage water resources available, conjunctive use will be of the top ten most used in Texas.

In order for a habitat conservation planning processes to be effective, appropriate valuation for environmental protection should be considered. Recently, efforts have been made in other states to link non-market value tools with interdisciplinary science to create a method for determining natural resource worth.

Recommended Future Projects

A project performed through the University of New Mexico with funding from the EPA proposed a method for developing valuation techniques to aid in resource preservation by combining "two stated-preference methods, choice models and dichotomous choice contingent valuation models" (Environmental Protection Agency 2007). The objective of this project was to develop a *hydro-bio-economic model* that will have valuation results dependent on hard science.

Valuation of natural resources is one integral part in a new dynamic of water management. Assigning monetary value to a resource previously viewed as free is a step being slowly adopted throughout the country and world. Texas' industry and growing population cannot afford a late adoption of such methods. Our water resources are valuable and need to be carefully regulated by water's inherent economic importance.

Gathering data to support the benefit of invested capital to protect such fragile natural resources, and various species dependent of health flows, is an important step in establishing more widespread and successful HCPs. With The Meadows Center for Water and the Environment, teams of skilled research and scientific specialists work together to gather valuable data and facilitate stakeholder involvement in various water-related projects. Development of natural resource valuation opportunities in Texas is expected to offer appropriate evidence for the value of environmental conservation efforts. This investment of resources will provide communities with the tools necessary to manage their resources more efficiently as well protect sensitive ecosystems that are located nearby.

Section 11: Environmental Education and Policy

Take-away Points:

1. Formal environmental education standards are established through the SBOE and the TEA.
2. Informal environmental education programs are supported to both supplement formal environmental education and to provide ecological information and training to the public.
3. Environmental education and outreach are useful and often required components of WPPs and TMDLs.

Formal Water Education in Texas

In Texas, all formal water resource curricula adheres to the Texas Essential Knowledge and Skills[44] (TEKS) that are developed through the Texas Education Agency (TEA) (Texas State Board of Education 2011). The State Board of Education (SBOE) forms a TEKS review committee comprised of community members who have "expertise in the subject matter in which he or she is appointed [as reviewer] (Texas State Board of Education 2011)." These standards clarify what students should know upon graduation from elementary, middle, and high school in all subjects including science and water-related studies (Texas State Board of Education 2011). In 2009, the science TEKS were revised to include a more interdisciplinary approach to science and resource management (Texas State Board of Education 2011). Introductory science courses in elementary and middle school integrate water resources into general science, but formal aquatic science is only available to high school students in grades 10 and above (Tables 5 and 6).

[44] http://www.tea.state.tx.us/index2.aspx?id=6148

Elementary Science Standards

Science education begins in elementary school when students begin to use scientific processes to make informed decisions (Texas Education Agency 2011). The TEA introduced revised science TEKS in 2009 to include the National Academy of Science definition of "science" and to encourage "classroom and outdoor investigations for at least 80% of instructional time in kindergarten and grade 1, 60% in grades 2 and 3, and 50% in grades 4 and 5 (Texas Education Agency 2011)". In order to establish general scientific knowledge, elementary school students receive instruction in the four disciplines of science: physics, chemistry, life science, and earth and space science (Texas Education Agency 2011).

An element included in the revised TEKS emphasizes the importance of recognizing recurring themes that "transcend disciplinary boundaries" in mathematics, technology, and sciences (Texas Education Agency 2010). This allows teachers to combine information from different disciplines, thereby introducing to interdisciplinary subject matter in preparation for middle

TABLE 5: WATER RELATED ELEMENTS IN 8TH GRADE TEKS

Grade	Scientific Reasoning	Earth and Space	Organisms & Environment	Matter and Energy	Force Motion
Elementary (K-5) TEKS	1. Water conservation 2. Problems associated with a lack of water in a habitat	1. Water uses/ properties 2. Water cycle & weather (sun-ocean relationship) 3. Water sources 4. Erosion process 5. Water as a renewable resource	1. Examine water as a basic need for organisms 2. Water and wildlife (fish) 3. How water moves through plants	1. Water properties - freezing, evaporating 2. Condensation	
Middle School (6-8) TEKS		1. Model effects of human activity on a watershed and groundwater 2. Water as a necessity for life in our solar system	1. Organism competition for water in an ecosystem		1. The role of Water in weathering

school. With regard to water in science, elementary school students are expected to graduate with an understanding of the water cycle, conservation methods, and the basic properties of water (Texas Education Agency 2011).

Middle School – Revised TEKS for grades 6-8 directly outline interdisciplinary methods for science instruction, but do so under the heading of specific courses: physical sciences (grade 6) organisms and the environment (grade 7), and earth and space science (grade 8) (Texas Education Agency 2011) (Table 5). Building upon basic knowledge about the hydrologic cycle and water resources received in elementary school, middle school students further explore the importance of water in the biosphere. Examples of this include modeling storm water runoff and the effect of diminished resources on life in an ecosystem. Students in middle and high school are expected to be able to "distinguish between scientific decision-making methods and ethical and social decisions that involve the application of scientific information (Texas Education Agency 2011)." This requires not only that students comprehend and have the capacity to demonstrate scientific skills, but also have the ability to design experiments to answer questions scientifically. Scientific instruction in middle school focuses on the following strands:

1. Scientific investigation and reasoning,
2. Matter and energy,
3. Force, motion, and energy,
4. Earth and space, and
5. Organisms and environments (Texas State Board of Education 2011)

High School – The interdisciplinary science instruction that students receive in middle school allows for exploration into specific scientific fields using real-world case studies in high school.

Students are required to take pre-requisite biology, chemistry, or physics courses before enrolling in upper-level science courses (Texas State Board of Education 2011). Once core courses have been successfully completed, upper-level courses allow students to explore specific earth and physical sciences. All of the upper level courses require some water resource-related TEKS incorporation (Table 6).

TABLE 6: WATER RELATED SCIENCE TEKS FOR GRADES 10-12

Course	Chemistry (Grade 11 or 12)	Earth and Space Science (Grade 12)	Aquatic Science (Grade 10)	Environmental Systems (Grade 11 or 12)
Prerequisite	1 unit of high school science and Algebra I	3 units of science + 3 units of math	High school biology or chemistry. Chemistry can be taken concurrently	1 unit of high school life science + 1 unit of high school physical science
Water-related essential knowledge and skills	1. Water in chemical and biological systems 2. Predict products in acid base reactions that form water	1. Human-influenced environment changes (water pollution) 2. Time-scale of natural resource use 3. Natural processes, changes to the environment 4. Effect of resource use on the global environment 5. Global water circulation 6. Components and fluxes within the hydrosphere (effect of over pumping on groundwater and aquifers.)	1. The water cycle in the aquatic environment 2. Water sources and the amount of water in a watershed 3. Fresh and salt water adaptations in organisms 4. Energy and matter flows through fresh/salt water systems 5. The impact of water policy (Clean Water Act)	1. Laboratory Water Quality Test kits 2. Diagram the hydrologic cycle, identify sources, water management, and quantity

High school students are also required to synthesize scientific knowledge and social ethics in order to explain environmental phenomenon and justify social action (Texas Education Agency 2011). For example, the Aquatic Science course requires students to fully understand the water cycle and the effect of human influence on water quality and quantity. Using this information, students are able to understand the CWA and how science is used to create policy.

Informal Environmental Education in Texas

Informal education is used to describe education programs and activities that take place outside of the school setting. This is a very broad term and can apply to everything from nature and science technology centers, museum programs, and K-12 outdoor programs, to teacher training workshops and continuing education programs and certifications (Texas Statewide Systemic Initiative 1999). Informal science educators in Texas develop curriculum to promote hands-on or experiential learning and scientific literacy by using scientific techniques in the field. Many of these programs fall under the umbrella of environmental education, which is defined by the Environmental Protection Agency (EPA) as, “a process that allows individuals to explore environmental issues, engage in problem solving, and take action to improve the environment (Texas Statewide Systemic Initiative 1999).”

Formal water resource education including aquatic biology and biology courses contain complex water-related curricula such as freshwater macro invertebrate studies, understanding the water cycle, and water quality studies (Texas Statewide Systemic Initiative 1999). In Texas, formal science education standards for K-12 students are established through the state standards for student knowledge outlined in the Texas Education Knowledge and Skills (TEKS). Successful implementation of Science, Technology, Engineering, and Mathematics (STEM) in K-12 curricula is vital to increase student retention in science-related fields (Thomasian 2013).

Informal science programs extend beyond prescribed time and curriculum limits of in-classroom learning, thereby allowing students to obtain comprehensive instruction through hands-on STEM methods (Texas Statewide Systemic Initiative 1999). The Texas Statewide Systemic Initiative (SSI) is an organization funded through the Texas Education Agency (TEA) and the National Science Foundation (NSF). As a TEA contractor, SSI is responsible for developing new mathematics and science standards for the state of Texas (Texas Statewide Systemic Initiative 1999). There are many resources in Texas for informal education in the sciences that are recognized by SSI that create effective informal education programs, which supplement existing formal education science standards (Texas Statewide Systemic Initiative 1999).

In 1996, the SSI Informal Science Education Action Team was founded to create a scientific learning community to exist outside of the classroom (Texas Statewide Systemic Initiative 1999). This action team contains a diversified group of 23 members involved in both formal and informal science education. The Informal Science Education Action Team created the Informal Science Guidelines, which provide informal educators with guidance about how to effectively develop informal education programs. In order for informal science lesson plans to become easily incorporated into formal curriculum, informal educators must do the following:

1. Co-develop original programs with formal educators to improve science-based learning,
2. Align existing programs with current K-12 TEKS for science learning,
3. Provide "valuable learning opportunities for both in-service and pre-service educators", and
4. Work within the community to engage all parties (students and parents) in experiential learning (Texas Statewide Systemic Initiative 1999).

Texas Environmental Education – In Texas, there are many informal education groups that develop lesson plans and activities to be used by formal educators, organizations, and informal learning facilities. In order to ensure that informal education programs are TEKS-aligned and scientifically complete, the Texas Environmental Education Advisory Committee (TEEAC) under the TEA, coordinates with local, regional, and state authorities tasked with developing environmental education materials (Texas Statewide Systemic Initiative 1999). In order for an organization to be recognized as distributing TEKS-aligned environmental education activities in Texas, that organization must be a member of TEEAC and attend annual meetings to ensure continued membership (Texas Education Agency 2011). TEEAC is affiliated with the Texas Association for Environmental Education (TAEE), a branch of the National Association for Environmental Literacy (NAEE). The TAEE works with many regional and state groups to promote environmental literacy across the state of Texas, introduce new programs and host educational events, and connect TEEAC providers in similar fields for funding opportunities, curriculum-sharing, and to promote interdisciplinary collaborative efforts. This is further facilitated through the EE Regional Service Providers, who are available to provide assistance for informal educators statewide.

Many TAEE members are also affiliated with the Informal Science Educators of Texas (ISEA) group, which is an organization similarly dedicated to increasing voluntary efforts in science, technology, and mathematics statewide (Texas Statewide Systemic Initiative 1999). In addition to fostering networks and programs for informal educators, ISEA is also a partner with the Science Teachers Association of Texas (STAT), and continues to promote collaboration for improved Informal Science Efforts (ISE).

It goes without saying that the ecological wellbeing of Texas is ultimately in the hands of the next generation. Educational decisions being made now provide the framework for a fruitful connection between the natural world and how our behavior can influence the integrity of our state’s environment. Applying an array of programs to state curriculum results in an increase in “environmental literacy” for future generations. Through a collective approach to furthering environmental education, a tendency for more ecological awareness and future oriented decision making by the next generation is expected.

Defining Environmental Literacy

In the United States, the relationship between social behavior and environmental health is not entirely understood by the general public. Environmental literacy is at times thought to be the same as environmental awareness. In actuality, it is a more complex concept that involves understanding the dynamics of the natural world, and the connection between human actions and environmental changes (NSF 2003). This can be taken for granted, resulting in ecological health taking a backseat to industrial progress. Such oversight is detrimental to the health of all entities in an ecosystem, including humans.

An illustrative example is the connection between forest dynamics and logging. If too large an area is harvested, not only are the rate of re-growth slower and the potential for nutrient leaching increasing, but the biodiversity of the forested area is also jeopardized. Through understanding the effect of ecosystem fragmentation on wildlife and the role of tree root systems in maintaining water quality, harvesters can better plan environmentally sound logging practices.

The Advisory Committee for Environmental Research and Education[45] (AC-ERE) formed through the National Science Foundation in 2000 developed a 10-year agenda to address environmental research challenges between human and environmental systems. In 2003, AC-ERE released a report on the state of environmental literacy in the U.S., stating that the public will need to understand environmental matters in order to assess risk and “understand how individual decisions affect the environment and local and global scales (NSF 2003).”

[45] http://www.nsf.gov/geo/ere/ereweb/advisory.cfm

Sustainable resource management operates under the idea that everything we as humans need for survival exists within our natural environment (EPA 2013). As the basis of sustainability and to ensure natural resource availability for future generations, environmental and human systems must be understood as interconnected from the very beginning (Cole 2005). Effective environmental literacy promotes environmental stewardship through hands-on training and applied knowledge (Cole 2005).

***Environmental awareness* –** This first step toward environmental literacy occurs when an individual has general knowledge of environmental issues and a deeper understanding of the causes and implications of environmental phenomena (U.S. Environmental Protection Agency 2013). Awareness has been shown to contribute to public support for environmental policy and management.

***Personal Conduct and Knowledge* –** The next step involves combining environmental awareness with individual action. Examples of this informed action are reducing one's carbon footprint through recycling, composting, and reducing individual run-off pollution.

***True Environmental Literacy* –** Obtaining true environmental literacy requires a "depth of understanding" of environmental topics stemming from underlying environmental principals (Cole 2005). Environmental literacy implies that individuals have the appropriate skills to investigate the subject, comprehension of how to apply knowledge and skills to a problem, and the ability to fully explain the connection between environmental conditions and societal behavior.

Environmental Literacy in Texas

Although it is not a formal educational requirement in state schools, Texas informal educators have created TEKS-aligned K-12 environmental education curricula for science, technology, engineering, and mathematics (STEM) courses. In partnership for this effort, NGOs, former educators, scientists, informal outdoor educators, and policy specialists joined forces to create a framework for natural resource education and environmental literacy and to implement environmental education into curriculum at the ground level (TAEE 2013).

Formally introduced in 2013, Texas Natural Resource/Environmental Literacy Plan[46] is a non-partisan effort created through the Texas Association for Environmental Educators and the Texas Partnership for Children in Nature[47] (TCIN). The roots of this effort stem from the No Child Left Inside Act[48] (H.R. 2054), which was first introduced in Congress in 2009 and then re-introduced in 2011 into the Senate as S. 1981[49]. Despite the legislative delay, educators nationwide continue to use informal environmental resources to supplement formal lesson plans in school. Many recognize the value of environmental education and experiential learning. These efforts have been shown to inspire students to pursue careers in science and produce a more effective approach to interdisciplinary instruction (NSF 2003).

Conclusions and Analysis

Ultimately, the prioritization of such educational strategies could benefit Texas's ecological future tremendously. Increasing the level of "Environmental Literacy" through "Formal" and "Informal" environmental education can provide the next generation with the appropriate tools in making wise decisions for Texas. This can be done by implementing well developed programs to

[46] http://taee.org/tnrelp_online.pdf
[47] http://texaschildreninnature.org/about-us/the-texas-partnership-for-children-in-nature
[48] http://www.govtrack.us/congress/bills/111/hr2054
[49] http://www.govtrack.us/congress/bills/110/s1981

state curriculum and enhancing not only the environmental knowledge of the students but a clearer understanding of science as well.

Despite how readily available informal education resources may be the costs to implement these programs are high. Ability to purchase materials for formal education opportunities and transportation and attendance costs for outside learning contributes to program adoption. Also, according to a study on the success of the Meadows Centers informal education at Spring Lake in San Marcos, Texas, formal educators lack the experience, and knowledge necessary to provide sufficient in-class environmental education in comparison to an informal educational setting (Sansom 2013). Before potential legislative action to change state requirements is passed, many financial obstacles must be resolved. Due to these issues such programs are often abandoned for activities that are cheaper in terms of resources and time.

Recommendations for Future Studies

Research into the efficacy of all informal environmental outreach programs has not yet been developed. Many informal programs contain similar methods, information, and audience but the level of success of existing Texas-specific programs has not been measured. Analysis of informal programs for teachers will provide insight into what programs are most used by teachers. Oftentimes, educators are already overextended and may not be motivated to seek out additional training for themselves. Developing policy and educational incentives to encourage external programs and educator involvement will enhance informal efforts and promote environmental literacy as a formal resource.

Section 12: Transboundary Policy between Texas, Neighboring States, and Mexico

Take-away Points:

1. Texas is a member of five interstate compacts and a transboundary treaty with Mexico as a measure to improve proper resource allocation between the countries.
2. Over-allocation of surface water in the Rio Grande River basin has necessitated greater emphasis on transboundary environmental flows policy.
3. Shifting climate puts strain on existing compacts.

Texas is one of four states bordering Mexico, and all border states having a strong vested interest in allocation of transboundary water resources. In addition to sharing a border with another country, Texas is also a member of five separate interstate compacts between neighboring states. Diverting water flowing to meet the water desires and requirements of separate communities along and through boarders of neighboring states creates tension. Compacts can help to outline and set limitations on authority. The following section will discuss some of the specifics of the interstate compacts as well as the tentative details between Texas, the United States, and Mexico over the Rio Grande and the Rio Grande Basin.

Early Treaties and Agreements

The Rio Grande River is the fifth longest river in the United States and extends from its headwaters in Colorado to the Rio Concho in Mexico (Texas Water Development Board 2010). In Texas, a 1,250-mile stretch of the river forms an international boundary between Ciudad Juarez, Chihuahua in Mexico, El Paso, Texas and the Gulf of Mexico (Center for Strategic and

International Studies 2003). Historically, agricultural activities and development within the Rio Grande River basin have required a division of water rights between the two countries.

The 1848 Treaty of Guadalupe-Hidalgo was the first treaty for water use in the Rio Grande between the United States and Mexico, and established the first joint commission between the countries. No specific water regulation was referenced here, but it did establish the boundary between the United States and Mexico. This treaty and the second, the Treaty of 1853, made it clear that no construction work in either country may “impede or interrupt the navigation on the Rio Grande River” (Jarvis 2005). Stipulations laid out in these agreements also included prohibiting the construction of storage dams or diversion dams, and thus prevented development for any major irrigation and domestic water use.

