CHANGING PATTERNS OF WATER, ACCESS, AND PUBLIC DISCOURSE IN THE LOWER COLORADO RIVER VALLEY OF TEXAS, 1970-2015

by

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DEDICATION

To my two little "wonders," Louis and Forest, You gave me the courage to start this and the strength to finish it.

To my loving and supportive wife, Amanda, I couldn't have done this without you. You lived every moment of this journey with me, and during the high and low times, you remained calm and steady and supportive.

To my fellow environmentalist, Marsha Hill, I wish you were here;
you would've enjoyed this.

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After the print has been pressed and the ink has dried, the achievement contained herein will but diminish and whither with time as the words rest snuggly on a shelf next to other works that undoubtedly bear similar stains of sweat and blood. Others will judge whether the words that follow amount to anything, but to the author, the writer, the one who lived the journey, what follows is a victory. I did my best and that is all I could do. But I did not do it by myself. While the errors and omissions are solely my own, I could not have finished this task alone.

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LIST OF ABBREVIATIONS

Abbreviation	Description
amsl	Above Mean Sea Level
cfs	Cubic Feet per Second
CPM	Change Point Model
cwt	Hundredweight (i.e., 100 lbs.)
EAA	Edwards Aquifer Authority
FSA	Farm Service Administration
FIN	Freshwater Inflows
LCRA	Lower Colorado River Authority
NASS	National Agricultural Statistics Service
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
PCPI	Per Capita Personal Income
SAWS	San Antonio Water System
SPI	Standard Precipitation Index
STPEGS	South Texas Project Electric Generating Station
TASS	Texas Agricultural Statistics Service
TCEQ	Texas Commission on Environmental Quality

TVA	Tennessee Valley Authority
TWDB	Texas Water Development Board
TTWP	Trans-Texas Water Program
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

ABSTRACT

This mixed-methods study analyzes changes in water, access, and public discourse in the lower Colorado River valley of Texas from 1970 to 2015. The waters of the lower Colorado River have sustained urban populations and agricultural operations for over a century. Yet, recent, rapid urban growth and a changing climate have led to the prioritization of urban water uses over agricultural water uses. Public discourses, captured by the news media, have documented the mechanisms urban and agricultural water interests have used to maintain, acquire, or control its water resources. Therefore, the purpose of this research is to examine the spatial and temporal patterns of water use and access between urban and agricultural interests, to identify periods of change in water use and access among urban and agricultural water interests, and to analyze the mechanisms that urban and agricultural water interests used to enable or constrain water access. My findings suggest that social, political, economic, and environmental conditions influence who gets water, when, where, and for what purposes and that water use and access has evolved through three distinct periods of change. Urban interests have increasingly expanded their influence in decisions related to water distribution and access by entering into strategic alliances with the regional water authority and by leveraging the power of local and state officials in water matters. Agricultural interests, however, have struggled to maintain access to their historic share of water despite forming new social ties and outlining water's economic importance.

1 INTRODUCTION

Driven by continued population growth, commitments to sustaining economic development, and a changing climate, competition for water resources is intensifying across the world (Molle, Wester, and Hirsch 2007; Hellegers and Leflaive 2015; OECD 2015). Competing interests vying for dwindling water resources are testing the institutions, infrastructure, and policies that govern water allocation. In many developed nations, traditional water resources allocation systems – a number of which were created over a century ago – are ill-equipped to respond to additional demands and increases in water-related hazards, such as drought and floods (Hellegers and Leflaive 2015; OECD 2015). Many water allocation systems are gradually transferring water from uses of low economic return to those that produce high economic return. Much of these transfers have moved water from agricultural uses to industrial and urban uses (Howe 1998; Molle and Berkoff 2009). Reallocation of agricultural water, however, is frequently contentious (Celio and Giordano 2007; Celio, Scott, and Giordano 2010; Birkenholtz 2016), and conflicts over access to water resources have emerged as allocation systems struggle to balance urban and agricultural needs with environmental and economic needs (Molle, Wester, and Hirsch 2007). These trends are expected to extend into the near future especially in water stressed regions (Molle, Wester, and Hirsch 2007).