A Convention designed to address transboundary water allocation between Mexico and the United States in 1889 established the IBC, headed by a member from each government. The IBC was tasked with resolving any conflict or differences that may develop on the frontier between Mexico and the United States, including those regarding construction along a riverbed (Jarvis 2005). Although none of these early treaties were created specifically for water rights management, the area within the Rio Grande River basin was under significant development and there were conflicts regarding use and allocation on both sides of the border.

Water Supply Treaties in the 20th Century

During the early 20th century, an equitable division of Rio Grande water below Fort Quitman, Texas was clearly required to sustain the increasing number of farms and growing cities. Between 1860 and 1890, roughly 400,000 acres of land in the San Luis Valley of Southern Colorado had become irrigated farmlands. Water diverted from the Rio Grande River for these efforts resulted in serious water shortages in the Juarez Valley area. These changes led to a massive depopulation of the Juarez Valley area. In response, a Joint Commission through the IBC, tasked with investigating the effects of this irrigation, established an embargo to suspend all water rights in the upper basin for irrigation purposes, which held until 1925. The studies performed by the IBC resulted in the Convention of 1906, which provided Mexico with the amount of water that had been historically used before water had been diverted upstream. The brief 1906 Treaty essentially stated that the United States agrees to deliver 60,000 acre-feet of Rio Grande water each year, and that Mexico agrees to waive all water rights from the “delivery point downstream to Fort Quitman, Texas.” If damage to a facility or extreme drought occurs, any water available will be prorated between the two countries (Jarvis 2005).

As an answer to irrigation woes and to prevent agricultural losses, the Convention of 1933 created the Elephant Butte Dam in Truth or Consequence, New Mexico. The construction of this dam ensured that farmers in the Mesilla Valley in New Mexico and the Cd. Juarez-El Paso Valley would receive water required for farming (Metz 2013). This also effectively shortened the river boundary between the El Paso- Cd. Juarez regions. In 1944, a new treaty was developed to clearly define Rio Grande water allocation from Fort Quitman, Texas to the Gulf Coast and from the Colorado River and the Tijuana River. This agreement specifically outlines the amount of water allocated to each country from specific water bodies, and it allowed for the development of the Falcon and Amistad Dams. Within the 1944 Treaty, Mexico also agreed to supply the United States with an average of 350,000 acre-feet per year from tributaries south of the border. As a measure to ensure that the new requirements were met, the IBC was renamed the International Boundary and Water Commission (IBWC), with the charge to “apply and enforce treaty provisions” (Jarvis 2005).

In 1969, an agreement was formed that, should an extreme hydrologic event (such as drought) make it impossible for Mexico to fulfill these obligations over a five-year cycle, the deficit would have to be made up in the following five-year cycle (Center for Strategic and International Studies 2003). As a measure to protect both countries from changing boundaries and to maintain the status of the Colorado River and the Rio Grande as international territories, a final agreement, the Treaty of 1970, was signed.

Current Transboundary Water Policy Issues

There are numerous problems associated with the current policy structure. Sharing a finite resource between farmers in the agricultural sector and municipalities has created tensions between parties on both sides of the border; policy change may not be enough to sufficiently ameliorate the situation. The IBWC is tasked with addressing existing problems and managing current resources, including water deliveries determined by the treaty, and mitigating and preventing damages from floods. Obtaining citizen input for improved management of local resources has also contributed to designing more effective water management policy.

Shifting Climate

Persistent drought in northern Mexico and the American southwest have threatened the water supply of this already vulnerable river system. The U.S. federal government has identified the Upper Rio Grande as a river basin among those with the highest potential for conflict and crisis, especially in drought conditions. Over-allocation of water resources is a problem in this river basin; it is an on-going problem that arid regions all over the world face (Ward, Michelsen and DeMouche 2007)[50]. Deficits in total water demands during conditions of severe drought in 2010

[50] See Climate Modification

were projected to be 645,513 acre-feet, and by 2060 these potential deficits are projected to increase to 836,475 acre-feet. These deficits are exacerbated by the continual failure of Mexico to deliver water promised in accordance with the 1944 Treaty (Texas Commission on Environmental Quality 2011). In 1997, Mexico ended the 1992-1997 accounting cycle with a deficit of more than 1 million acre-feet citing extreme drought. The current cycle extends from 2010 to 2015 and Mexico is also currently in arrears due to abnormally dry conditions. However, the problem with this claim is that there is no language in the current agreement to define what exactly constitutes “extreme drought” conditions.

Environmental Flows in the Rio Grande River Basin

Recognizing that 450 native species and 700 migratory species depend on wetlands and resources in the Rio Grande River basin, transboundary management of environmental flows is now a consideration in water management (Center for Strategic and International Studies 2003). Although there is no transboundary mechanism for maintaining environmental flows, water quality and quantity are currently assessed through separate federal and state organizations on both sides of the border. However, different methodologies and standards are often used on both sides of the border, making comparative analysis difficult.

Because the Rio Grande is a transboundary system that is shared by many native species of flora and fauna, measures have been taken to improve methods for obtaining data on sustainable water use for environmental purposes (Teasley and McKinney 2010). A report prepared by the Center for Strategic and International Studies for the U.S. Mexico Binational Council has called for more research into the nature of riparian habitats in the river basin and the effect of shifting climate on water needs (Center for Strategic and International Studies 2003).

State Transboundary Agreements

In addition to the major international transboundary water agreement between Texas and Mexico, Texas is also a member of five interstate compacts for the equitable sharing of several rivers. These localized compacts help Texas and its neighbor states agree upon a reasonable and equitable sharing of five separate rivers: the Rio Grande, Pecos, Sabine, Canadian, and Red Rivers.

Before the Rio Grande reaches Mexico, it must first pass through Colorado, New Mexico, and Texas. The international agreements in place address all of the water below Fort Quitman, New Mexico. From the headwaters to the dam in Fort Quitman, an interstate compact between Colorado, New Mexico, and Texas manages the Rio Grande. This agreement helps to mitigate any potential conflicts regarding the river by putting a water allocation structure in place for the three states.

The Pecos River Compact

Approved by Congress in 1948, Texas and New Mexico signed the Pecos River Compact, which requires New Mexico to "maintain deliveries of water to Texas based on 1948 water-use conditions in New Mexico" (Texas Commission on Environmental Quality 2010). Nearly 350 miles of the 900 miles that makes up the Pecos River flows through Texas. The Pecos River flows southward from north-central New Mexico and connects with the Rio Grande before flowing into the Amistad Reservoir. Water withdrawals and diversions out of this river system have resulted in decreased water quantity and quality over time. In some areas, salinity is so high that plans for saline water into pits for salt extraction have been developed.

Texas had for many years considered New Mexico to be deficient in fulfilling the contractual agreement and in 1974 Texas took New Mexico to court over the matter. As a result of the case, the Supreme Court ordered New Mexico to comply with the compact having found that the state failed to deliver 340,100 acre-feet of water for the period between 1950 and 1983. Although some animosity existed between the states for a time, New Mexico and Texas have since been able to work cooperatively for the most part to ensure that compact agreements are complied with.

The Sabine River Compact

The Sabine River flows east of Dallas and along the Texas-Louisiana border and supplies resources for mining, industrial, municipal, irrigation, recreation, D&L, and hydroelectric purposes (Texas Commission on Environmental Quality 2010). The need for a compact became clear when water rights holders in both states held competing claims. Compact commissioners now oversee water quality measurements and ensure compliance in both states. Because the Sabine River exists in a region with abundant rainfall, ensuring that both states respect the Sabine River Compact ratified by Congress in 1954 has not caused much difficulty.

The Canadian River starts out in the Cimarron Mountains in New Mexico and Colorado and flows through Texas and Oklahoma. The interstate compact governing the apportionment of this river, ratified in 1954, is between Texas, New Mexico, and Oklahoma. Though Texas filed suit, and won, against New Mexico early on, this interstate compact continues to allocate equitable sharing of the Canadian River (New Mexico Water Resources Research Institute 2012).

The Red River Compact

As the Red River travels, from its headwater in the panhandle of Texas to the mouth of the Mississippi River in Louisiana, its flows are shared by Texas, Oklahoma, Arkansas, and Louisiana. The Red River Compact, an agreement between these four neighboring states, describes the equitable appropriation of water from the Red River and its tributaries (Staudenmaier 2013). The Red River runs for 1,350 miles and forms sections of the border between Texas and Oklahoma and has been a point of contention between the two states for some time. In 1978 the four river states of Texas, Oklahoma, Arkansas, and Louisiana singed and congress approved the compact to govern their respective rights on the Red River on one of the five sections. This compact gives its commission limited authority over pollution, currently federal and state entities are working to alleviate silt pollution. There has been a legal dispute between Oklahoma and Texas when the Tarrant Regional Water District claimed the right to divert water from Oklahoma to Texas based on the compact. Oklahoma, with approval of the district court, held that the Red River Compact authorized Oklahoma to block use of water by other states. Disagreement about language in the Compact between Tarrant County, Texas and Oklahoma has brought issues of appropriate rights of shared water to the U.S. Supreme Court (State Impact: Oklahoma 2013).

TRWD vs. Herrmann

The Red River is divided into five “Reaches” for practical and administrative reasons. In the Tarrant County vs. Herrmann case, proper use of allocated water from Sub-Basin 5 of Reach-II was in dispute (Figure 21) (Staudenmaier 2013). The Tarrant County and the Tarrant Regional Water District (TRWD) had filed a lawsuit in 2007 for access to allocated waters agreed upon in the Red River Compact. The TRWD applied for the acquisition of 310,000 acre-feet of water per

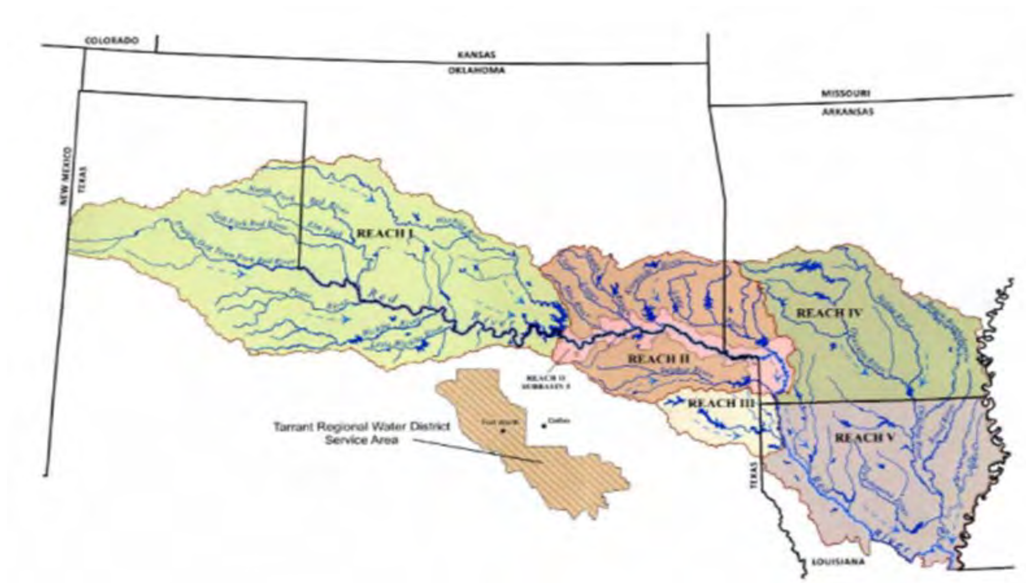

FIGURE 20: REACH DIVISION OF THE RED RIVER COMPACT (STAUDENMAIER 2013)

year from the Kiamichi River within Oklahoma's borders at the same time as filing its suit (Staudenmaier 2013). The basis of their complaint was used against state regulations that prevent any selling of state water as a protective measure for their state. This was seen by TRWD to be not only a conflict with Texas' right to access water within Sub-basin 5 of Reach-II, stated in the Red River Compact, but also the commerce clause of the U.S. Constitution (Staudenmaier 2013).

Ultimately, the Supreme Court agreed to hear the case based on the significance it bears toward national policy on interstate water relations (State Impact: Oklahoma 2013). Texas' former withdraw of water was after the waters of the Kiamichi River met the Red River (Staudenmaier 2013). The increased salinity of the Red River is more expensive to treat and provide to the growing population in Tarrant County, thus a desire to withdraw from the Kiamichi had been proposed. In the language of the Red River Compact, it never stated at what point a state was allowed to withdraw water from the Red River (Staudenmaier 2013). This was a point Texas identified as a possible reason for interstate access. Such a dispute provided the U.S. Supreme Court an opportunity to identify unspecified details in interstate compacts (Staudenmaier 2013).

Their decision was based on the assumption that if Oklahoma had intended to allow their water within their borders to be taken by another, they would have specified such action and given proper channels and means the acquisition would be made (Casteel 2013). With the Supreme Court siding with Oklahoma in this case they provided states with clarity on what is and is not appropriate action in allocating another states waters. Because state water requirements vary throughout the United States, proper water relations are important in providing a clear understanding of what is considered appropriate use and acquisition. As Texas' water shortages and growing population continues, the need to acquire more water will be more common.

Conclusions and Analysis

In order to have a general discussion about appropriate management of environmental flows stretching through designated state and international boarders, a more extensive investigation of specific issues in water relations must be developed. Transboundary water relations in Texas are vast and cover many topics throughout multiple regions of the state. As a measure to handle the array of public interests and interstate and international treaties, development of a comprehensive report of various regional case studies including the Red and Rio Grande River water management regions is necessary. In this comprehensive review of Texas' water policy, such case studies are not included. However, construction of watershed-specific studies but would be invaluable to an in-depth understanding of the current situation.

Furthermore, investigation into possible shifts in public opinion and management strategies with allocation of transboundary waters and the problems with surface water management is recommended. As community and statewide water stress grows, transboundary agreements may change or become more disputed. Providing such a study can be of benefit when determining the best strategies for a diplomatic agreement in shared surface water flows.

Finally, a comparative analysis of surface water management techniques between Texas, New Mexico, Oklahoma, Louisiana, and Arkansas, as well as an analysis of the various policies is needed. Providing background to the special interests various regions of our state have with their neighbors allows researchers to diagnose trends and management strategies that exist. Although interests in additional water resources have a direct correlation to what region these waters travel through, an appropriate agreement of scale will generate more productive decision making for future water disputes.

These additional studies will not only reinforce Texas' water securities but could give communities throughout Texas and its border regions the ability to develop more adaptive decision-making. Such agreements are expected to provide evidence supporting environmental flows management in resource-stressed regions.

Section 13: Energy and Water Policy

Take-away Points:

4. Texas' energy production and consumption are the highest in the nation (400 billion kilowatt-hours of energy).
5. Intensive energy and water production methods such as fracking and desalination require massive amounts of both resources.
6. Given Texas' perennial drought conditions, the greatest concern regarding fracking is the permanent and substantial loss of freshwater resources.
7. The Webber Group at the University of Texas at Austin performs continuing research on the energy-water nexus.

The Energy-Water Nexus in Texas

Recognizing the need to support the union of energy and water industries at the policy level, the house committee for Environmental Regulation developed HB-4206 during the Texas 81st Legislature session in 2009 (Stillwell 2010). This bill would require applicants seeking a permit to construct an electric generating facility show that "a sufficient amount of water is available for use in connection with the operation of that facility" (Texas Legislature Online n.d.). Energy usage in water storage and delivery may also be analyzed in reclamation projects as a result of H.B. 4206.

Other bills at the federal level such as the *Energy and Water Research Integration Act (S. 531)* introduced and passed 2009, and those currently in legislation, H.R. 3183 and SB-1436 have been developed to increase research and provide decision makers with a better understanding of the nuances in the energy-water nexus. As an added measure, SB-1436 and companion bill H.R. 3183 also appropriate $33 billion to establish agencies designed to increase energy and water development (Stillwell 2010).

The Energy-Water Nexus

As both the second most populated state in the country and the state with the highest rate of population growth over the last decade, Texas' energy production and consumption are the highest in the nation (Stillwell 2010). This growth is heavily concentrated in large, metropolitan centers along the I-35 corridor and in certain cities along the coast where water availability is not constant. High weather variability across the state results in an uneven distribution of water resources from west (drier) to east (wetter) (Stillwell 2010). Constraints on water resources due to the increase drought and heat waves also mean increased restraint on, and cost of, energy production (Poumadre, et al. 2005). In the past, energy and water have been regulated as separate entities. However, the growing Texas population and prolonged drought have required that decision makers begin to recognize the interconnectedness of these two resources when creating new regulatory policies for energy production and water use.

Generally speaking, public utility usage and public policy separate the relationship between water and energy within a residential and commercial setting. This distinction ignores the complexity of the relationships between these resources. Certain environmental legislation, relating to energy production and water has become more common in recent years (Stillwell 2010). In particular, with the recent influx of highly publicized and contentious hydraulic fracturing practices in and around sensitive ground water features, residents reliant on nearby wells have expressed interest and concern for groundwater integrity (Osborn 2013).

Wastewater treatment plants, coal production, and hydroelectric plants require both water and energy for different uses. Conversely, without energy, wastewater treatment plants could not effectively treat water for safe consumption, and water-intensive energy productions provide treatment facilities with the power to effectively complete daily duties. Currently, Texas produces and consumes nearly 400 billion kilowatt-hours of energy each year (Stillwell 2010).

The high volume of energy-intensive refining, manufacturing, and chemical industry activities result in an in-state consumption of 10% more energy created for use by the industrial sector than any other state. Nationwide, consumption of electricity in the home equals 37% of all energy

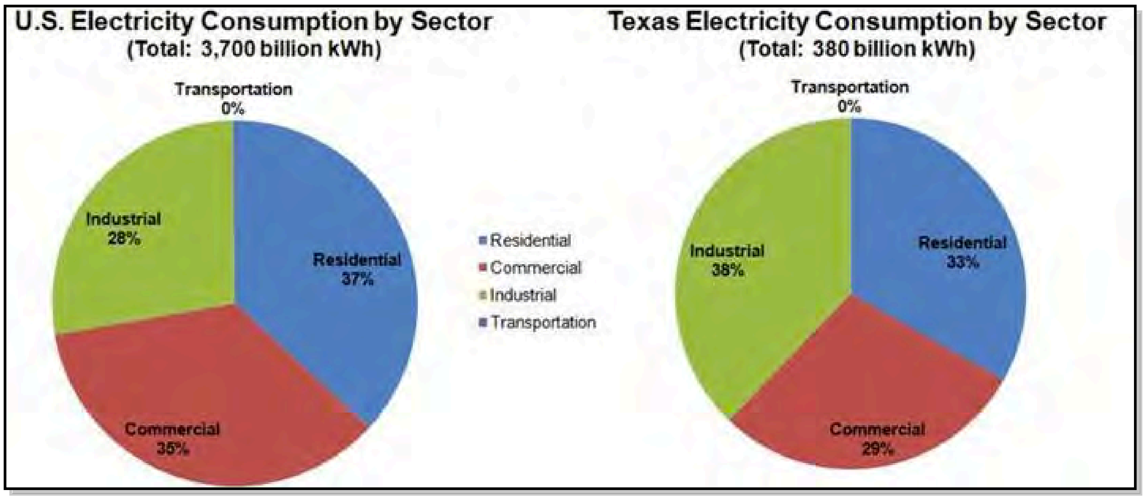

FIGURE 21: ENERGY CONSUMED -U.S. AND TEXAS

consumed (Figure 22). The amount of electricity produced for in-home use is 33% of total energy consumed (Stillwell 2010). The inherent and dependent relationship of both of these entities upon one another is referred to as the energy-water nexus, which explains the relationship between the energy required for water and the water required for energy production (Stillwell 2010).