In the United States, water scarcity is high across large swaths of its central, southern, and western portions (Vörösmarty et al. 2000; Oki and Kanae 2006; Mekonnen and Hoekstra 2016). In these areas, approximately 130 million people experience severe water scarcity during a portion of the year (Mekonnen and Hoekstra 2016) as demands on many U.S. river basins approach the amount of freshwater available. In particular, consumptive water use in the Rio Grande and lower Colorado river basins is one-half of the total renewable supply, and in the California, Great Basin, Missouri Basin and Texas Gulf regions, consumptive water use is between 20 and 40 percent of the renewable supply (Dziegielewski and Kiefer 2007). These U.S. regions historically supported irrigated agricultural crop production – and many still do. Yet, during times of scarcity, water allocation systems in these regions have struggled to meet the demands of all users, and conflicts have emerged as growing urban areas compete with agricultural interests. Many of the conflicts have emerged because of rigid allocation systems that continue to operate under rules and regulations created under a pro-water development ideology that began over a century ago. Therefore, the purpose of this dissertation is to examine the changing relationship between urban and agricultural water users in a highly-developed watershed in the United States undergoing increasing urban expansion and experiencing chronic, acute periods of drought.

1.1 Water resources development and management

Over the past century, the development of water resources in the United States has varied based on location, water abundance and scarcity, and related goals. In the eastern United States, water developers manipulated rivers primarily to aid regional commerce by facilitating the transport of goods down rivers or through locks and canals and by creating power for manufacturing processes. In the U.S. Midwest and West, water developers constructed dams and reservoirs to prevent floods, protect scarce water resources, and provide water for agricultural operations (Doyle 2012). During this same time, water resources management in the United States has typically taken one of two forms. First, under supply-side management, water managers secure and develop water resources to bolster supply. The goal of supply side management is to continually develop water resources in order to meet growing user demand. Building dams to store water and constructing irrigation systems for agricultural use achieve these development goals. The second management practice, demand-side management, focuses on managing demand through efficient use of available water. Under demand side management, water managers distribute water resources based upon the need of users relative to the available water supply. In many cases, water managers rely on water markets, as well as water management plans and future projections, to allocate water across different users, and increasingly, demand-side management attempts to balance ecosystem health with economic needs. These development and management approaches along with their primary goals have shaped control over and access to water resources in the United States.

The ownership, development, and management of water resources in the United States and among many developed countries has vacillated between public and private interests (Bakker 2002). In general, early development and management of water resources in the 1800s was initiated by private entities under *laissez-faire* capitalism (Gumprecht 2001; Armstrong, Evenden, and Nelles 2014). Often, under this scheme, private companies delivered water to more affluent areas, resulting in an uneven distribution of water across populations. In other words, those with greater wealth and political power received water, whereas those that occupied lower socioeconomic statuses did not receive water. A shift began to occur in the 1900s to public control over water resources as progressive ideals gave way to the implementation of greater market controls and as an interest emerged in steering the U.S. economy towards greater social welfare (White 1995). The control, development, and management of water resources, underscored by Keynesian economics, resulted in the provision of water in a more equitable manner across socioeconomic levels under public control (Bakker 2002). During this time, water development efforts focused on increasing water supply, particularly in arid and semi-arid regions of the United States, as the country's population grew and spread westward (Worster 1985).

For much of the early to mid-20th century, water management continued to center on supply development. Public water utilities and large federal projects sought to exploit water resources for the purposes of economic growth (Worster 1985; Pisani 1992). Water resources development focused on improving navigation, developing hydropower electric power, controlling floods, and irrigating agriculture (often in combination) (see, for example, Molle 2009; Hooper 2011). At this time, water development and management was influenced by three interconnected ideas: 1) the multiple-purpose storage project, 2) the basin-wide program, and 3) comprehensive regional development (White 1957).

Under the multi-purpose storage project, water developers built dams to store water for various means, including irrigation, municipal water supply, hydroelectric power, flood control, improved navigation, and recreation. The basin-wide program stressed development of all available water resources in the watershed. In the case of comprehensive regional development, regional urban planners and water managers assumed that economic growth and development would coincide with public investment undertaken in federal dam projects and associated infrastructure development. For example, the development of water resources along the Columbia River paralleled plans to develop urban settlements. These new urban settlements would use the newly generated hydroelectric power achieved through dam projects along the river (White 1995).

Supply side management, however, came with extraordinarily high environmental and social costs. Over 75,000 dams fragment river systems across the United States, adversely affecting important hydrologic and ecological processes (Graf 1999). Dam projects across the United States have interrupted migrating fish patterns, depleting their natural stocks, and disrupted natural ecosystems, holding back vital sediment transport. The construction of vast reservoirs has forced many communities to relocate elsewhere (Scarpino 1985; White 1995; Evenden 2004). Dam projects have also limited American Indian communities' access to sacred tribal sites and ancestral fishing and hunting grounds (White 1995).

A move to an integrated water management strategy came about in the early 1970s, during the environmental movement, as water resource development subsided (Cech 2010). The focus of this strategy centered less on building water supply capacity and more on managing increasing water demands in closing or closed river basins. Demand side management in general and integrated water management more specifically sought to balance growing human water demand with increasing recognition of the importance of water for the healthy functioning of environmental systems. There have been three primary approaches to river basin development and management in the United States since the 1930s (Table 1). Yet, despite the push to embrace a more integrated, holistic river management system, governance of water resources on a basin-wide scale has proven problematic and attempts have had mixed success overcoming a range of physical, political, and social influences (Vogel 2015).

Table 1. Historical approaches to water management (White 1957; Molle 2009; Hooper 2011).

Management approach	Time period	System view	Goal	Allocation	Focus
Hydrocentric or single-sector (supply oriented)	1930s to 1960s	Physical system consisting of hydrological and geomorphological characteristics	Economic development	Maximize available yield for the most effective distribution among users	Single use, e.g., hydropower
Multi-purpose (supply oriented)	1930s to 1960s	Physical system consisting of hydrological and geomorphological characteristics	Economic development and flood control	Maximize available yield for the most effective distribution among users	Multiple uses, e.g., recreation, hydropower, navigation, and irrigation
Ecosystem or integrated (demand oriented)	1970s to present	Integrated ecological system with social and environmental interconnections	Healthy ecosystem functioning	Equitable distribution across human and non-human users	Multiple uses, e.g., recreation, hydropower, navigation, irrigation, and environmental

Throughout the development of water resources in the United States, water governance institutions have held an enormous amount of regulatory authority and administrative power in which to execute important decisions related to the use and distribution of water resources. Their recommendations, decisions, and policies have played a principal role in determining how water is distributed across many competing demands.

1.2 Water allocation among competing demands

A number of water users – from urban to industrial to agricultural to environmental – compete for water resources at the basin scale (Table 2). Water allocation involves the distribution of available water across these multiple demands in a way that manages the risk of shortage and adjudicates between competing uses (OECD 2015, 13). An allocation system provides the framework that guides decision-making processes related to the distribution of water across users. It consists of a combination of policies, laws, and mechanisms, as well as the institutions, arrangements, and infrastructure, used to circulate available freshwater resources and dictate who gets water, when, where, and for what purposes (Hellegers and Leflaive 2015; OECD 2015).

Table 2. Water demands, objectives, and effects (Dunne and Leopold 2002 [1978]; Gupta 2008; Cech 2010).

Water demands			***Objectives***	***Effects***
Municipal and industrial	Municipal	Domestic	Drinking, cooking, washing, watering, and air conditioning	Pollutes surface water and groundwater and removes some water from the river system
		Public	Public facilities and for fire fighting	
		Commercial	Shopping centers, hotels, and laundries	
		Industry (small; from public supplies)	Manufacturing and production	
		Distribution losses		
	Industry (large; self-supplied)		Manufacturing and production, e.g., thermal power, steel, paper, chemicals, textiles, and petroleum refining	
	Waste treatment and dilution		Treat, dilute, and purify municipal and industrial wastes	
Agriculture	Irrigation		Crop production	Adds nutrients, sediment, and agricultural chemicals to surface water and groundwater, and removes some water from the river system
	Livestock		Livestock production	
	Distribution losses and wasted water			
Hydropower	Power generation		Power production	Regulates river flow
Navigation	River regulation		Release upstream water to raise water depth	Retains water in system
	Lock-and-dam		Increase depth	
	Artificial canalization		Create or connect channels with ship locks	

Table 2. Continued.

Water demands		*Objectives*	*Effects*
Other	Flood storage	Flood control	Prevents downstream floods
	Recreation	Swimming, fishing, and other recreation activities	Retains water in system
	Water export	Water diversion for municipal, industrial, and commercial uses	Removes water from system
	Ecological functions	Maintain ecosystems	Retains water in system

In general, the primary goal of an allocation system is to distribute water resources equitably across the range of competing water demands according to plans outlined and agreed upon by water users (Gupta 2008). In practice, water allocation, and by extension water resources management, however, does not always achieve a fair distribution among competing demands (Swyngedouw 2004; Bakker 2007; Loftus 2012). Instead, a host of social, economic, political, legal, and environmental factors that varies and changes both across space and time influence water allocation decisions (Swyngedouw 1999; Norman and Bakker 2009; Brooks and Linton 2011; Jepson 2012).