The dependency of energy production on water in Texas is not solely concentrated in one area. Converting any energy source into electricity produces waste-heat, which is extinguished through a cooling process. Thermoelectric power plants operating using a “steam cycle” depend on a consistent water supply to maintain efficiency and energy production (table 7). Although the majority of water resources withdrawn for hydroelectric purposes is not directly consumed, but rather used for cooling, energy production through these plants still requires 2.5% of total water consumed statewide (Stillwell 2010).

TABLE 7: WATER RELATIONSHIP IN ENERGY PRODUCTION

Texas	Population	Energy Produced Ann. (KWh)	Energy Consumed Ann. (KWh)	Water Required Ann. (Thermoelectric ML)
Total	23 Million	400 billion	380 billion*	595,000

*Some energy is expended during production. Source: (Stillwell, et al. 2010).

Ongoing In-state Research on the Energy-Water Nexus

Dr. Michael Webber, associate director of the Center for International Energy and Environmental Policy in the Jackson School of Geosciences and director of the Webber Energy Group through the University of Texas at Austin, works with graduate students to further explore the energy-water nexus in Texas. Dr. Webber and team are exploring ways to use less water in thermoelectric cooling, and to stop using potable drinking water for electricity production (Lebwohl 2012). This is important to ensure the longevity of current resources, not only for the population of Texas, but also to prevent damage to riparian ecosystems. Dr. Webber is in the process of studying the nuances of the Energy-Water cycle in Texas with his students. He has received sponsorship for this work through the Texas State Energy Conservation Office, NSF, Environmental Defense Fund (EDF), Energy Foundation, TWDB, and others for this five-year project (2007-2012) (Webber Energy Group 2012).

The Relationship between Energy Production and Environmental Flows

In order to make better decisions regarding water conservation and energy production, it is important to understand which power plants are drawing water from which basin in order to complete the cycle. Certain river basins in environmentally sensitive areas host flora and fauna populations that may be especially at risk. Having a central repository of information will help scientists and engineers monitor the effect of losing water for energy use on watershed basins and long-term supply in different regions.

With the advent of hydraulic fracturing ("fracking") in Texas, water-intensive mining activities have also compromised sub-surface resources. The recent boom in shale gas extraction nationwide is a result of successful fracking practices revitalizing formerly unproductive fields. The economic benefit of fracking to the petroleum industry includes profits from expansions in trucking, pipeline services, oil well equipment and services, transportation, storage, refining and distribution. Petroleum and chemical engineering jobs have seen a corresponding growth rate in both the applied and research sectors (U.S. Department of Energy 2011). Fracking fluids are primarily (99%) fresh groundwater produced on or near the well site that is mixed with a cocktail of chemicals and fine sand. This fluid, or "slickwater," expedites the fracturing of shale resulting in the release of trapped natural gas (Railroad Commission of Texas n.d.). The quantity of water used in the process varies, but on average, a producer will use five million (15.3-acre feet) gallons of water per fracking well (Nicot and Reedy 2012). These estimates will peak at 148,262,399,285 gallons of water (455,000-acre feet) per year in Texas alone by 2030.[3]

Fracking in Texas

In Texas, the productive shale strata at a depth of four- to twelve-thousand feet below the surface is commonly referred to as the *Eagle Ford Shale Play* in South Texas and the *Barnett Shale Play* in North Texas (Figure 23). The test wells in the Texas Panhandle's *Cline Shale* show that this play contains 3.6 million barrels of oil per square mile, which equals approximately 30 billion barrels of oil (Railroad Commission of Texas 2013).

Many shale strata are naturally radioactive. Refuse water returning to the surface post-fracking

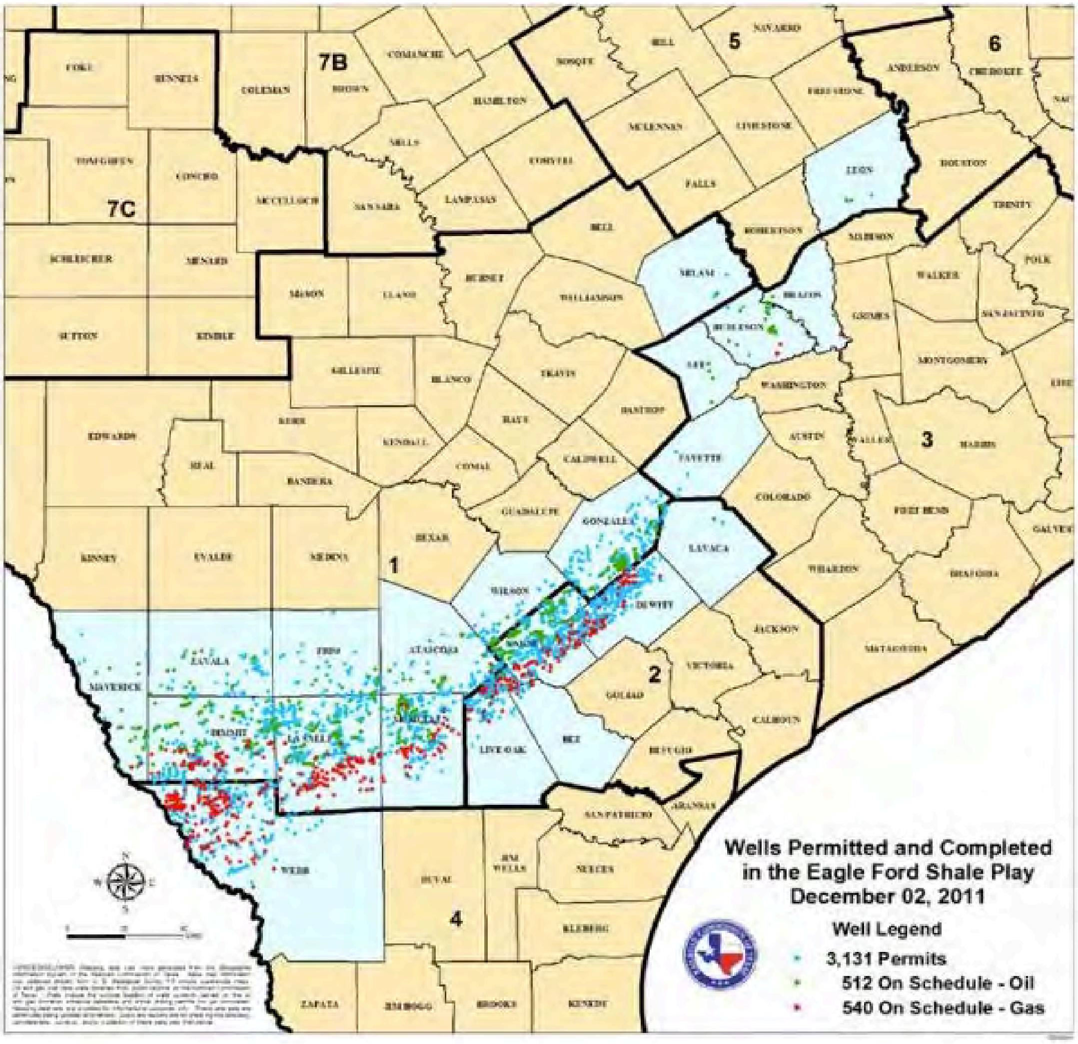

FIGURE 22: WELLS PERMITTED EAGLE-FORD SHALE (RAILROAD COMMISSION OF TEXAS 2011)

often measure radioactive levels that exceed TCEQ standards. Such water is too contaminated for most wastewater treatment systems to process (Railroad Commission of Texas 2013). This contaminated water is disposed of by deep-well injection thousands of feet below the surface, permanently rendering that water unusable for future use (Railroad Commission of Texas 2013). The additives used in fracking may contain diesel fuel or other potentially hazardous chemicals (Groundwater Protection Council 2013). Texas state law requires public disclosure of all of fracking agents used in each specific well. However, volume ratios are exempt from disclosure in Texas.[51]

Desalination

In 1961, Dow Chemical Complex in Freeport, Texas constructed the first seawater desalination demonstration plant in the United States (Shirazi 2012). Four years later, the installation of the first desalination plant designed for a public water supply in Texas occurred in Port Mansfield. The Port Mansfield plant was powered by electrodialysis and had a 250,000-gallon per day capacity (Shirazi 2012). Presently, there are 38 desalination plants in Texas that are a part of the public water system. These plants have a combined design capacity of more than 25,000 gallons per day (.025 MGD). In addition, 50 PWS desalination plants also contribute to water resource produce less than 500,000 gallons daily (0.5 MGD) collectively. The bulk of these plants are now powered by reverse osmosis.

Projections for Desalination

In the 2007 State Water Plan put forth by the TWDB, the use of desalination is expected to provide approximately 310,000 acre-feet of water by the end of 2060 (175,000 acre-feet from groundwater sources) (TWDB 2013). According to the Texas Water Code (Section 16.060) the TWDB is required to provide necessary steps to further the development of water desalination in the state and provide biennial reports of their progress (Texas Water Development Board 2012). Since 2002 the TWDB has funded over $3 million in studies including feasibility studies, pilot plant studies, and guidance for permitting (Texas Water Development Board 2012).

Current expectations for desalination involve previously unusable water supplies to be the future of Texas' water resources has aroused extensive funding for projects all over the state. Growing populations in coastal areas have necessitated a number of coastal desalination facilities;

[51] Fracfocus.org 2013

including those in Brownsville, TX and Laguna Madre near South Padre Island have begun feasibility studies for future projects (Figure 24).

However, costs associated with desalination are notoriously high. The proposed construction of a San Antonio facility to mitigate their impacts on the Edwards Aquifer freshwater supply could cost approximately $145 million dollars in its initial phase. Additionally, plans for an Odessa based plant could prove to be larger than the previously constructed plants in El Paso, the Kay Bailey Hutchison Desalination Plant (KBHDP) (Galbraith 2012). The $91 million KBHDP, completed in 2007, has the capacity to supply 27.5 million gallons a day (MGD) and is currently

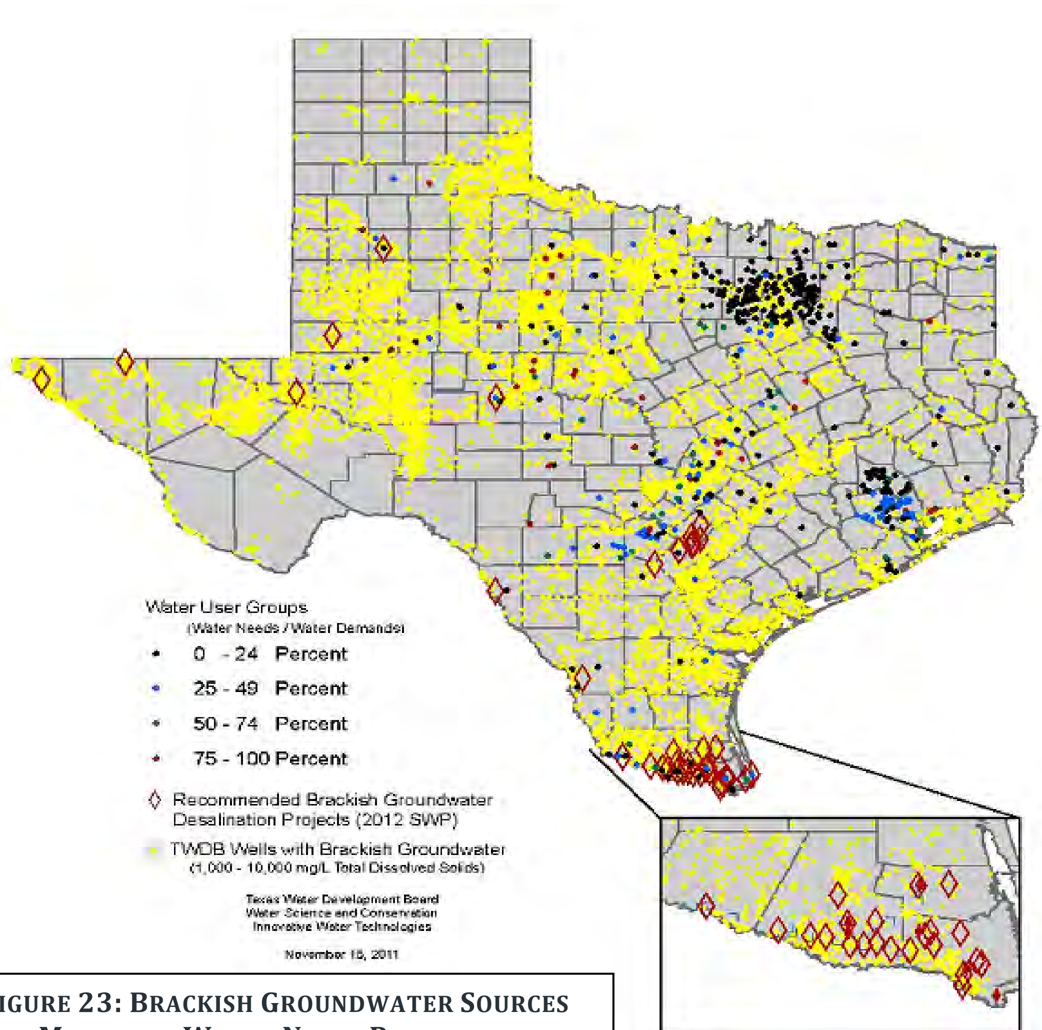

FIGURE 23: BRACKISH GROUNDWATER SOURCES AND MUNICIPAL WATER NEEDS RELATIVE TO PROJECTED DEMANDS-2010 (TEXAS WATER DEVELOPMENT BOARD 2011)

the largest desalination facility in the state.

State financial assistance programs, federal appropriations, and private participation may be used to fund desalination projects (TWDB 2013). Desalination research and funding for converting saline and brackish water into usable water began through the 1952 Saline Water Conversion Act (Martella 2013). In 1982 desalination efforts were transferred from recently established offices such as the Office of Saline water and the Office of Water Research and Technology within the Department of Interior, to the Bureau of Reclamation and allowed little or no funding for research and development. Until 1991, renewed federal interest in desalination provided a six-year period of research and development. The Water Treatment Technology Program and Desalination and Water Purification Research Development Program receive authorization from Congress under the Water Desalination Act of 1996 (Martella 2013). Today, Reclamation is the only federally funded agency that pursues new ways to make desalinating water more efficient (Martella 2013). Along with federal support, research and development and additional funding is supported by over 20 different independent agencies and foundation (Martella 2013). In Texas the TWDB was directed by Governor Rick Perry to prepare recommendation on developing a large-scale seawater desalination facility in Texas (Martella 2013).

All aspects of local governments are involved in the research and funding for desalination projects in Texas. Funding has been found from river authorities to groundwater conservation districts and from city governments to the Texas Legislature. Governor Rick Perry has indorsed and pushed publicly for investments in Texas' future by exploring desalination projects. The economic and environmental cost of desalinating water maintains significant variability.

Conclusions and Analysis

The Future of Fracking in Texas

Natural gas produces half of the carbon dioxide, one-third of smog forming nitrogen oxides, and a fraction of the sulfur dioxides and mercury that are emitted into the atmosphere by burning oil or coal (U.S. Department of Energy 2013). The greatest danger of natural gas lies in its escape prior to consumption. With attention to detail and enforced regulation, containment of natural gas is attainable and within the industries' current ability. Given Texas' perennial drought conditions, the greatest concern regarding fracking is the permanent and substantial loss of freshwater resources.

The Future of Desalination in Texas

Depending on the location, feed water source, feed water quality, plant size, process type and design, intake type, pre and post-treatment processes, concentrate disposal methods, regulatory issues, land costs, and distribution of water to and from the plant (Shirazi 2012). Through examination of six brackish groundwater desalination facilities completed in the last ten years, total production cost of water ranges from $1.09 to $2.40 per thousand gallons or $357 to $782 per acre-foot (Shirazi 2012).

With an increased interest in pursuing such an intensive water resource acquisition process, many costs are to be examined. Major benefits to desalination include the preservation of stressed freshwater aquifer. The population of Texas is expected to double in the next 50 years with an increase of water demand of 27% and a simultaneous decrease in groundwater availability by 32% (TWDB 2013). Major setbacks and water desalinations biggest struggle is its costs. Energy costs in desalinated viable quantities of groundwater and distribute to the public can more than double current municipal costs of water. Improved technology and an increase in technological research will lead to the development of a variety of methods to be used in existing and future facilities (table 8).

TABLE 8: SUMMARY OF CHARACTERISTICS OF MAJOR DESAL TECHNOLOGIES (KRISHNA 2004)

Characteristics	Reverse Osmosis (RO	Electrodialysis reversal (EDR	Multistage flash (MSF)	Multiple-effect distillation (MED)
Energy cost	Moderate	High	High	Very High
Energy/Salinity	Increases with salinity	Increases fast wish salinity	Independent of salinity	Independent of salinity
Applicable to	All water types	Brackish	Seawater-brine	Seawater-brine
Plant size	Modular	Modular	Large	Large
Bacterial Contamination	Possible	Post treatment always needed	Unlikely	Unlikely
Final Product salinity	On demand	On demand	Can be <10 mg/L TDS	Can be < 10 mg/L TDS
Complexity	Easy to operate; small footprint	Easy to operate small footprint	Only large complex plants	Only large complex plants
Susceptibility to scaling	High	Low	Low	Low
Recovery	30-50% (seawater) up to 90% for brackish water	High	Poor (10-25%)	Low but better than MSF

Recommendations for Future Research

In order to accurately grasp how new mining techniques affect river systems in Texas, separate research into activities in individual basins will assist with decision-making efforts. Research into the environmental response to fracking activities has been limited up to the present. Understanding how fracking and desalination practices affect available water, fuel, and existing groundwater resources will give decision-makers a more comprehensive idea of the ecological ramifications of these practices and how they relate to natural resource management.