Water varies both spatially and temporally due to its physical aspects, its fluidity, and its mobility, which subvert human attempts to govern and control it. The natural processes of the hydrologic cycle and environmental phenomena that affect water supply have been leveraged as opportunities to adjust the policies concerning the distribution of, access to, and control over water resources (Bakker 2000; Kaika 2003). Extreme natural events, such as drought and floods, have been used to amend existing water allocation systems, often with a disproportionate impact across society (Bakker 2000). Scientific knowledge also has been used to strengthen water allocation decisions, creating uneven patterns of water distribution among users (Budds 2009). In developing regions of the world, water allocation systems regularly bias urban uses, resulting in an unequal distribution of water resources between urban and rural areas (Swyngedouw 1997; Bakker 2003a; Swyngedouw 2004; Scott and Pablos 2011; Bell 2015). In many agricultural-producing regions the United States, however, farmers have received the majority of water historically (Molle and Berkoff 2009). Yet, this trend is changing in the United States as growing urban areas now increasingly compete with agricultural interests for control of available water supplies.

In order to understand how, when, where, and under what circumstances water allocation systems have begun to prioritize urban interests ahead of agricultural interests, my dissertation research documents decades of change in the consumption and control of water resources within a semi-arid, rapidly-urbanizing watershed prone to recurring droughts and floods. Specifically, I examine the changing relationship between long-established, commercial agricultural water users in the lower Colorado River valley of Texas and the recent competing water demands of one of North America's fastest growing urban areas. A series of water allocation decisions brought on by recurring droughts and a growing urban population have fractured an otherwise equitable relationship among urban and agricultural water users in the valley. More recently, this relationship has become increasingly strained during a prolonged drought in the area.

I examine the relationship between urban and agricultural water users in the valley using a mixed-methods research design. First, I documented spatial and temporal patterns of water use, defined periods of change in water use, and analyzed the environmental discourses and counter-discourses that urban and agricultural interests use to either control, maintain, or acquire access to the basin's water resources. In this way, this study offers an environmental geography of competition for finite water resources in a rapidly urbanizing region.

1.3 Problem statement, purpose statement, and research questions

In 2015, the Texas Commission on Environmental Quality (TCEQ) approved the Lower Colorado River Authority's (LCRA) recommendation to extend an emergency order withholding water from downstream farming communities for the fourth year in a row. Many southeastern Texas coastal areas depend on the annual water releases for agricultural irrigation and crop production, particularly rice farmers. Complicated by a host of factors, including a prolonged drought, growing urban water demand, and a complex state water law, the decisions to withhold downstream water flows drew the attention of many interested stakeholders. These stakeholders included urban and agricultural actors, local and national environmental and conservation organizations, and governmental agencies who advocated both for and against the LCRA's recommendations. This was the first time since the creation of the LCRA in 1934 that water had been restricted to downstream consumers.

Debated in public and private forums and picked up by the media and other public information outlets, many narratives around this restriction developed as stakeholders sought to sway popular opinion in favor of their interests. This restriction and set of accompanying narratives, however, are only the latest iteration in a series of events that illustrate the evolving interests of stakeholders in the allocation of water resources along the lower Colorado River. Numerous social, political, economic, and environmental actors and events have influenced access to and control over surface water resources in the basin.

The purpose of this dissertation is to provide an environmental geography of water resource use and access along an urban-to-agricultural gradient in the lower Colorado River valley, to identify periods of change that led to the prioritization of urban water uses over agricultural water uses, and to analyze discursive systems used to enable or constrain water access during periods of change. Throughout the dissertation, my analyses examine the complex relationship between a major urban area and its wider influence on the basin's water allocation system and how this relationship affects spatial and temporal outcomes of water use and access in both urban and agricultural portions of the watershed. In doing so, I give particular attention to how "natural processes that are larger than an urban system instigate varied human responses" in water management (Colten 2012, 203). As such, this research answers the following questions:

1. What temporal trends and spatial patterns occur in water use and access among urban and agricultural interests in the lower Colorado River valley of Texas from 1970 to 2015?
2. In what years do significant changes occur in water use and access among urban and agricultural interests, and what do these changes reveal about water use and access between urban and agricultural interests?
3. What distinctive periods of water use and access develop in public discourses, and through public discourses, how do urban and agricultural interests enable or constrain access to the water resources of the lower Colorado River given the underlying, changing social, political, economic, and environmental conditions?