Secondly, analysis of public perception and understanding of mining and desalination should be developed to gauge public awareness of these topics. Identifying geographic areas and river basins where local stakeholders are most aware of the environmental changes associated with these industries will help inform decisions about where to emphasize outreach efforts and best management practices for water quality management.

Section 14: Climate Modification

Take-away Points:

1. The highly variable nature of Texas weather and the size of the state result in a high-risk of annual flooding and drought conditions.
2. Changes in climate affect water resources required for many industries, including agriculture, mining, energy production, and urban development.
3. Educational materials for drought are made available through TCEQ and TWDB for business owners and stakeholders at every level.

Introduction

Since before Texas became a state, water and climate have shaped the culture, landscape, and way of life for residents. While the climate of Texas can be quite varied, due to its geographic size and location, drought affects every portion of the state to some degree. For over a century regulations and policies have been put in place to alleviate the negative effects of discharge into waterways. It has only been since the 1920s that water conservation and preparedness for drought has been enacted, and not until the 1950s did serious and widespread adaptive measures begin to develop. This section provides a discussion on the background and affects drought has had on the state and is projected to have in the future, followed by actions currently in place to mitigate the impact of drought, and finally legislative responses to drought management.

Texas is a state of extremely variable weather conditions. Much of the western portion of the state is semi-arid with prolonged periods of drought, while eastern and coastal areas experience humid subtropical climes and flooding. It is often the case that the state will go through periods of drought followed by heavy rainfall. While drought can be a slow-motion disaster often lasting years, it is accompanied by other circumstances such as wildfires, dust storms, agricultural downfall, and economic hardship. Despite this it has been shown that drought has been a catalyst for policy and regulation changes in the state to better prepare for future drought conditions.

The major droughts of the 20th century provided a major shift in the way Texans view the future of water in the state. The severe droughts of 1917 devastated native grasses, giving way to invasive species to permanently take over in many regions. Extreme heat and record low rainfall in 1925 resulted in parched conditions causing great agricultural turmoil (Texas State Library and Archives 2013). That year, weather events inspired the Texas Legislature to authorize the formation of water control and improvement districts. Four years later, the Brazos River Conservation and Reclamation district was established in 1929. Together, these projects became the first river authority and first United States entity to specifically manage water resources for an entire river basin. During the drought in the 1934 Dust Bowl region stretching from the Panhandle to the Great Plains, the LCRA was established to respond and provide water supplies, electricity, and flood control to suffering populations. Over the next decade, the LCRA built 6 dams in to combat flooding and create reservoirs for periods of water scarcity. It was not until the drought of record occurred in the 1950’s that Texas was galvanized to enact scientifically based water planning throughout region (Texas Water Resource Institute 2011).

From 1950 until 1957 Texas experienced the worst drought in its history and it is still known as the drought of record. This means that this specific drought event is the worst-case scenario with regards to drought conditions. Resulting desolation faced by farmers and ranchers in the state during the 1950s drought forever changed the character of Texas and provided an impetus for rural to urban migration. In 1940, roughly 29% of employed Texans were farmers, and this dropped to 12% by 1960 as the rural to urban migration continued. In terms of economic damages, it is estimated that roughly $22 billion in 2011 dollars were lost due to the drought. The state began water programs in earnest due to this in the form of dams and reservoirs construction under the auspices of the TWDB. Groundwater water resources were tapped and deemed an important resource for the future. Over a 10-year period, groundwater usage increased fivefold by 1957 (Mashhood 2011).

Twenty years after the drought of record, another catastrophic period of drought occurred from 1970 until 1971. Cattle and agricultural entities suffered most during this disaster. Cotton and wheat crops are severely damaged, and more than 100,000 cattle died from lack of water and feed. During this time, the Red River went dry, and fears regarding water management rekindled. As acquiring new water sources is recognized as less financially and environmentally feasible and in the wake of two droughts, water conservation has become the new focus for the Texas State Water Plan (Henry 2011).

While there were many periods of drought conditions since the 1970's it was not until 2011 that conditions became disastrous. During this time Texas experienced the hottest and driest year ever since recordkeeping began in the state. Lakes, rivers, streams, reservoirs, and aquifers began to dry at alarming rates. Of the 4,700 public waterways, 1,000 had imposed water restrictions and 23 estimated they would run out of water completely within six months (Combs 2012). The economic impact will be felt for years as the agricultural losses in 2011 are estimated to be $7.62 billion, cattle sector losses, over $3.2 billion, and cotton loss accounted for $2.2 billion. Homes destroyed due to fires cause by drought conditions greatly exceeded previous years and caused entire communities to be displaced and lives disrupted (Figure 25) (Amico, DeBelius and Stiles 2012). The full impact this drought has had on the state is still being felt as climate projections indicate that drought may become the new normal.

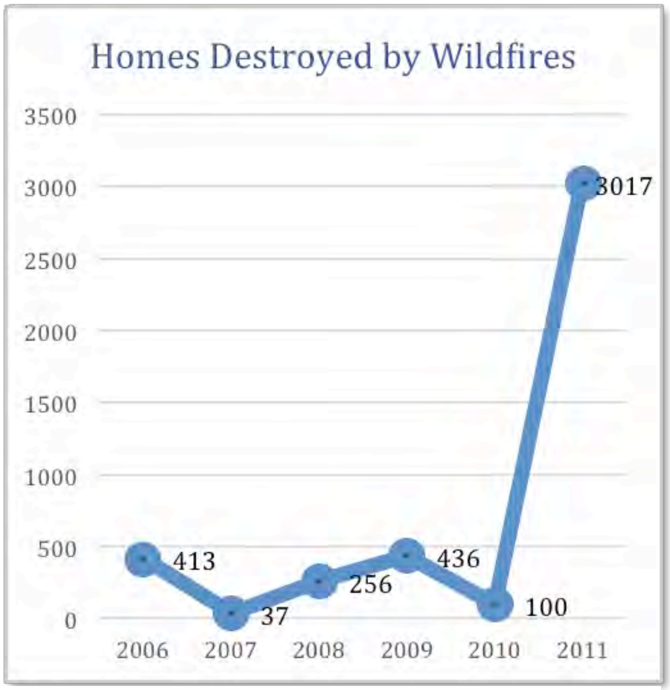

FIGURE 24: WILDFIRE DESTRUCTION 2006-2011 (AMICO, DEBELIUS AND STILES 2012)

The future of Texas is assuredly going to include droughts and times of scarcity. Forecasting the details of this can be quite challenging however. Federal administrative offices through NOAA expect drought condition will continue through 2013, in addition, state and national meteorologist warn that ocean patterns are disturbingly similar to those during the drought of record. This is particularly worrisome as state reservoirs levels are lower that they have been in two decades (Heinrich 2013).

How we prepare for drought now and in the future

Texas is a popular state and has a booming population. It is estimated that by 2060 the population will nearly double from 2010 and water demands will be higher than ever. Coupled with the uncertainty that could be a result of climate change, population growth presents a clear risk to guaranteeing that water accessibility is ensured to communities across the state. State, federal, and private entities are applying techniques to help ease the effects of drought in the future and the TWDB issued the 2012 State Water Plan for Texas that provides recommended actions to provide long-term water supply solutions to meet needs during drought of record conditions (Texas Water Development Board 2012).

Drought Resilience Panning

The only way to reduce the impact of drought is to properly prepare and increase hazards resiliency. In Texas several agencies govern and managed different aspects of water in the state each offering different perspectives and approached for drought management. The TWDB is the primary agency that deals with financial assistance and conservation education for responsible water development in the state. In order to manage drought-related information for planning purposes, the TWDB compiles and releases the State Water Plan that outlines how the state can meet its water needs in times of drought and inform the public and policymakers about the reality of climate conditions. The TWDB serves on the Texas Drought and Preparedness Council, charged with supporting drought management efforts through assessment, monitoring, mitigation, and assistance (Texas Water Development Board 2012). Finally, the TWDB also provides agricultural water conservation funding to increase water use efficiency in this sector and supports regional water development plans that incorporate the statewide water plan for efficient and orderly conservation efforts for surface and groundwater resources.

Educational materials including information regarding surface water levels wildlife management during drought or otherwise is distributed to the public through the TWDB and the TCEQ. In response to the 2011 drought, the TPWD created the Drought Survival Kit to educate individuals and businesses about changing water habits to better conserve surface and groundwater resources. The TCEQ responds to droughts by consulting public water systems to track use during water restrictions. Through tracking and managing water-rights draws of surface water, regulatory agencies better ensure proper withdraws from these sources (Texas Commission on Environmental Quality 2012).

Groundwater Conservation Districts allow for more localized control over groundwater resources in regions where there is a risk of over pumping; it is the state's preferred method for groundwater management. Supporting local-level efforts for groundwater management, "Groundwater conservation districts are units of local government with the authority to regulate the spacing and production of water wells" (Groundwater Protection Committee 2011). Although Texas utilizes the rule of capture for groundwater, a GCD can help regional landowners jointly manage aquifer drawdown. GCDs have the ability to regulate the number of wells, including appropriate spacing and production, while also protecting current water user rights, and identifying a long-term aquifer management plan, which is contingent on Desired Future Conditions. These are a set of quantifiable target goals to help control aquifer drawdown (Far West Texas Planning Group 2011). In working to maintain healthy groundwater levels, GCDs play a vital role with drought preparedness.

Flood Management

Introduction

Although drought is a main concern for water resources and policy, flood events associated with precipitation variability is also a source of planning anxiety. Floods have been the most destructive and frequently occurring natural hazard facing Texas, providing over 90% of the state's disaster damage (State Hazard Mitigation Plan 2010). Most areas in Texas have a risk for flood event in any season of the year because of desiccated ground and low annual precipitation. Of especial concern is the Hill Country region located in central Texas as this area is considered

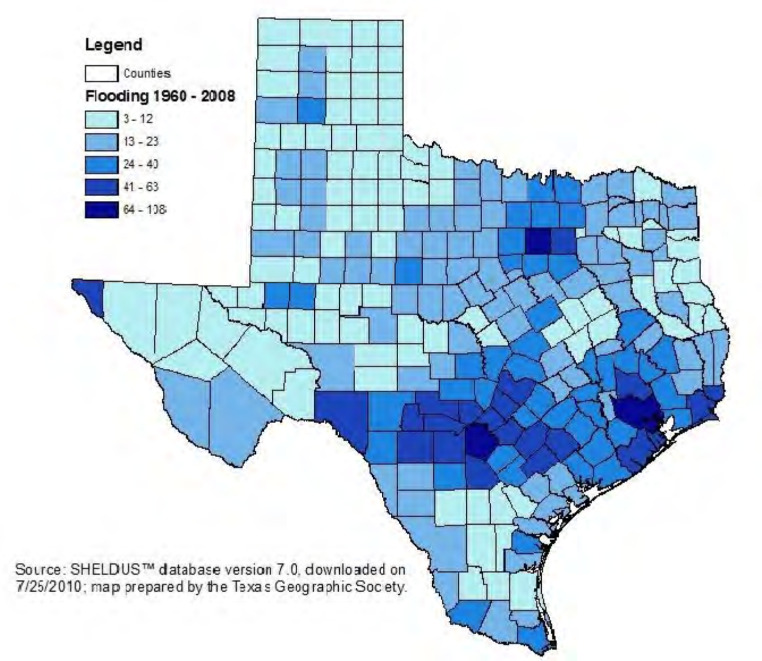

FIGURE 25: FLOODING FREQUENCY BY COUNTY

one of the three most flash-flood prone regions in the world (Figure 26) (State Hazard Mitigation Plan 2010). This is contributed in part by climatic factors and physiography. Texas experiences an average of about 400 annual flood events and, since 1953, Texas has had 30 Federal disaster

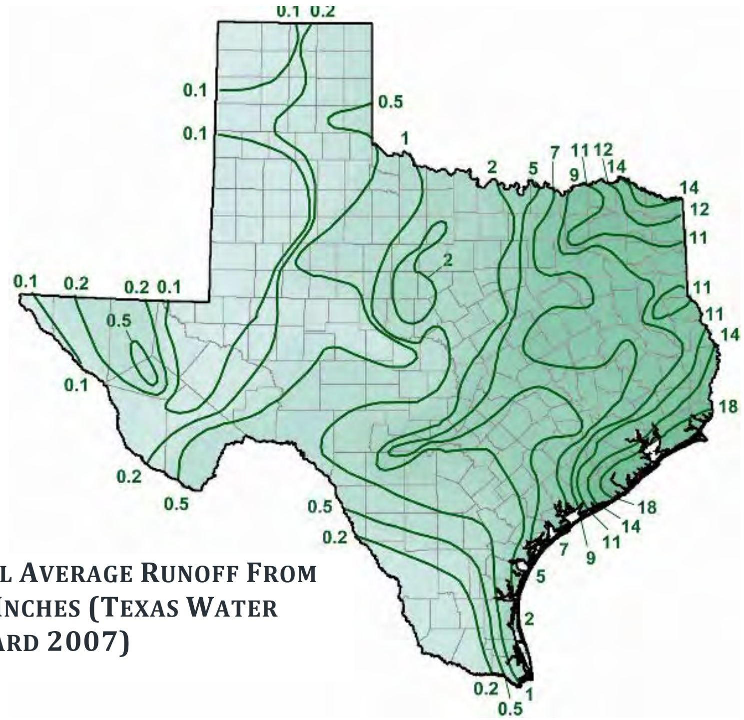

FIGURE 26: ANNUAL AVERAGE RUNOFF FROM PRECIPITATION IN INCHES (TEXAS WATER DEVELOPMENT BOARD 2007)

declarations due to flood events, costing over an estimated $1.4 billion in insurance claims (State Hazard Mitigation Plan 2010).

Flood waters occur when the run-off exceeds the carrying capacity of a water-body. The run-off is a product of the interrelation of climatic and physical characteristics of a specific landscape (State Hazard Mitigation Plan 2010). In Figure 27 we can see the confluence of increased run-off in and around the Hill Country region of Texas

Flood management policy

During the 77th Texas Legislative session, the Texas Water Code was amended to authorize the political subdivision to adopt comprehensive floodplain management and participation in floodplain management initiatives (State Hazard Mitigation Plan 2010). This is the only situation in which the state has granted floodplain management power for counties to enforce standards and restrict growth in floodplains. Fewer than 10 of the 254 counties have moved forward to enact any enforcement language. Only Denton, Bastrop and Harris counties have adopted or planned to adopt Community Rating Systems (CRS) Program (State Hazard Mitigation Plan 2010). In order to promote such projects in Texas, the TWDB administers a loan and grant program to provide financial assistance for the planning and construction of water related infrastructure and water quality improvements. As a part of the financial assistance program, the TWDB also allocates funds for planning and implementation for flood mitigation projects (Texas Water Development Board 2013).

Resilience and Adapted Management

Discussions about coastal resilience in the wake of a flood in Texas often center on communities Gulf Coast regions. Coastal communities are especially susceptible to economic and physical damage resulting from hydroclimatic variations. Although most likely to face flood damage from storm events, communities in the Gulf Coast often exhibit an elevated capacity for resilience. Resiliency is defined as the ability for an ecological system to resist or absorb impacts, and maintain or return, more or less, to the same form, function, structure, or qualitative state (Adger 2000). A study performed by The Center for Texas Beaches and Shores, the Departments of Marine Sciences and Landscape/Urban Planning, and Texas A&M University at Galveston examined the level of community resiliency when comparing urban and rural settings found that the level of resiliency is dependent on the level of infrastructure present.

Community resiliency implies the “robustness, rapidity, and enhancement in response to natural disasters (Brody 2013). One element of this has to do with the level to which an environment has been adapted for large populations. In comparing the two different economic regions, there is an obvious and “pronounced difference” in impervious surfaces and thus the level of intensity of the floodwaters was far greater in areas of concentrated development. It is also interesting to note differences when comparing the loss of naturally occurring wetlands in urban versus rural settings. Areas with primarily rural housing were shown to have a significantly greater percent loss compared to urban areas (Brody 2013). Additionally, there was a greater average area of counties/parishes found outside of the 100-year floodplain in rural areas. Many of this could be identified with the level of sprawl outside urban centers but in terms of flood mitigation activities, the report found that urban jurisdiction have implemented far more structural and non-structural BMPs than rural areas, thus making urban areas far more resilient when facing repetitive flood events (Brody 2013).

BMPs for Flood Management

Though this study was done on a large scale and focusing on coastal regions, the interesting results suggest the positive impacts of implementation of urban BMPs, especially when introduced with higher levels of impervious cover. In the Hill Country, many counties have moved forward in managing its storm water impacts on water quality including models to measure established TMDLs as well as WPPs[52]. A 1990 EPA-issued NPDES regulation is designed to protect storm water quality in small cities and urban areas (Hays County 2011). This program is mandated under the CWA to address urban sources of storm water discharges from MS4s (municipal separate storm sewer systems) that affect water quality (Hays County 2011). This essentially mandates that a city receive a permit relating to the level of storm water discharge entering the system.

An MS4 is a way to mitigate the effects of impervious cover on water quality. The MS4 consists of a comprehensive Storm Water Management Program (SWMP) that reduces pollution and protects water quality by establishing Six Minimum Control Measures (MCMs) which includes

[52] See Appendix 4

BMPs. Best Management Practice measures for these situations can be mechanism to prevent or reduce the discharge of pollutants by establishing schedules, prohibitions, maintenance procedures, structural controls and/or ordinances (Texas Commission on Environmental Quality 2008).

Due to relatively frequent and severe flooding throughout Texas, Congress began passing flood control acts in 1936, 1944 and 1954 (Natural Resource Conservation Service 2009). Since that time, the Natural Resource Conservation Service (once the USDA Soil Conservation Service) has assisted in construction of almost 2,000 flood management dams in 145 watershed projects across Texas. Besides providing flood protection, these projects afford $118 million in annual benefits and preserves over 10,000 acre feet of water storage and 60,000 acres of created, enhanced, or restored wetlands among other benefits (Natural Resource Conservation Service 2009).