In order to accomplish my research goals and answer my research questions, I employ a mixed-methods research design that 1) quantifies spatial and temporal patterns of water use and access in the lower Colorado River valley and 2) analyzes discourses and counter-discourses that urban and agricultural interests use to enable or constrain access to water during periods of social, political, economic, and environmental change. Together, my research methods provide a more comprehensive picture of how water use and access has evolved in the lower Colorado River valley from 1970 to 2015 with a particular focus on the relationship between two primary water users in the basin: urban and agricultural water interests.

My study provides an understanding of how water allocation systems develop, evolve, and persist; how these systems affect the spatial distribution of water resources; and how changes in these systems influence access. I describe the recent progression of surface water resource control in the river valley. Specifically, I compile annual time series data sets of variables on or related to water use in the valley. I use these data sets to identify changes in water use and access among urban and agricultural interests during the study period. Next, I use the results to define periods of change in water use and access between urban and agricultural interests. I use these periods to begin an analysis of public discourses presented in news media coverage of basin water issues. Specifically, I locate, identify, and code discourses within newspaper articles covering issues on or related to water use in the lower Colorado River basin. Then, I identify the underlying political, social, economic, and environmental conditions that affect the distribution of water in the valley. I merge the results of both the quantitative and qualitative analyses to define periods when the relationship between urban and agricultural water interests have changed. Finally, I document the mechanisms agricultural and urban water interests use to constrain or enable access to the basin's water resources within these periods.

Few studies have documented the social, political, economic, and environmental currents underlying the transfer of water from agricultural uses to urban uses, the spatiotemporal patterns associated with this shift, and the mechanisms used to control, maintain, or acquire water resources. Those that have explored water appropriation from agricultural uses to urban uses have done so in developing regions of the world (Celio and Giordano 2007; Molle, Hoogesteger, and Mamanpoush 2008; Celio, Scott, and Giordano 2010; Birkenholtz 2016) and the American West (Howe, Lazo, and Weber 1990; Moore, Mulville, and Weinberg 1996; Villarejo 1996). This research, situated in the Southwestern United States, provides additional information on the movement of water from agricultural uses to meet growing urban demand. Specifically, the results of this dissertation research highlight the geographic patterns and processes related to water use in the lower Colorado River valley of Texas while illuminating the effects of a rapidly-expanding urban region on traditional agricultural water use. The results also identify the primary mechanisms that urban and agricultural interests use to constrain or enable access to the valley's water resources at particular influential moments. Together, the results reveal a larger environmental geography of water use, access, and control in the river basin from 1970 to 2015. My study also uses a replicable method to identify changes in the relationship among urban and agricultural water interests and to locate alterations in water use and access between the two interests. In this way, the mixed-methods approach adopted here provides a way to monitor trends in water usage and access across a number of variables in an effort to stabilize changes that may harm one or more water interests. These contributions have the potential to inform both theoretical research related to water resources access and control as well as practitioners responsible for water resource allocation in urbanizing regions.

1.4 Theoretical framework

This dissertation research draws heavily on the theorization of socio-natural "hybrids" as developed by Latour (1993) and advanced by scholars examining the interconnectedness of water and society. It also draws on Ribot and Peluso's (2003) “theory of access.” In this section, I expand on the notion of socio-natural hybrids and explain how they influence this research. I end the section with a description of a “theory of access,” and how I use it within the context of my dissertation.

Latour’s formulation of socio-natural “hybrids” has provided many human-environment researchers with a theoretical framework in which to breakdown the normative nature/society binary (e.g., where nature is deemed different and separate from humans). His theorizations have been used to synthesize and excavate processes at work in the production of multidimensional environmental issues (see, for example, Swyngedouw 1999). Latour (1993) explained that society and nature work on two distinct ontological levels: 1) non-human things and 2) human things. He suggested that the existing society-nature dualism is the creation of modern science, where, through an act of “purification,” objects are divided between categories of nature (i.e., non-human things) and society (i.e., human things). Working to subvert the modern scientific division between the subjects of society and the objects of nature, Latour (1993) suggested that “objects” or “things” are a mixture of both society and nature, which he called “hybrids.” In other words, the physical material processes of nature and social discursive constructions of nature formulated and evident in political, social, and economic systems are not separate processes but together produce and reproduce nature.