Conclusions and Analysis

With the high-level of variation in extreme weather patterns in Texas, it is difficult to maintain a statewide strategy towards protecting against extended droughts and flash floods. Reflecting upon the most recent and prolonged drought Texans are experiencing, motivation to improve policy and conservation measures in some of the drier regions of the state is of absolute importance. The TWDB provides the planning and funding opportunities for RWPGs to establish more cost effective, conservation oriented strategies to fight such lack of regular precipitation.

Yet, in the Hill Country, residents know the impacts of far too much rain at any given time as well. Such a drought and flood-prone region can only wrestle with the policy questions most pressing at the moment. As the drought that claimed over $7.5 billion in agricultural losses in

2011 continues, much of our legislative decisions on water resources are looking towards the future of Texas' growing population and continued unpredictable precipitation rates. With recent passage of Proposition 6 and the restructuring of the TWDB, unknown yet promising steps to a more secure state are underway.

Recommended Future Projects

Many cities that are experiencing massive impacts of drought on their water supply while simultaneously experiencing an increasing population must take notice of conservation methods implemented in other parts of our state and country. A study to comprehensively provide cost-benefit information towards different conservation methods would be helpful for communities looking for the most influential way they can implement water-wise infrastructure. Also, an increase in community conservation incentives will allow water supply to withstand precipitation variability and depleting resources throughout Texas.

Furthermore, in order to appropriately manage against extreme rain events in the Central Texas and Coastal regions, our perception must accept the frequency of major storm surges and flash flood probabilities. Funding entities such as the TWDB must supply educational and specialized research in various areas of the state to improve accessibility to, and implementation of, BMPs to mitigate the effects of storm water in urban and rural areas. Improving the level of connectivity between the information gathered by the TWDB, USGS and TCEQ will better inform communities about effective ways to manage runoff during extreme storm-surges. Additionally, extra education and awareness with riparian landowners throughout the central Texas region to better prepare themselves to the inevitability of damaging flood events. This will allow for faster evacuation and, ultimately, improved community resilience during times of repeated devastation.

Section 15: Texas 83rd Legislative Session

Take-away Points:

1. The 83rd Legislative Session proposes funding for water plan projects through HB-4.
2. In order to maximize funds, RWPGs have been tasked with prioritizing existing project lists.
3.

Owing to the recent drought and projections for needs in the near future, water resource conservation and planning are important topics for consideration during the 83rd Legislative Session. The following will touch upon some of the legislation dealing directly with water and drought in the state; many more bills have been introduced than passed or signed by Texas Governor Rick Perry.

The 83rd legislature brought about a fair amount of change with how Texas will deal with its water management in the future. Legislation discussed in this section includes HB- 4 and Senate Joint Resolution (SJR) 1. Both legislative bills provide options for resource allocation to secure funding for water-related projects across the state. If current projections are accurate and the state does not adopt increasingly novel and comprehensive plans to prepare for drought, than there will not be enough water for every sector, community, and industrial program. These recent bills reflect a growing concern among individuals and policymakers in the state that may prove invaluable to the continued success of the state.

Perceiving the effects of implemented legislation will require some time until the full regulatory impact is realized. Such acts includes the Drought Preparedness Council with SB-662 that will now be required to meet as necessary to carry out provisions of drought management. The council will also be composed by key entities across the state with public education institutions and government agencies. With SB-198 homeowners associations will no longer be able to prohibit xeriscaping on one's own property. Lastly, SB-1870 created the West Fort Bend Water Authority and outlines their powers and authority in the state (Texas Legislature Online 2013).

The Texas State Water Plan

The TWDB has been responsible for addressing water needs in the state of Texas for nearly 60 years. The passage of Senate Bill 1 in 1997 by the 75th Texas Legislature created RWPGs and a regional water planning process for which the TWDB is responsible for overseeing. Measures to determine funding for the Texas State Water Plan are of great importance to supporting future water conservation, marketing, and planning statewide. Water Plan funding and legislation passes through the Texas Legislature provides methods of funding and marketing to ensure that recommendations made by the TWDB can be implemented.

In order to ensure that the Texas Legislature is kept abreast of the state of water conservation and financing projects statewide, the TWDB must provide a biennial report with legislative priorities for the agency. Recommendations in the most recent report include those regarding annual water loss audits, state funding for acquiring designated reservoir sites identified in regional water plans, and interbasin transfers. A primary legislative priority identified by the TWDB for the 83rd Legislative session was for congress to identify a permanent solution to financing the State Water Plan (Texas Water Development Board 2012).

Texas State Water Plan 2012

The 2012 Texas Water Plan is the most recent water plan developed through the TWDB. This is the ninth state plan and the third one designed around the regional water planning process (Texas

Water Development Board 2012). It contains a list of strategies, solutions to water resource shortages in times of drought, and addresses water needs of all water user groups in the state. Water management strategies and policy recommendations suggested by state water plans reflect current issues affecting water resource management (Combs 2012). Improvement solutions to water management address statewide concerns regarding environmental management, scarcity, competition for resources, and cost. Adaptation efforts are especially important considering Texas' projected population growth between 2010 and 2060 is 82%.

Despite the near doubling of the population, TWDB reports that the projected rise in water demands to meet state needs is merely 22%. Though projected increases appear to be low, any increase taxes an already stressed resource. The amount of available reserves is declining as population creeps upward. If new projects for water conservation are not approved, models produced through TWDB forecast negative results like statewide economic downturn and population decrease. More than 50% of Texans may face a need of about 45% of their required water resources in times of recurring drought by 2060. Without new water projects, 50 years from now, the state of Texas will be 8.3 million acre-feet short of water requirements (Combs 2012).

Recommended Management Strategies for 2060

In order to maximize statewide water conservation efforts, the 16 regional water-planning groups recommend water management strategies. These are plans or projects designed to accommodate state needs during times of drought. Recommendation strategies are first developed regionally through municipalities and water districts before being expanded for broad application at the state level.

According to the water conservation strategies suggested by TWDB in the 2012 Water Plan, the recommended strategies are projected to result in 9.0 added million acre-feet per year by 2060. Some strategies are designed to increase water conservation with existing resources, and others develop current resources. Table 9 provides a general breakdown of the percentage of water resources to which each effort contributes. The measures recommended are listed in Table 10.

TABLE 9: WATER RESOURCES CONTRIBUTED BY SOURCE

Water source contribution	Percentage by volume
Other surface water	33.9%
Irrigation Conservation	16.7%
New Major Reservoirs	16.7%
Reuse	10.2%
Groundwater	8.9%
Municipal Conservation Methods	7.2%
Groundwater Desalination	2.0%
Conjunctive Use	1.5%
Seawater Desalination	1.4%
Aquifer Storage and Recovery	0.9%
Other (rain harvesting, conjunctive use)	0.3%
Brush control	0.2%
Weather modification (cloud seeding)	0.2%
Surface Water Desalination	0.1%

(Texas Water Development Board 2012)

Policy Recommendations

As a measure to ensure successful implementation of recommended strategies, TWDB puts forth a list of policy recommendations to guide decision makers in construction of water conservation policy. Policy recommendations made by TWDB address the specific issues related to voluntary water transfers (Texas Water Development Board 2012). Planning groups also make recommendations to the Texas Legislature about where to designating specific reservoir sites with unique ecological values. Strategic recommendations supply decision makers with the background knowledge required to support suggested methods of water management. The issues, for which policy change or improvement are recommended through the 2012 Water Plan, are briefly described in Table 10.

TABLE 10: TWDB WATER POLICY RECOMMENDATIONS

Issue	**Recommendations for legislation**
Reservoir site and stream segment designation	Designate three additional sites for reservoir construction.
Reservoir site designation	Provide a mechanism for supplying the cost of reservoir construction and maintenance.
Interbasin Transfers of Surface Water	Sanction decisions that eliminate arbitrary restrictions on surface water transfers
Petition Process on the Reasonableness of Desired Future Conditions	Remove TWDB from this process, as it is not a regulatory agency.
Water Loss	Require public utilities to conduct water audits every year instead of once every five years (Texas Water Development Board 2012).
Financing the Water Plan	Develop a sustainable method to ensure financing assistance for implementation of water plan strategy (Texas Water Development Board 2012).

(Texas Water Development Board 2012)

Other Recommendations

Texas Water Matters, a collaborative partnership between National Wildlife Federation, Lone Star Chapter of the Sierra Club and Galveston Bay Foundation has additional policy recommends and strategies to improve water conservation efforts in Texas. A large step in improving environmental quality and maintaining riparian ecosystem health lies in confirming standards for environmental flows (Texas Water Matters n.d.). As an additional method to include community leaders in environmental flow standards implementation, Texas Water Matters recommends that state water funding mechanisms also include incentives for improved land stewardship (Texas Water Matters n.d.).

This group also recommends revising water projections to accommodate need rather than demand, and to include water required to maintain ecosystem health as such a need. Funding metrics for water reuse and infrastructure projects need to be clearly defined in order for decision makers to identify projects that merit state financial assistance (Texas Water Matters n.d.).

Policy enacted through the 82nd Legislative Session

A major item for the 82nd Texas legislation that convened on January 11, 2011 legislation was the focus on statewide funding and planning (Texas Water Development Board 2013). Significant advancements in this area were made in 2011 and 2012, namely regarding legislation related for improving water conservation methods (table 11) (Texas Water Development Board 2013).

TABLE 11: TWDB LEGISLATION AGENDA-82ND LEGISLATIVE SESSION (TEXAS WATER DEVELOPMENT BOARD 2013)

Description	Bill No.	Effective Date
Codification of TWDB's current bonding practices	SB 660	Effective Sept. 1, 2011
Require yearly water audits for entities receiving TWDB	HB 3090	Effective Sept. 1, 2011

financial assistance		
TWDB development of rainwater harvesting training tools for county employees	HB 3391	Effective Sept. 1, 2011
Require gallons per capita per day reporting methodology be established	SB 181	Effective June 17, 2011
Landowner's vested ownership interest in groundwater defined	SB 332	Effective Sept. 1, 2011
Rural Water Assistance Fund statute changes	SB 360	Effective Sept. 1, 2011
TWC Chapter 36 uniformity language change for groundwater conservation district management plans	SB 727	Effective April 29, 2011
Allen's Creek Reservoir's construction deadline extended from 2018 to 2025	SB 1132	Effective Sept. 1, 2011

Despite the legislative progress achieved in 2011, there is still much to be done to ensure that existing resources may be properly maintained in the years to come. This requires improving water management strategies, securing funding for the State Water Plan, improving the water auditing process, acquiring new sites for water storage, and eliminating restrictions on interbasin transfers (Texas Water Development Board 2013). Considering the continued need for funding to improve water-related projects prioritized in the 2012 Water Plan, the TWDB suggested several strategies designed to ensure funding for the 83rd Texas Legislation.

Financing the State Water Plan

Since the beginning of the regional water-planning program, the TWDB has provided more than $974,487,000 to implement 35 projects through 44 grants or loans statewide (Texas Water Development Board 2013). In 2007, the State Water Plan set forth by the TWDB resulted in approval of $1.67 billion from the Texas Legislature to provide funding for State Water Plan projects. In 2011, the 82nd Legislature authorized another $100 million to be dedicated to State Water Plan projects that will be available in 2012 and 2013. Additionally, the TWDB has also provided $530 million to supplement 2007 Water Plan projects. However, the amount of funding currently available for 2007 Water Plan and 2012 Water Plan projects falls short and a permanent solution has yet to be completely formed.

It is argued that in order to maintain progress, "a long-term, affordable, and sustainable method to provide financial assistance" for implementation of State Plan projects must be identified (Texas Water Development Board 2013). Estimated capital costs of all water management strategies recommended in the 2011 regional water plans totals $53 billion, and water providers will require approximately $27 billion is state financial assistance for municipal use strategies.

Water Project Funding in the 83rd Legislative Session

During the 83rd Legislative session, several bills were introduced that focus on finding a permanent source of funding for the Texas Water Plan and associated projects. Many of these bills were left pending in a subcommittee, or did not pass the House. Senate Bill 22 was introduced to the Senate and suggested making an appropriation from the economic stabilization fund in order to ensure that certain water-related projects would be financed (Texas Legislature Online 2013). Although Water Plan projects are heavily dependent on the money distributed through the Texas Legislature, the TWDB is also responsible for financing large-scale projects out of funds. In July of 2013, the San Antonio River Authority received an approved $4.3 million loan from the TWDB to develop a watershed master plan for Karnes and Goliad counties and to perform a "nutrient study" for Bexar County (Nowlin 2013).

Finding a permanent solution for water project funding is vital to ensure that water resource management currently underway is completed and that future projects do not face long delays. Within the 2012 State Water Plan, there are more than 560 projects recommended by regional planning groups statewide that total approximately $53 million (Texas Water Development Board 2012). Regional Water Planning Groups have been asked to prioritize water projects so that available funding may be used in the most impactful way. By doing this, water projects in regions across the state considered to be the most pressing will be addressed first and long-term plans can be made to address other smaller projects.

Utility companies will be required to conduct annual audits of water lines to check for loss, and to inform customers of audit results according to HB 857, 1461, and 3605. Furthermore, utility companies under HB 252 are required to notify the Texas Water Commission if it believes its water supply will be depleted in 180 days. Water suppliers are required to implement both water conservation as well as drought contingency plans when drought is declared within their county with HB 3604, instead of implementing just one or the other (Dowell 2013).

Two bills passed dealing with municipalities Senate Bill (SB) 385 and 654. The former authorizes municipalities to deal with commercial lenders to develop projects and programs with the intention of reducing water and energy consumption. The program is known as the Property Assessed Clean Energy or the PACE program. According to SB 654, municipalities no longer have to enforce water ordinances in criminal suits but can now be pursued in civil action instead (Texas Legislature Online 2013).

Funding the 2012 Water Plan

A landmark bill signed into a law in May of 2013, House Bill 4 has formed mechanisms for funding projects deemed most necessary by RWPGs across the state. House Bill 1025 (HB 1025) authorizes a one-time transfer of $2 billion from the state's "Rainy Day Fund" to sponsor water projects through the TWDB (Root 2013). Using this funding, HB 4 sanctions the creation of an infrastructure bank to provide money for water projects such as reservoirs and conservation programs if voters approve Senate Joint Resolution 1 in the fall of 2013 (Root 2013). To this end, Proposition 6 is a constitutional amendment that is up for a vote in November 2013 that will establish a State Water Implementation Fund For Texas (SWIFT) and State Water Implementation Revenue Fund for Texas. Formation of these groups will provide assurance that critical water resources are available and that priority water projects receive required funding (The Meadows Center for Water and the Environment 2013).

How will SWIFT work?

The SWIFT is a special account, which will operate outside of the state treasury at the discretion of the TWDB. Separate accounts may be established within the fund by the board for different purposes such as bond management and other project development. Once the effective date for SWIFT has been established, state representatives will elect members of the SWIFT Texas Advisory Committee who will be responsible for recommending rules to the TWDB for account management.[53]

[53] Recommended rules for SWIFT management to be made by the SWIFT Texas Advisory Committee by September 2014

Funds for water project implementation are kept in a trust and distributed through the TWDB in order of priority. Until projects are confirmed through the board, funds for SWIFT are kept in escrow and managed by the Texas Treasury Safekeeping Trust Company (hereafter referred to as the Trust).[54] These monies may come from a variety of sources such as taxes or fees collected in relation to the fund, investment earnings and associated interest accredited to SWIFT, funds allocated to SWIFT by law, and money transferred to SWIFT under a bond enhancement agreement.[55] The Trust is responsible for managing SWIFT resources and can only recover costs incurred by the fund from SWIFT earnings. The TWDB is responsible for directing project funding in cooperation with the Trust. This includes bond enhancement agreements and revenue bonds, although the TWDB does have some limitations when it comes to bond management.[56]

Project prioritization can be found in Conservation efforts are also supported through HB 4. Regional Water Planning Groups are responsible for determining which projects within their areas require immediate attention and providing that information to the board.[57]

The assets available in SWIFT are managed by the TWDB with the assistance of the Trust and the SWIFT Texas Advisory Committee. Requiring that RWPG prioritize projects is expected to ensure the best use of SWIFT resources and streamline the funding process. By September of 2014, all RWPGs must have submitted a prioritized list of projects to the TWDB for implementation. Funding from HB-4 incorporates leveraging a $2 billion one-time capitalization with bonding authority from TWDB (The Meadows Center for Water and the Environment 2013). In order for a plan to be eligible for SWIFT funding, it must be present in the State Water

[54] HB 4 Sec. 15.431-2(b)

[55] HB 4 Sec. 15.431-2(b) – see also Sec. 15.435 for bond enhancement agreement authorizations.
[56] HB 4 Sec. 15.436
[57] HB 4 Sec. 16.053

Plan (SWP). Potential program managers must submit a water conservation plan and complete a request for financing information (The Meadows Center for Water and the Environment 2013).

There are certain goals that the Texas Water Plan is working to accomplish over the next five years in order to alleviate water stress most effectively. Of all funded projects, 10% will specifically support rural areas, including agricultural water conservation. Another 20% of funded projects will support water conservation or reuse, including agricultural irrigation projects (The Meadows Center for Water and the Environment 2013).

Water Conservation Legislation

During the 83rd Legislative session, several other bills were introduced that focus on increasing conservation efforts in Texas. These bills are listed in Table 12. Education and conservation are recognized as important efforts in resource management. Bill associated with these efforts introduced during the 83rd legislative session focus on increasing funding for research, establishing BMPs and water contingency planning during drought, and requiring utilities to perform regular water audits.

TABLE 12: WATER CONSERVATION LEGISLATION (THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT 2013)

Legislation	Strategy	Description
SB 1 by Senator Williams and Representative Pitts	Conservation and education assistance	Provides an additional $1,000,000 in grant funding opportunities and $2,000,000 for environmental flows and instream basin research
HB 3604 & HB 3605 by Representative Burnam and Senator Hegar	BMPs to be established by agency rule	Requires implementation of water conservation plan and drought

	Certify that projects meet current industry design and construction standards	contingency plan during emergency drought conditions.
HB 1461 by Representative Aycock and Senator Fraser	Requires each retail public water utility required to file a water audit to notify each of the utility's customers of the water loss reported in the water audit	Utility's annual consumer confidence report; Next bill the customer receives after the water audit is filed
HB 857 by Representative Lucio III and Senator Ellis	Enhance conservation measures for public utilities	Requires all retail public utilities supplying potable water to file an annual water audit[58]
SB 198 by Senator Watson and Representative Dukes	Water conservation: landscaping	Ensures that HOAs cannot prohibit drought-resistant landscape or water-conserving natural turf. Allows HOAs to require the homeowner to submit a plan for such use.

[58] Exceptions: Retail public utilities under 3,300 and not receiving financial assistance are required every 5-years.

Other Legislation

Other bills designed to fund the State Water Plan were introduced to congress during the 83rd Legislative session, but failed to be successful. House Bill 11 was introduced to the Texas Legislature in the spring of 2013, but died in the house. This bill proposed by Representative Allen Ritter (R-Nederland) would allocate $2 billion from the Rainy Day Fund to create a water infrastructure bank from which statewide water projects may be funded (Barer 2013).

Actual funding requested in this bill associated with water projects recommended by TWDB in the water plan has not been easy to obtain. The reasons why HB-11 faced so much contention are purely fiscal and related to the allocation of funds into water only. Opponents of HB 11 called such spending irresponsible and feared that allocating such an amount would break state spending limits (Buchele 2013). If the $2 billion could not be reached, an amendment introduced by State Representative Brandon Creighton (R-Conroe) recommended that funds for water projects be taken from cuts made elsewhere. This action did little to secure the votes of Democrats interested in securing money for other areas like education, and instead resulted in the bill failing to receive enough votes in April of 2013 (Buchele 2013).

Senate Joint Resolution 1

Although HB 11 was referred back to House Appropriations Committee, it is unlikely that the bill will survive. Other bi-partisan legislation designed to create a water infrastructure bank that provides loan money may still be approved in the form of SJR 1 and HB -9. Releasing of funds connected to the passage of HB-4 depends on whether or not SJR 1 passes in November 2013. This resolution would allocate billions of state dollars from the Rainy Day Fund towards education, water and roads and is linked to HB-4.

House Bill 19 is a bill that would also allocate money out of the rainy day fund ($3.7 billion) for roads and water projects. As of August 2013, it is unclear how this money will be divided. In order to progress, the bill was required to be out of committee by May 6, 2013. However, no action was taken to determine by the House Appropriations committee on HB 19 so the future of this legislation is unclear.

Other Water-related Legislation Passed in 83rd Session

Several bills introduced through the 83rd Legislature focus on issues with international water rights between the United States and Mexico (table 13). One such bill that was successfully passed and signed by the governor in June of 2013 is HCR 55 developed by Democratic Representative Eddie Lucero of Harlingen, Texas. This bill urges the United States to take action regarding shared water resources that are due to the U.S. from Mexico in accordance with the 1944 Treaty (Lucero 2013).

House Concurrent Resolution (HCR) 55 is of especial interest to Texas decision makers because of the desperate nature of international Rio Grande-Rio Bravo water rights. According to the Treaty of 1944, Mexico is required to dedicate an average of 350,000 acre-feet of water annually over five years (International Boundary & Water Commission 2013). Mexico has been in arrears since the 1992-1997 cycle, and currently owes more than 390,000 acre-feet for the 2010 cycle. This puts an enormous amount of stress on agricultural producers in the Rio Grande River basin. Therefore, it is hoped that HCR 55 will inspire the U.S. Department of State to take appropriate action and assure Mexico’s compliance with the 1944 Treaty.

TABLE 13: 83RD LEGISLATIVE SESSION - OTHER WATER-RELATED LEGISLATION

Bill Number	Description	Date Signed by Governor	Effective Date
HB 252	Requires local water authorities to inform the	6/14/2013	9/1/2013

	TCEQ if they have less than 180 days of water supply available.		
HB 857	Requires all public water utilities providing potable water to submit an annual audit.[59]	6/14/2013	9/1/2013
HCR 55	Urges the United States to ensure that Mexico complies with the Treaty of 1944.	6/14/2013	9/1/2013

Amendments to the Texas Water Code

Congress-approved amendments to the Texas Water Code continue to be published. Many of the amendments to the Texas Water Code passed during the Regular Session are related to tax and property codes for water and sewage use. Although they are relevant, most of these changes are not directly related to funding for water projects in the Texas Water Plan or the management of water resources.

Additional legislation passed during the 83rd Legislative session containing information about changes to the Texas Water Code relate to the Omnibus Water District Bill and the option for municipal management districts to tax services such as water and sewer for single family residences, duplexes, and triplexes (Mott and Wheeler 2013).

Other Water Conservation Bills

[59] Regarding text in HB 857, smaller utilities that serve less than 3,300 people need only submit an audit every five years (Barer 2013).

Drought management, xeriscaping, and a number of other water-related bills have also been introduced to the state legislature. Many did not pass, were been put on the calendar for review, or sent to a committee. For many years, homeowners associations in Texas (HOAs) have imposed limits to xeriscaping, composting, and other resource-saving techniques for residents. This past session, the state congress managed to pass several pieces of legislation proposing to increase xeriscaping with drought-resistant vegetation including turf, and installing rain barrels.

Senate Bill 198 – Effective 9/1/2013

This bill states that property owners' associations may not impose limitations on homeowners that restrict xeriscaping and water conservation. Such activities include, the installation of efficient irrigation systems; installing a rain barrel or underground drip system, or using drought resistant turf (Watson 2013). Associations can, however, regulate xeriscaping requirements within a community. This includes the types of materials used, where systems may be constructed, and shielding of certain system types (Watson 2013).

Senate Bill 662 – Effective 9/1/2013

The purpose of SB 662 is to include the Electronic Reliability Council of Texas (ERCOT) power region into the Drought Preparedness Council, which was first established by the 76th Legislature (Texas Department of Public Safety 2011).

Conclusions and Analysis

Securing funds for water projects in the State Water Plan will provide secure resources for water projects that demand immediate attention. Passage of this bill not only secures the creation of a water-funding mechanism for the next 50 years if voters approve Proposition 6, but also provides for full-time governance by the TWDB and motivates regional decision makers to prioritize projects. Passing this legislation is a great achievement for increasing the longevity of water resources statewide, and increasing the work for which the TWDB is responsible. Funds from this measure will go towards improving infrastructure and providing loans to contractors for water storage facility construction and maintenance.

Taking steps towards managing the water debt owed to Texas by Mexico through HCR 55 is also vital in order to find a resolution to this problem. During the beginning of the 2011 drought, agricultural losses alone totaled more than $7.62 billion statewide (Fannin 2012). Farmers living in the basin already must contend with extended periods of drought, so receiving water reserves promised to them will help sustain existing agriculture in the basin and take economic stress off of farmers and ranchers.

When it comes to water resource security for Texas, it is clear members of both political parties agree that the issue is paramount for the future of the state. As is typical with change, new responsibilities for the TWDB will undoubtedly require time for problems to be sorted out. Should SWIFT be instituted, funding distributed for water projects sanctioned within the SWP will have to be accounted for carefully to confirm that resources are allocated properly. With the solidification of a funding resource in SWIFT, the TWDB and RWPGs across Texas now have the muscle to enforce project development and conservation efforts.

However, methods for determining project prioritization still need to be developed. Legislation focusing on water conservation efforts for individuals and municipalities inspires confidence for future regulatory resource maintenance. Encouraging educational efforts and research into environmental flows is also a positive step. Informing localized efforts for environmental flows management is expected to increase program effectiveness.

Section 16: Conclusions

Managing Water as a Single Source in Texas

Introduction

As our two freshwater resources, groundwater and surface water are a part of a complex and interrelated system connected by a sensitive hydrologic cycle. In order to appropriately manage these two resources understanding the implications of their relationship is imperative. Yet, for as long as Texas water policy has identified groundwater as a freshwater resource, ground and surface water have been developed and managed separately. By simply focusing on one component of an interconnected hydrologic system, effective management will be difficult due to unclear and unregulated management of one or both parts of the system (Winter 2002). Yet, in relatively recent years the western United States has begun developing strategies to identify groundwater and surface water as a single resource to be managed together (Colorado Department of Natural Resources n.d.). As an interconnected system, recognizing this as a beneficial strategy could provide direction for future water resource management.

Application in Colorado and Washington in relation to Texas

Colorado and Washington are two states with existing simultaneous groundwater and surface water policy. In both states, the Riparian Water Law, derived from the English Common Law, established the rule of prior appropriations, or first in time/first in right, as basis of water rights. As the implications of increased technological advances in water resource extraction, the process began to be more efficient and intrusive.

Since the late 1800's Colorado has had a variety of surface water districts managing water appropriations. But it was not until 1965 that groundwater management districts were established (Colorado Department of Natural Resources n.d.). As we can witness in Texas, implementation of management areas are not the only assurance a state needs to appropriately distribute water resources. A constant power struggle between the rights of the individual above the rights of the whole are at the core of court room decision making, and for water policy, establishing new policy for water can, and many times has been, discussed through courtroom decisions and statutes on future conflict. Ultimately, in Colorado before the 1970's, litigation to regulate tributary wells were found constitutional and resulted in requiring surface and ground water rights to be administered together (Colorado Department of Natural Resources n.d.). This decision was due to the obvious interrelated effects of groundwater extraction to surface water flows. With a previously stated water policy of prior appropriations, the limiting of one's water right by extracting groundwater was seen as interfering with the individual with the proper permit for surface water use.

Likewise, in Washington the 1917 State Water Code established that; all unclaimed water belonged to the public, water rights were created by the appropriations doctrine, that the state will administer a centralized water right, and the establishment of an adjudication system through the courts (Washington Department of Ecology 2006). Though Texas' surface water is owned and rendered by the state as public water requiring appropriate permits to withdraw from, Texas' land and thus ground water, is first owned on an individual basis. Washington's 1917 doctrine established that the public must apply for a permit to establish surface water rights and by 1945 the mass majority of the state was drilling wells for acquisition of ground water. Yet, by court room litigation, leading to the U.S. Supreme Court, a decision establishing the inseparable link between water quality and quantity requiring the ground water and surface water to be managed together (Washington Department of Ecology 2006). The 1945 Groundwater Code established the permitting process of ground water rights to protect water quality and the term of hydrologic continuity was established as a basis of Washington's single resource state water policy in a 1994 case (Hubbard v. Department of Ecology).

We can see that Colorado and Washington had two similar but different reasons for joining the two resources as a single entity to be managed together under the state's jurisdiction. While Colorado was establishing protection of water rights through water quantity, Washington was taking one step further in defining the separation of quality and quantity as legally inseparable.

What perspective does this give Texas water policy?

As Texas is developing its water resource policy to adjust to recent shortages, borrowing certain assumptions from other states could bring to light the missing link between natural resources and private property rights. Texas is very different in basic governmental philosophy and policy compared to Washington and Colorado. Texas has less than 2% of its total land area owned by the state or federal government, compared to Washington's 36% and Colorado's 39% (National Wilderness Institute 1995). It is easy to see the fundamental problems in establishing public ownership of a resource that was once viewed as a private asset. Public attitudes are steeped in culture and as a traditionally conservative state. Texas maintains an attitude of limited governmental control and individual rights reigning supreme to that of public interest. This is often a rural vs. urban ideological difference throughout our country, but the effects of water resource management in Texas is a particularly sensitive subject that needs clarification due to resent shortages and increasing population.

What's the Big Deal?

It is clear that the shifting distribution of peoples and industry in Texas eastward and towards the coasts results in water stress felt primarily west-Texas agriculture and smaller rural areas with declining populations. Greater regulation of groundwater resources is certainly needed to ensure that sufficient water exists within the systems and maintain aquifer integrity. However, the regulation of water as two separate entities presents numerous problems and makes management of existing resources difficult. Given that groundwater is treated as property, restricting pumping on private property is difficult even with GCD management in place. Individual management of the most precious resource in the state provides owners with a sense of freedom and liberty. That is to say, 'I possess water on my land that I am responsible for managing and using as I see fit.'

Regulatory Management

Revoking this right or amending it to give the state more of a role in well management is not generally seen as a desirable, or indeed viable, option. So if water were to be managed as a single entity, would regulation improve, and if so, how? Resource regulation involving methods of controlling surface water by institutional actors still often involves litigation with neighbors sharing a transboundary surface water body, mismanagement of resources, and lack of protection for riparian and estuarine environments. Many stakeholders living in locations without a central watermaster continue to depend on the TCEQ and courts to settle disputes involving water use priority. The results are lengthy legal battles, which are expensive and difficult to resolve because of lack of evidence. Yet many citizens would rather manage water use conflicts alone rather than pay for a watermaster, despite the success of the program. It seems that, unless the TCEQ deems it necessary to institute a program, private citizens will not seek out regulatory management.

State-level regulation provides a framework for data collection, information synthesis for action, and the ability to enforce conservation efforts legally. In many ways, regulatory efforts have been successful. Projects for water conservation infrastructure have been identified and mechanisms are in place through agencies to provide funding and project guidance. The existing system for surface water resource allocation, although not perfect, does operate to promote fair and equitable use for stakeholders in Texas river basins based on when rights become active and priority. However, there are some obvious problems with the existing system. Currently, the process for rights allocation does not adequately take into account projections for changing climate, drought, or flooding and the health of riparian systems.

Environmental flows management, as we have seen, is not completely enforced using scientific evidence and is often fraught with conflict-of-interest. River authorities charged with managing the buying and selling of water rights are also involved with overseeing environmental flows management within a river basin. This system must be repaired to ensure that ecosystems depending on freshwater influxes receive the resources required to stay healthy. Since beginning industrial water project development in Texas during the last century, riparian systems have been altered beyond recognition. Such changes are, for the most part, irreversible. Any further modifications exacerbate existing problems and affect a great many important industry sectors including fishing and tourism. Clearly, this is an area that needs immediate attention.

What This Means for Water Users in Texas

A recurring theme in this document is change in weather, population, industry, and development. Texas is a state facing many an uncertain future regarding resource availability. True, at the moment, there is plenty of water existing for use, both on the surface and underground. In fact, it is not certain exactly how much subsurface water is directly available for human use. This question is being addressed by TWDB and other private entities, and it must be determined in order to plan for future restrictions.

Comprehending How Everything is Connected

Understanding how shifting resources will affect the energy industry and fracking activities in individual watersheds is also extremely important. Steps must be taken to educate stakeholders at the local level about the energy-water nexus, and how current actions affect future resources. Tactics for holistic management systems for energy and water need to be developed so that Texans can make the connection between water use, energy production, and how resource considerations are intertwined in BMPs. Valuation of ecological resources and environmental education are considered to be softer, or not as necessary components to environmental management.

But how can decision makers and stakeholders act responsibly without information that is easily digestible and readily available? According to a study on nationwide Environmental Literacy, adults in America receive most of their information from media sources, and much of the information is old or outdated (Cole 2005). A bigger problem for Texas communities lies in understanding the human-environment reaction at the local level and how current actions affect future resources. The state of environmental literacy among adults in the individual Texas watersheds is unknown. Education needs to be emphasized more effectively not only in informal and formal and formal programs for students, but also in local programs for adults. This includes incentive programs and local mandates for energy conservation practices that provoke questions from the community and provide economic impetus for adults to become interested in local water issues.

As we have seen, water permeates every aspect of our daily lives. Improper management of this resource will present future generations with greater difficulties than we face now. Understanding the amount of resources that we have available, how to improve management to ensure that ecosystems receive the water required to maintain essential functions, and learning to manage shared resources are only some of the larger problems. It is yet unclear if it will soon be possible to manage surface and groundwater as one system. Doing so would likely result in better surface water quality and groundwater supervision. But in order to do this, existing problems within the current state-level regulatory systems must be addressed. It is unlikely that citizens will confidently invest in federal governance if conflict-of-interest and current resource management is not executed as efficiently and in as fair a manner as possible.

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Appendix 1 – TCEQ Water Permit Data

Active Water Permit Use by River Basin											
	Canadian	**Red**	**Sulphur**	**Cypress**	**Sabine**	**Neches**	**Neches-Trinity**	**Trinity**	**Trinity-San Jacinto**	**San Jacinto**	**San Jacinto-Brazos**
Municipal/Domestic	2	48	25	20	51	32	1	135	0	11	4
Industrial	11	32	14	30	72	52	11	157	4	42	20
Irrigation	22	227	24	37	82	115	131	358	18	51	51
Recreation	11	80	14	34	89	120	6	399	2	90	28
Domestic/Livestock Use Only	0	3	3	6	6	9	0	26	0	0	0
Other	2	13	7	5	14	12	13	10	1	9	11
Total	**48**	**403**	**87**	**132**	**314**	**340**	**162**	**1085**	**25**	**203**	**114**

Active Water Permit Use by River Basin (continued)												
	Brazos	**Brazos-Colorado**	**Colorado**	**Colorado-Lavaca**	**Lavaca**	**Lavaca-Guadalupe**	**Guadalupe**	**San Antonio**	**San Antonio-Nueces**	**Nueces**	**Nueces-Rio Grande**	**Rio Grande**
Municipal/Domestic	247	3	169	0	6	1	102	27	0	20	2	160
Industrial	231	15	118	8	4	1	75	37	6	18	14	148
Irrigation	1151	75	1425	24	62	7	409	311	3	299	58	1213
Recreation	179	0	128	2	5	0	108	43	5	27	13	27
Domestic/Livestock Use Only	0	0	0	1	1	0	8	2	1	37	4	29
Other	123	14	33	1	1	1	36	15	4	14	12	21
Total	**1931**	**107**	**1873**	**36**	**79**	**10**	**738**	**435**	**19**	**415**	**103**	**1598**

U.S. Census Bureau Population Data

The 15 Fastest-Growing Large Cities from July 1, 2011 to July 1, 2012				
Rank	**Area Name**	**State Name**	**Percent Increase**	**2012 Total Population**
1	San Marcos city	Texas	4.91	50,001
3	Midland city	Texas	4.87	119,385

4	Cedar Park city	Texas	4.67	57,957
7	Georgetown city	Texas	4.21	52,303
10	Conroe city	Texas	4.01	61,533
11	McKinney city	Texas	3.95	143,223
12	Frisco city	Texas	3.92	128,176
13	Odessa city	Texas	3.83	106,102

Acre-Feet total by UseCode:

UseCode	Acre-feet	Percentage
Municipal	16432220.05	33.323%
Industrial	18360319.36	37.233%
Irrigation	4781934.979	9.697%
Mining	192003.51	0.389%
Hydroelectric	9089551.00	18.433%
Recreation	32552.20	0.066%
Other	202999.11	0.412%
D&L	14918.00	0.030%
Storage	202602.02	0.411%

Appendix 2: How Much Water is in the Texas Hill Country?