The use of socio-natural “hybrids” has been operationalized in research on water resources. Scholars have traced the connections made between the material realm of water and social systems, while observing hybridity of water as an “intermediar[y] that embod[ies] and express[es] nature *and* society….” (Swyngedouw 1999, 445, emphasis in original). Moreover, drawing from Latour’s (1993) modernization theory and

Swyngedouw's (see, for example, 1997; 2004) work on the hybridity of water resources, scholars have suggested that in its present form the hydrologic cycle neglects or overlooks the human dimensions of water and instead focuses on water as a physical substance distinct and disconnected from social systems. Yet, the hydrologic cycle is a construction of scientific practice, and as such, it represents one understanding of water based on a particular set of historical and geographical conditions in which it was developed (Linton 2008), and it effectively separates water from the human dimension through Latour's process of purification.

Humans, however, over the course of history have modified the hydrologic cycle in a variety of ways (e.g., irrigation systems and dams) that have thoroughly intertwined water and society. As such, "water is a "hybrid" thing that captures and embodies processes that are simultaneously material, discursive, and symbolic" (Swyngedouw 2004, 28). In other words, water moves not only through a material dimension but also through social, political, and economic dimensions forming a dialectal relationship between society and nature, where water changes society, and society, in turn, changes water. Thus, the movement of water between human and non-human dimensions produces a socio-natural object via:

> interrelated tales, or stories, of social groups and classes and the powerful socioecological processes that produce social spaces of privilege and exclusion, of participation and marginality; chemical, physical, and biological reactions and transformations, the global hydrological cycle, and global warming; capital, machinations, and the strategies and knowledges of dam builders, urban land developers, and engineers; the passage from river to urban reservoir, and the geopolitical struggles between regions and nations (Swyngedouw 1999, 446).

The hybridity of water is constituted in a complex mix of political, economic, social, environmental, technical, and discursive processes where nature is socially constructed yet also given agency (Figure 1).

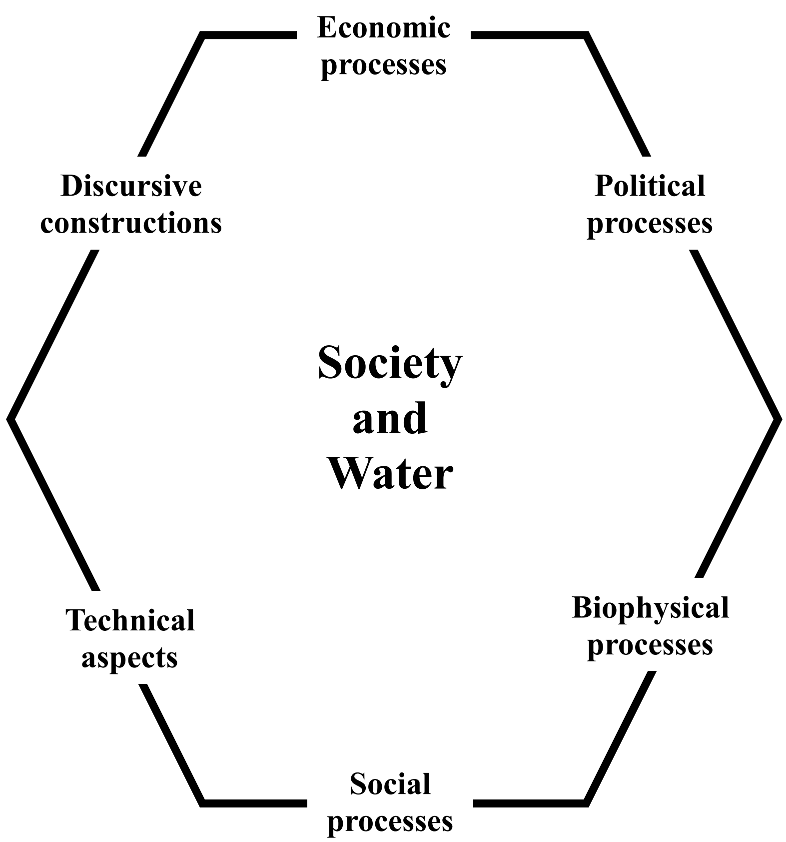

Figure 1. Mix of political, economic, social, environmental, technical, and discursive processes constituting the society-water relationship (after Swyngedouw 2004).