Background

The Texas Hill Country is one of the fastest growing regions in the country in a location straddling semi-arid and humid subtropical weather conditions. It is a region in central Texas that contains all or parts of Bandera, Bexar, Blanco, Comal, Gillespie, Hays, Kendall, Kerr, Medina, Travis, and Uvalde counties (Texas Water Development Board 2009) (Figure 28). Freshwater rivers, streams, and creeks crisscross beautiful limestone landscapes and feed fragile karst aquifers. As of summer 2013, there is no method for determining the total amount of surface and groundwater resources available in the Hill Country. Groundwater is stored in fragile and complex karst aquifers and the exact volume is difficult to determine, especially so because Groundwater Conservation Districts (GCDs) and Groundwater Management Areas (GMAs) do not contain entire aquifer systems. Water is a dynamic resource and may flow from one area to another depending on environmental and anthropogenic pressures. Because the Hill Country also is not treated as a demarcated region by the Texas Water Development Board (TWDB) with a separate GCD, it is also difficult to gather information about surface and groundwater within the exact area contain in the perceived boundary. Surface water flows in and out of streams, creeks, rivers, and lakes that overlap counties both in and out of the Hill Country and individuals with water rights stemming from a particular river may not reside here. Groundwater from subsurface aquifers also feeds these rivers, and that water is not always from the Trinity Aquifer, but may be water flowing out of the Edwards Aquifer. The problem with determining the total amount of water in an area is that water is not a source with boundaries that may be immediately defined.

Presently, the TWDB is able to determine how much water is used and therefore available in the Hill Country portion of the Trinity Aquifer by using Groundwater Availability Models (GAMs). In order to obtain all available groundwater for the Trinity Aquifer in the Hill Country, the model

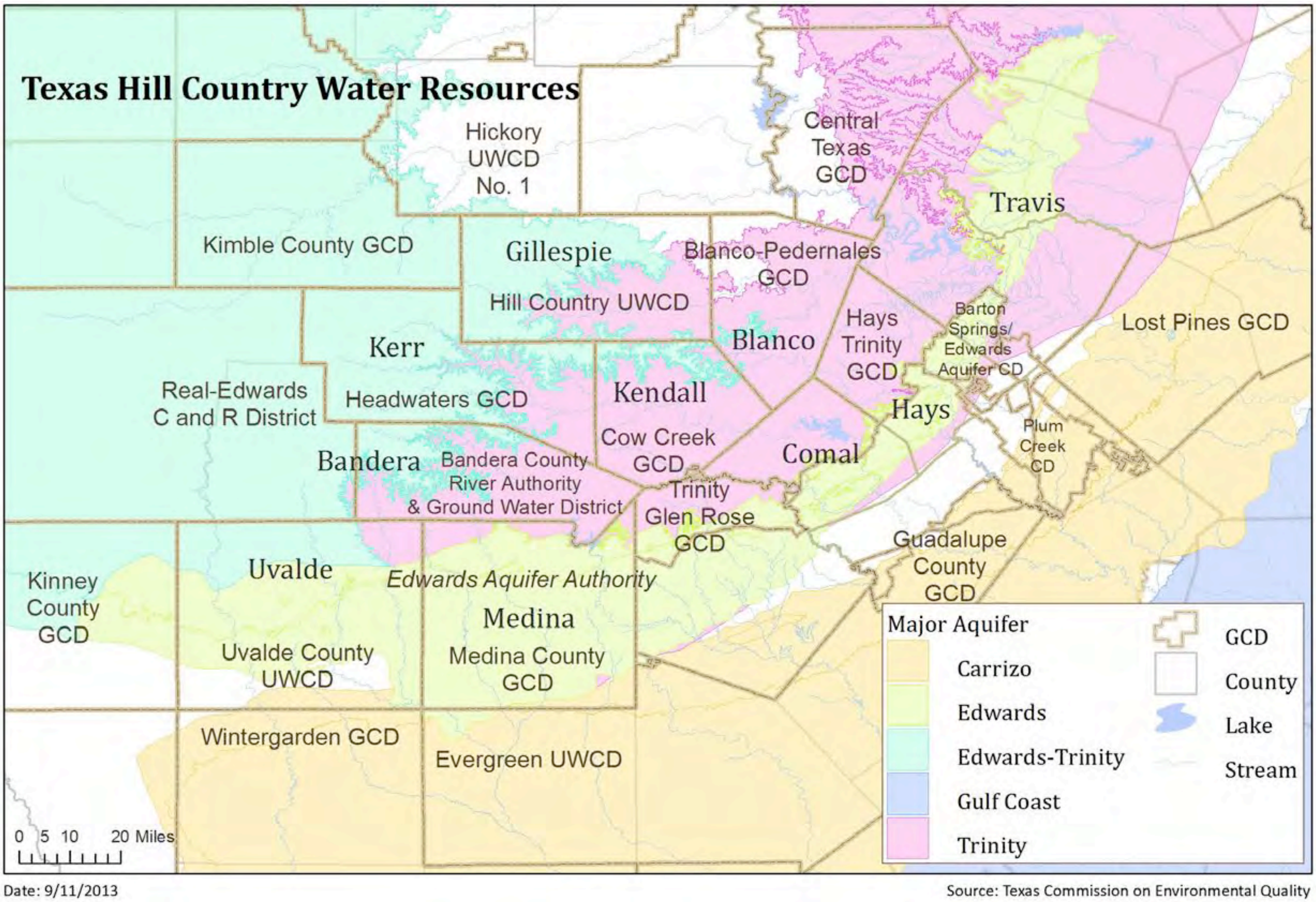

FIGURE 27: WATER SYSTEMS IN THE HILL COUNTRY

divides the aquifer into three separate sections: Upper, Middle, and Lower Trinity (Texas Water Development Board 2009). The TWDB receives estimates of available groundwater based on the

Desired Future Conditions (DFCs)[60] for that region and then uses these estimates to predict water depth over a 50-year period (Texas Water Development Board 2013).

Research Methods for Groundwater Resources

In order to establish an estimate of total resources, it must first be determined what exactly is known about the current amount and nature of groundwater and surface water in the Hill Country. The TWDB GAM for GMA 9 includes the Hill Country Priority Groundwater Management Area (PGMA) (fig. 3) that also includes the Blanco-Pedernales Groundwater Conservation District in the Middle Trinity Aquifer. In total, seven GCDs are established in the Hill Country to help ensure responsible groundwater use (table 14). This region also contains smaller portions of the Edwards and the Carrizo-Wilcox Aquifers, but most resources are drawn from the Trinity. Surface water resources are diverted from the Pedernales, Guadalupe, and Colorado Rivers into dams and reservoirs and released for municipal, irrigation, industrial, and environmental purposes. Many other smaller rivers, such as the San Marcos, within the watershed basins are not taken directly into consideration as that water is free flowing.

Current volume for lakes and reservoirs are catalogued and compiled for a general idea of how much surface water is available in the Texas Hill Country. It is not possible to determine the exact total as lake levels fluctuate daily and information for some systems is not available. However, it is possible to give the amount of water presently contained by these lakes and the total potential capacity for each system.

Groundwater Resources in the Hill Country

[60] Within the Texas Water Code, Title 31, Part 10, §356.2, Desired Future Conditions are defined by the TWDB as, "the desired, quantified condition of groundwater resources (such as water levels, water quality, spring flows, or volumes) for a specified aquifer within a management area at a specified time or times in the future."

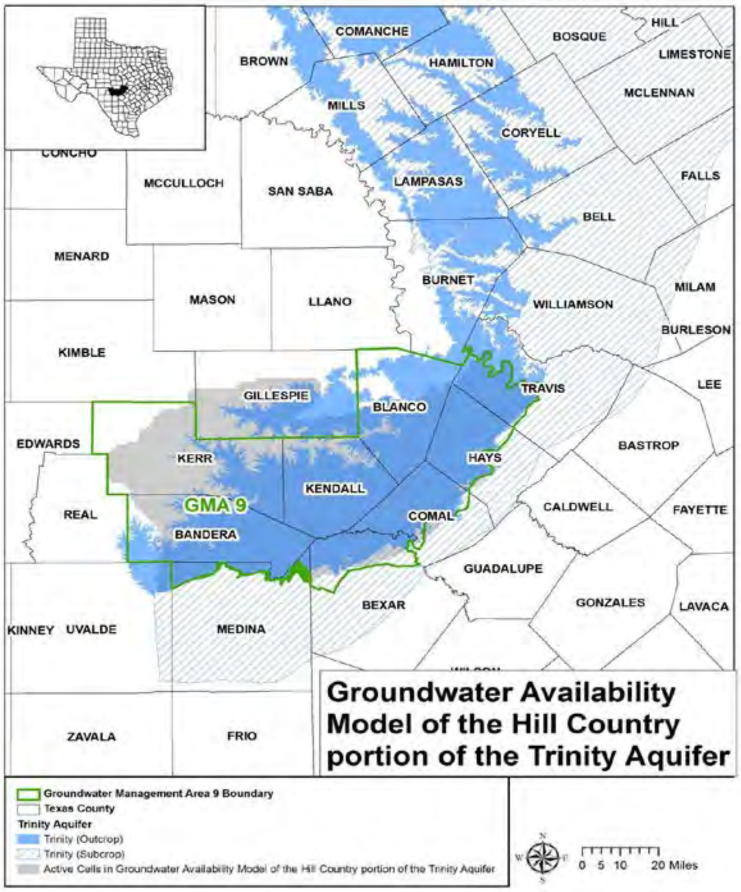

FIGURE 28: GROUNDWATER RESOURCES IN THE TEXAS HILL COUNTRY (HASSAN 2012)

The Edwards-Trinity Aquifer represents an area of approximately 35,500 square miles in central-west Texas (United State Geological Survey n.d.). Within GMA 9, the Edwards-Trinity Plateau

and the Upper, Middle, and Lower sections of the Trinity Aquifer contain the majority of groundwater resources for the region (United State Geological Survey n.d.). Local groundwater resources are managed through Groundwater Conservation Districts (GCDs), which are responsible for submitting requests for desired future conditions of groundwater resources to the associated Groundwater Management Areas (GMA). These bodies are established and

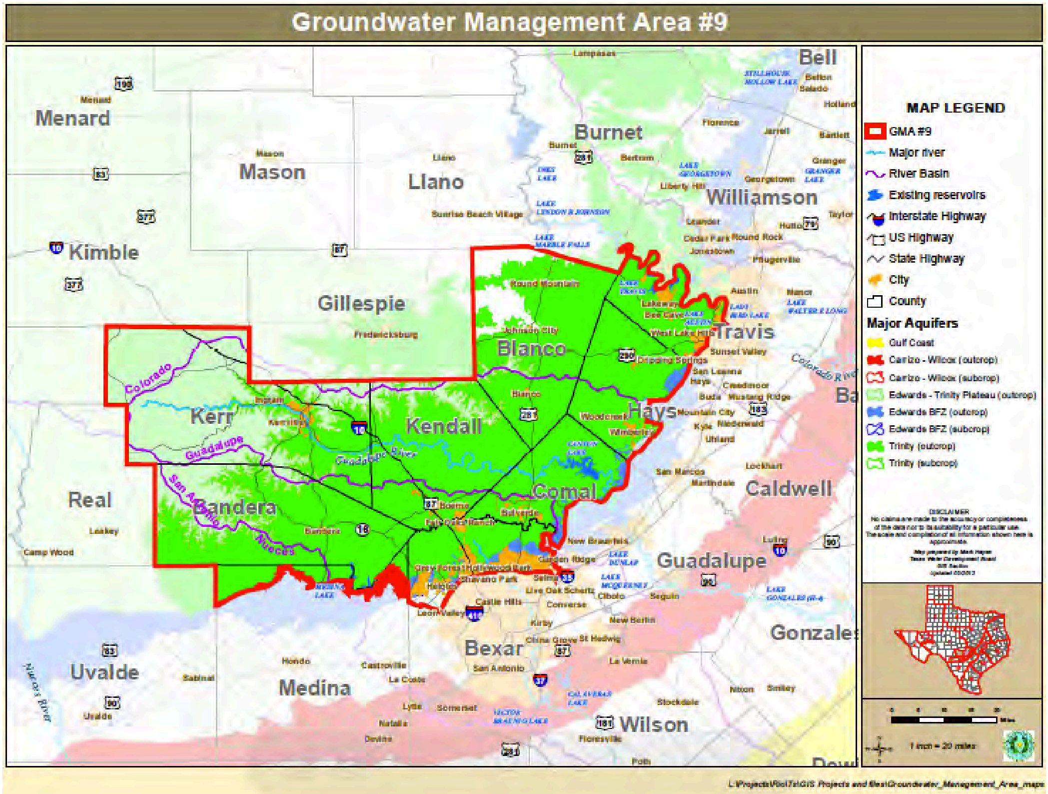

FIGURE 29: MAJOR AND MINOR AQUIFERS IN THE TEXAS HILL COUNTRY (TEXAS WATER DEVELOPMENT BOARD 2013)

maintained through the Texas Water Development Board (TWDB). The Trinity Aquifer that stretches across the Hill Country from Travis County in the northeast to Medina and Kerr in the

southwest (Texas Water Development Board 2009). As the largest aquifer in GMA 9, the Trinity Aquifer is the main source of groundwater in the Hill Country (Hill Country Alliance n.d.) (Figure 8). Other major aquifers within this region include the Edwards Aquifer and the Carrizo-Wilcox, but supplies from Trinity equal approximately 94,000 acre-feet per year (Jones 2009). The TWDB uses this amount to gauge the total amount of available groundwater resources in GMA 9 even though portions of other aquifers exist in this region. At this time, there is no information about the current total storage of the Trinity aquifer, but progress is being made. Total groundwater available is The TWDB is in the process of compiling this information for all aquifers in Texas through the total estimated recoverable storage Figures. Ideally, this number will represent the volume of water available in an aquifer. However, to estimate the amount of available water, updated Groundwater Availability Models (GAMs) may be used to determine the amount of groundwater available for use. This is defined in the Texas Water Code as the "estimated average amount of water that may be produced annually to achieve a desired future condition (Hassan 2012)." After GCDs are Groundwater Management Areas (GMAs) that are water resource management systems that control larger regions. The Hill Country and the portion of the Trinity Aquifer within this area is Region 9 in the GMA system (Hassan 2012). The total amount of available groundwater available in the Hill Country portion of the Trinity Aquifer reported in 2010 for this region is approximately 93,052 acre-feet (table 14). Although this number does not represent the total amount of groundwater resources available in this area, it does provide the best estimate of water available through GCDs in the Hill Country.

Surface Water Resources in the Hill Country

Total surface water is also difficult to accurately gauge. Rights to surface water within the Hill Country region are allocated for specific purposes, and many pre-existing water bodies do not carry consistent amounts of water due to drought. So to accurately answer the question "how much water is currently in the Hill Country", we must know if the question posed is referring to all water existing for current use, simply all-tangible water resources, even if it is already allocated elsewhere, or water that may potentially be available according to historical numbers. For this analysis, we assume that the amount of water we are attempting to identify is the total amount available in established systems, that is, in lakes and reservoirs.

The Hill Country is situated in the Guadalupe River Basin and contains a portion of the Guadalupe River, the Comal River, the Blanco River, and the San Marcos River (Texas Water Development Board 2012). In order to ensure that a sufficient amount of surface water is available to sustain instream flows and still meet water needs for municipal, industrial, and agricultural uses; dam systems are in place to maintain water flows. The chief water supply, flood control, and recreation reservoirs are Canyon Lake on the Guadalupe River above New Braunfels and the Highland Lakes reservoir system along the Lower Colorado above Austin (The Meadows Center for Water and the Environment 2013). The Highland Lakes System supplies water for more than 1 million people in the Hill Country and includes Lake Buchanan and Lake Travis (Lower Colorado River Authority 2013). There are a total of 13 major lakes in the Hill Country region (table 15).

TABLE 14: MODELED AVAILABLE GROUNDWATER IN GCDS AND NON-DISTRICT AREAS WITHIN THE HILL COUNTRY IN ACRE-FEET/YEAR

Groundwater Conservation District	Year					
	2010	2020	2030	2040	2050	2060
Bandera County RA & GWD	7,284	7,284	7,284	7,284	7,284	7,284
Blanco-Pedernales GCD	2,573	2,573	2,573	2,573	2,573	2,573
Cow Creek GCD	10,622	10,622	10,622	10,622	10,622	10,622
Hays Trinity GCD	9,109	9,098	9,095	9,094	9,094	9,094
Headwaters GCD	16,435	14,918	14,845	14,556	14,239	14,223
Medina County GCD	2,500	2,500	2,500	2,500	2,500	2,500
Trinity Glen Rose GCD	25,511	25,511	25,511	25,511	25,511	25,511
Total (district areas)	**74,034**	**72,506**	**72,430**	**72,140**	**71,823**	**71,807**
No District	19,018	18,770	18,753	18,741	18,725	18,696
Total (including non-district areas)	**93,052**	**91,276**	**91,183**	**90,881**	**90,548**	**90,503**

(Hassan 2012)

TABLE 15: RESERVOIR AND LAKE CAPACITY FOR SYSTEMS IN THE HILL COUNTRY

Water Body[61]	Total Conservation Capacity (volume when full) in Acre-Feet	Estimated Volume of Water Available in Acre-Feet	Percent Full
Canyon Lake[62]	378,781	304,894	80.5%
Lake Buchanan	876,000	330,000	38%
Lake Travis	1,113,348	376,973	33.9%
Brady Creek Reservoir	28,808	6,476	22.5%
Lake Austin	23,972	22,942	95.7%
Lake Georgetown	36,823	20,394	55.4%
Lake Granger	50,779	47,382	93.3%
Inks Lake	13,962	13,013	93.2%
Lake L.B. Johnson	115,056	111,431	96.8%
Lake Marble Falls[63]*	7,186		
Medina Lake	254,823	13,111	5.1%
Lady Bird Lake*	7,338		
Walter E. Long*	33,940		
TOTAL	2,940,816	1,246,616**	

(Guadalupe River Authority, the Army Corps of Engineers, and the LCRA.)
*Current volume data not readily available.
**Lake totals do not include Lakes Walter E. Long, Marble Falls, and Lady Bird.

Conclusions

In summary, using the data available on the amount of groundwater currently available for use in the Texas Hill Country portion of the Trinity Aquifer and the amount of surface water available

[61] Numbers for all lakes and reservoirs unless otherwise noted are accurate as of July 8, 2013. Data for Texas lakes in available through Texas Water Data, a project developed through Texas Parks and Wildlife Department (Texas Parks and Wildlife 2013).
[62] Data from Lower Colorado River Authority is dated July 8th(Lower Colorado River Authority 2013).
[63] Numbers for Marble Falls are most recent available. (Lower Colorado River Authority 2012)

in all Hill Country lakes, it can be estimated that the Hill Country contains 1,339,668 acre-feet of obtainable for use. This number does not include current discharge of all rivers that flow through the region, nor does it include the amount of water that may be available through private catchment systems. It is an extremely rough estimate, but one that may be used to improve current conservation goals and numbers for desired future conditions.

Surface Water Policy and Permit Holders

Within the 17 counties described as being within the Hill Country, a total of 1,695 permits approved by the TCEQ are active currently, with a total surface water allocation of over 3.3 million acre feet. This total volume excludes the previously defined exemptions of up to 200 acre-feet per 12-month consecutive period for landowners. These permits range greatly in purpose and volume, but can give a reasonable idea of the surface water resources allocated throughout the region (table 16).

County	Number of Permits	Volume (Acre Ft)	Average Per Permit
Bexar	156	103,693.81	664.70
Blanco	38	1,919.25	50.51
Burnet	79	1,546,119	19,571.13
Bandera	74	1,643.81	22.21
Comal	124	482,162.52	3,888.41
Edwards	34	1,797.1	52.86
Gillespie	108	4,862.44	45.02
Hays	69	78,691.08	1,140.45
Llano	48	3,211	66.90
Kendall	75	3,535.43	47.14
Kerr	249	21,051.4	84.54
Kimble	190	12,059.7	63.47
Mason	13	356	27.38
Medina	39	95,196.84	2,440.94
Real	96	9,022.91	93.99
Travis	250	974,079.327	3,896.32
Uvalde	53	10,412.4	196.46
Total Allocated	**1,695**	**3,349,814.02**	**1,976.29**
Average Per County	**99.71**	**197,047.88**	-

TABLE 16: WATER QUANTITY ALLOCATED BY COUNTY

Progress in Water Availability

We can surmise how much water is diverted from surface water sources and estimate the amount of groundwater drawn up from aquifer systems in the Hill Country. Determining the total amount of groundwater available in the Trinity, Edwards-Trinity Plateau, and the Carrizo-Wilcox Aquifer is still something to be determined. Through data collection regarding groundwater

conditions in this region, more appropriate withdraw amounts can be applied to the Texas Hill Country. With the sensitivity of our water situation at top priority, and central Texas populations increasing, precise measurements of our groundwater availability is a helpful tool in allocating resources and implementing conservation methods. In addition, surface water flows and quality is interconnected with many of Texas aquifers, and providing healthy hydrologic systems require a comprehensive approach (Texas Water Development Board 2013).

Many appropriate methods in producing an estimated total volume of our aquifers have been attempted, and the TWDB has led the way in providing accurate data for water quantity throughout the state. Currently, the TWDB is producing a detailed report on the Total Estimated Recoverable Storage (TERS) of the major and minor aquifers throughout the state. These reports provide information per Groundwater Management Area (GMA) to give regional specific information throughout the state. Though specific TERS reports for the GMAs within the Hill Country have yet to be released, the data acquired will provide the Hill Country with appropriate resources using geologically adjusted hydrologic equations. Full aquifer assessments for GMA 9, and the Hill Country’s Trinity, Edwards and Carrizo Wilcox Aquifers will be completed and available on the TWDB and provide us with further information on the methods used in estimating current groundwater conditions.

The equation used for this model assumes total storage of an aquifer as defined by the volume of groundwater removed by pumping till completely drained, while TERS is the measurement of volume to be recovered between 25 and 75% of porosity-adjusted aquifer volume (TWDB).

Specific aquifer characteristics are defined and calculated based on confined and unconfined geological basis. A confined aquifer has two geologically units of low permeability binding the top and bottom causing heightened pressure within the well, providing water level above the top of the aquifer (TWDB).

EQUATION 1: CONFINED AQUIFER PERMEABILITY AND TOTAL STORAGE

$$Total\ Storage\ = V_{confined} + Vdrained$$

$$V_{confined} = Area \times [S \times (Water\ Level - Top)]$$

Or

$$V_{confined} = Area \times [S_s \times (\mathrm{Top} - \mathrm{Bottom}) \times (Water\ Level - Top)]$$

An unconfined aquifer, experiencing no outside pressure, will have a water level equal to the aquifer level (TWDB).

EQUATION 2: TOTAL STORAGE OF AN UNCONFINED AQUIFER

$$Total\ Storage\ = V_{drained} = Area \times S_y \times (Water\ Level - Bottom)$$

$$V_{drained} = Area \times [S_y \times (Top - Bottom)]$$

$V_{drained}$ = storage volume due to water draining from the formation (acre-feet)

$V_{confined}$ = storage volume due to elastic properties of the aquifer and water (acre-feet)

Area = area of aquifer (acre)

Water Level = groundwater elevation (feet above mean sea level)

Top = elevation of aquifer top (feet above mean sea level)

Bottom = elevation of aquifer bottom (feet above mean sea level)

S_y = specific yield (no units)

S_s = specific storage (1/feet)

S = storativity or storage coefficient (no units)

(Texas Water Development Board 2013)

Understanding the TERS for GMA 9 will give the mysterious groundwater system of aquifers shape and allow for a better understanding of carrying capacity for the Hill Country region. Once this information is available for GMA 9, improved methods for aquifer protection and storage recovery may also be developed.

Appendix 3: Case Studies of Flood Events in the Hill Country

Rural Flooding:

The 1978 flood of the upper Guadalupe River was a catastrophic event brought on by tropical storm Amelia. This storm came while the area was in one of the most severe droughts in 20 years. Not until the end of July, when tropical storm Amelia formed, did the dry conditions deteriorate. As the storm crossed the Balcones Escarpment near San Antonio, it began producing extremely heavy rains (Baker 2012). The slow-moving storm produced rains exceeded 10 inches in 48 to 72 hours across a large area of Central Texas. Rains near Medina and Bandera County set the U. S. 3-day rainfall record of more than 48 inches (Hansen 1979).

In Kendall County, water level rose to nearly 41 feet and the peak discharge was 240 cubic feet per second in the 838 square mile drainage basin (Baker 2012). The U. S. Highway 281 Bridge was flooded (even though it stands 59 feet above the stream bed) and near Spring Branch, Comal County, where the contributing drainage area is 1,315 square miles, stage height was greater than 45 feet (Baker 2012). However, discharge in this reach had attenuated to 158.000 cubic feet per second (158,000 cubic feet per second is substantially greater than mean discharge of the Nile at its mouth with 1/1000th of the Nile's watershed). The Amelia flood was only the third largest recorded at the Spring Branch station. The highest stage, observed in 1869, was approximately 53 feet (Baker 2012).

Damage resulting from the Amelia flood was enormous. In Central Texas, 25 people were killed, 150 were injured, and 50 million dollars in property losses were sustained (Bomar 1979). All flood waters in the upper Guadalupe River watershed were contained by Canyon Lake reservoir in Comal County providing downstream residents with a limited risk of flooding. As a result, lake levels increased by 226,200 acre-feet or approximately 74 billion gallons (Schroeder 1979). Geomorphic effects of the flood were pronounced. De-vegetation, channel and flood-plain scour, large-scale deposition, modification of channel form, and temporary avulsion of meanders were common (Baker 2012). Along both the Guadalupe and Medina Rivers, an estimated 62 to 92% reduction of tree-crown cover in some reaches of the Medina. Effects of high-magnitude, low-frequency floods are much greater and more enduring in the bedrock-channel streams of Central Texas than in fine-grained alluvial channels of humid regions (Baker 2012).

Urban Flooding:

A specific example of the complexity of urban flooding is seen in the “Memorial Day” flood in 1981. Urban flooding often results from failure of drainage systems on top of excessive rains (Baker 2012). Heavy rains began falling and within a few hours 8 to 10 inches of rain had covered much of Austin. Severe flooding resulted in parts of the city and worsened conditions but substantial rains causing increased soil saturation the day before (Moore 1982).

A characteristic cause of urban flooding can also be associated with high percentage of impervious land which reduces further the potential soil infiltration. A remarkable aspect of the 1981 storm was the concentration of moisture in small, relatively stationary cells. The rains in the 1981 storm were produced in small, concentrated cells causing small drainage basins to be overwhelmed, producing massive flooding (Baker 2012). A large amount of the flooding resulted in a concentration of the storm in the upper reaches of the Walnut Creek watershed. The small watershed consisted of areas of residential and small commercial development with 25 to perhaps 50% impervious cover (U.R.S. 1977).

Some areas reached water levels of19.5 feet corresponding to 15,000 cubic feet per second discharge from a drainage area of 12.6 square miles (Massey 1982). Numerous homes and buildings were damaged by rising water and at Waters Park Road, just upstream from Burnet Road a few commercial buildings on the flood plain were completely destroyed or badly damaged (Baker 2012). One small manufacturing plant was submerged by more than 15 feet of very rapidly moving water. The flood waters were so strong they transported heavy industrial equipment more than one mile downstream (Baker 2012).

The Rural versus Urban Flooding Policy Dichotomy:

In House Bill 1018 in 1999, The Texas Legislature passed requirements that all counties and other jurisdictions in the state must develop minimum requirements of the NFIP (National Flood Insurance Program). Each participating jurisdiction must develop and maintain ordinances that regulate development within a 100-year floodplain identified by FEMA flood maps (Guadalupe-Blanco River Authority 1999). The obvious differences found in rural and urban environments during flood are associated with not only infrastructure challenges but access to appropriate resources. While it is expected that the severity of the floods may be magnified inside urban areas due to a higher concentration of impervious cover, the resiliency of the city’s infrastructure is much higher than that of rural areas.

Appendix 4: Hill Country TMDL and WPP case studies

Hill Country Case study: Cypress Creek Watershed Protection Plan

Description: The Cypress Creek WPP is sponsored by the TCEQ and administered through the Meadows Center for Water and the Environment. Located in the Guadalupe River Basin in Hays County, Cypress Creek in the Hill Country sits upon a fragile karst aquifer system. This region is currently experiencing large-scale population growth and with that, an increase in nonpoint source pollution such as fertilizer, pet and animal waste, oil grease, and human waste (The Meadows Center for Water and the Environment 2012). Established in 2008, this WPP contains two phases outlined in Figure 31.

Citizen Engagement: Obtaining water quality data and land use/land cover analysis only provide a portion of the environmental picture of a watershed. Stakeholder representation is essential to ensuring that concerns of the citizens living within the watershed are addressed. During Phase 1 of Cypress Creek WPP development, a team of water resource specialists from The Meadows Center for Water and Environment identified a list of 20 individuals from the community with a variety of backgrounds and expertise to form the Cypress Watershed Committee. These members then received about the general state and health of Cypress Creek and listened to the concerns of various stakeholders regarding watershed protection.

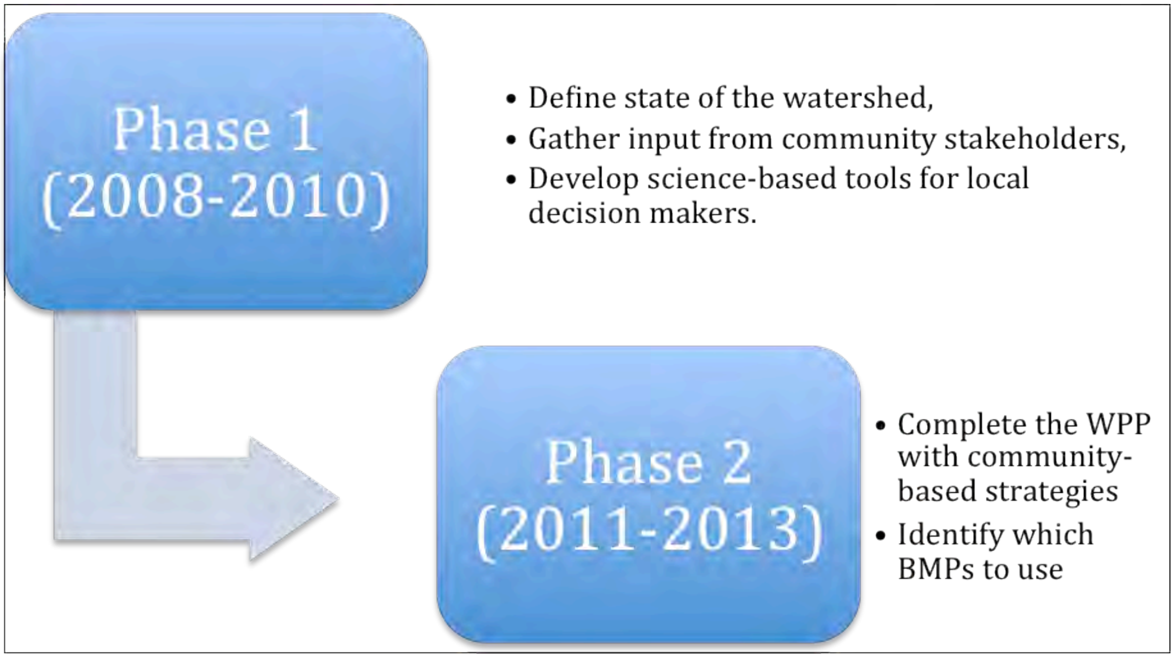

FIGURE 30: CYPRESS CREEK WPP PHASES 1&2 (THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT 2012)

During Phase 2 of the WPP implementation and planning process, smaller committees were formed and tasked with focusing their efforts into three areas of strategy: 1) education & outreach, 2) technical strategies, and 3) implementation strategies. Each committee received assistance from a facilitator from Texas Stream Team – a subprogram of The Meadows Center for Water and the Environment. The general purpose of this was to effectively give ownership of program development to the stakeholders while still providing necessary expertise, advice, and coordination.

Education and Outreach: Including stakeholders in every aspect of the WPP process is vital for ensuring program success and longevity. Texas Stream Team provided training in Water Quality Monitoring for *Citizen Scientists* in the community, Enviroscape, and biomonitoring educational events for educators and students. An important effect of this training is that community members can translate the science behind their observations during testing and watch data that community members collect “go live” through the Texas Stream Team Data Viewer.

These educational techniques help to remove the “mystery” behind scientific water analysis. Those who are trained as Trainers in Citizen Science can also pass that information along to peers, students, and other community stakeholders. This has been shown to increase the sphere of knowledge, maintain long-term Best Management Practices (BMPs), and keeps the community informed about the unique problems that exist within a local watershed. The Cypress Creek WPP is in the final year of BMP implementation, but the skills and training received by community members will remain in the community after the deadline has passed.

Involvement in Total Maximum Daily Loads

The Texas TMDL program is run through TCEQ Texas, there are 25 TMDLs established with approved Implementation Plans (I-Plans) or approval in progress (Texas Commission on Environmental Quality 2013) (Figure 19). During an assessment, if a stream segment is found to be in excess of the state maximum for a water pollutant, a TMDL will be implemented by the TCEQ. This means that employing methods of improvement is necessary under federal regulations outlined in section 319 of the CWA.

I-Plans for improving water quality and establishing a TMDL must include a public participation component. Like a WPP, citizen involvement increases the effectiveness of the I-Plan and increases the chance of program success.

Case Study: The Guadalupe River

In 2002, an assessment performed by TCEQ found segment 1806 of the Guadalupe River in Kerrville, Texas to be in excess of the state-approved standard for bacteria (Texas Commission on Environmental Quality 2013). The TCEQ contracted James Miertschin & Associates, Inc. as an administrator for the TMDL in Kendall County, TX. Project personnel identified potential sources of bacteria and provided their findings in a technical report to the TCEQ and stakeholders in the community.

Education and Outreach: Information, outreach documents, and educational materials about animal waste and *E. coli* from human sources provided community members with a general picture of where concentrations of bacteria existed within the segment. Texas Stream Team also provided training in bacteriology and citizen science so that community members are now able to

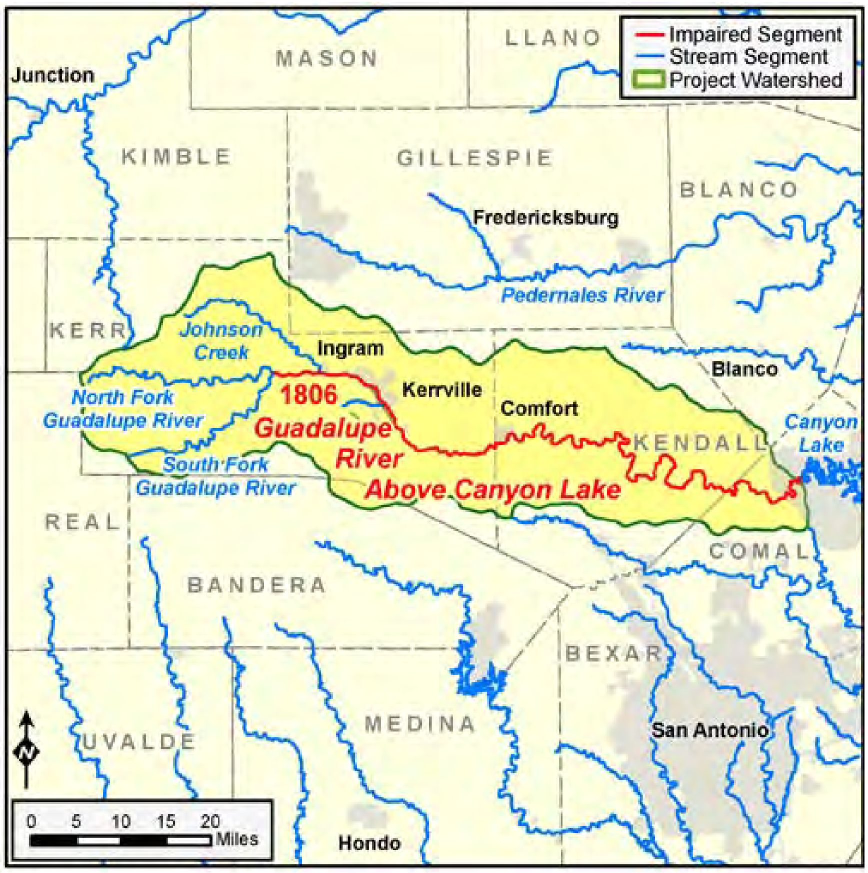

FIGURE 31: IMPAIRED STREAM SEGMENT 1806, GUADALUPE RIVER (TEXAS COMMISSION ON ENVIRONMENTAL QUALITY 2013)

collect data and identify areas with high bacteria counts. A partner in these efforts, the Upper Guadalupe River Authority, organized trash pick-ups and river clean-up days as an effort for adaptive management and community involvement. Infrastructural developments have also been made and stakeholders were encouraged to become involved with the I-Plan and TMDL process.