The other theoretical framework that I draw from in this dissertation is a "theory of access" (Ribot and Peluso 2003). Specifically, I use this theory to operationalize water as a hybrid thing to illustrate the wider relationship between the social, political, economic, and environmental processes found in discursive systems that have shaped access to the lower Colorado River valley's water resources. Access, as reflected in this dissertation research, refers to “the ability to derive benefits from [resources]” through an examination of the full “range of social relationships that can constrain or enable people to benefit from resources…” (Ribot and Peluso 2003, 153-154). In this understanding, access to resources is constituted within a political-economic framework where a variety of mechanisms support or prohibit the control, maintenance, and acquisition of access. It is through these mechanisms that access to resources is blocked, granted, or gained. In addition, access to resources is mediated through traditional rights-based or legal access. These mechanisms are used to support or deny access claims based on laws or societal norms. A host of other structural and relational mechanisms facilitates the ability to derive benefits from resources, including “access to technology, capital, markets, labor, knowledge, authority, identity, and social relations” (Ribot and Peluso 2003, 173). For the purposes of this study, I include physical processes (i.e., environmental stress) as an additional access mechanism that mediates an individual’s or groups’ ability to derive benefits from water (Figure 2).

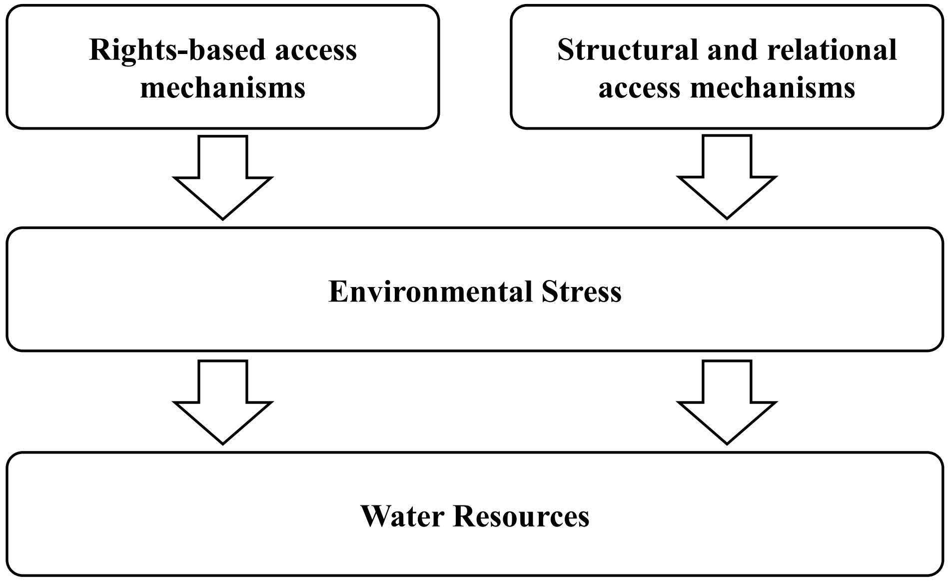

Figure 2. Theoretical model representing control and access to water resources (after Ribot and Peluso 2003).

Given that the distribution – and contestation – of essential, vital environmental resources, including water, is contingent on historical, political, and economic systems, among others, access to water resources is often determined by the positionality of an individual, group, or community within the wider operations of these systems. Those with access control the allocation of resources to other individuals, groups, or communities. For example, those seeking to maintain access to resources "often transfer some benefits to those who control it" (Ribot and Peluso 2003, 159). Through this process, some groups' or individuals' knowledge is privileged, whereas others' claims are marginalized and excluded. The specific relations of power that develop are often produced and reproduced through an environmental discourse that works to give preference for one set of beliefs over others (Bakker 2002; Budds 2009; Linton and Budds 2014). These discourses change over time and are highly influenced by regional history and geography – both human and physical.

A number of scholars have employed Ribot and Peluso's (2003) framework to understand the complex processes behind resource access. Scholars have used this framework to explore access to natural resources, including water (Sultana 2011; Bell 2015) and forests (Kelly and Schmitz 2016). My research extends the framework by looking for narratives of access captured in public discourse. It also provides an extended view of the different access mechanisms two groups – urban and agricultural water interests – use to constrain or enable access to the basin's water resources under various political, social, economic, and environmental conditions.

Pulling from both of these theorizations, this dissertation examines the contemporary mix of political, economic, social, environmental, and discursive processes and their legacies in ongoing discourses advanced by urban and agricultural water users along Texas's lower Colorado River from 1970 to 2015. In other words, I view the waters of the lower Colorado River as a socio-natural, hybrid object. In doing so, I recognize that social, political, economic, and environmental conditions influence who gets water, when, where, and for what purposes. Consequently, the set of variables under analysis reflect, as much as they can, political, economic, social, and environmental dimensions of water use in the basin, and the public discourses evaluated reflect social responses (i.e., via identification of access mechanisms) to changes in the distribution and availability of water in the basin. Together, this research provides an example of water as material, discursive, and symbolic and emphasizes how water changes society and how society changes water.

2 REVIEW OF THE RELATED LITERATURE

The principle focus of this dissertation research is to understand how changes in social, political, economic, and environmental processes affect surface water use and allocation strategies and to explore the resulting patterns of water use and allocation that evolved over space and time in the lower Colorado River valley of Texas. As noted in the introduction, water allocation is the process of distributing available water resources to an array of competing users across a watershed (Molle, Wester, and Hirsch 2007; Gupta 2008; OECD 2015). An overall goal, then, of water allocation is the legal distribution of water resources among users; however, this goal remains difficult to achieve for a variety of reasons. Research has explored the extent to which urban-rural relations and social, political, economic, and environmental processes shape water use and allocation. The following literature review focuses broadly on the findings of research relative to water resources development, its use and allocation, and influences on and outcomes of water allocation. Specifically, I discuss research across three broad themes as they relate to the allocation of water resources: 1) models of human-water development; 2) water allocation and the urban-rural nexus; and 3) other prominent factors affecting water allocation. I end the literature review with a discussion of research on discourse and discursive systems and the utility of news media coverage in chronicling and shaping public discourse and as an important data source.

2.1 Models of human-water development

The relationship between humans and water is complicated and complex. Humans depend on water for a variety of uses. Over time, humans have developed river basins in accordance with their changing needs, values, and ideologies. The result of this development has led scholars to theorize about river basin development and to consider humanity's relationship with water and river networks. A thorough review of the relevant literature reveals how scholars have attempted to understand and make sense of the changing relationship between society and water. In the following section, I discuss models of river basin development and human-water relations. My dissertation research draws from these models in order to frame the development of water resources in the lower Colorado River valley and the relationship between its waters and the people that use it.

2.1.1 Conceptual models of river basin development

As noted in the introduction, the development of water resources has evolved over time to meet the changing goals of water users and water institutions. Water resource scholars have constructed a range of theoretical models and conceptual frameworks in order to illustrate river basin development over time and to provide continuity for river basin analyses. These models assume that the development of water resources follows a similar trajectory (or "natural progression") in most river basins: water is harnessed to meet increasing demands and eventually requires responses to growing water scarcity as the river basin closes (Keller, Keller, and Davids 1998).

Keller, Keller, and Davids (1998) modeled river basin development based on six developmental sub-phases nested within three broad phases of river basin development, which I detail below. In the first phase, efforts concentrate on the exploitation of water resources. Within this category, two sub-phases exist. The first sub-phase consists of direct surface diversion to meet domestic and agricultural demands. As water demand increases, the second sub-phase focuses on building storage and distributing water supplies across a growing number of users. As basin-wide resources are developed and water supplies become limited, river basin development switches to the conservation of water resources (the second development phase). Within this phase, demand reduction and water treatment and reclamation efforts attempt to conserve water supplies so that all demands may be met. As the river basin closes (i.e., consumptive water use approaches available supplies), development priorities shift to the augmentation of water resources (the final development phase). Here, water transfers and desalination of brackish water attempt to reallocate and create water in order to meet increasing water demands in the river basin (Keller, Keller, and Davids 1998).

A similar but slightly different model identified three phases of river basin development: 1) development, 2) utilization, and 3) allocation (Molden, Sakthivadivel, and Samad 2001). In the development phase, efforts are concentrated on building infrastructure to secure water supplies to meet demand. During the utilization phase, infrastructure development still occurs but management of water supplies, such as irrigation water and municipal water supplies, becomes a priority. As the basin closes and water depletion approaches the amount of available water, demand management takes precedence. In this phase, management strategies reallocate water from lower value to higher value uses, typically from agricultural use to urban use (Molden, Sakthivadivel, and Samad 2001).

Others have attempted to “develop a theoretical model that links natural resource scarcity (such as water), with the ‘adaptive capacity’ of a society, in the hope that this can contribute to a deeper understanding of the social dynamics of resource scarcity,” via a three phase framework of river basin development: 1) supply phase, 2) demand phase, and 3) adaptive phase (Turton 1999, 1). The supply phase is marked by the exploitation of water resources with a goal of increasing water supply. The demand phase is concerned with increasing efficiency and allocating water effectively. The adaptive phase seeks to adjust to water scarcity in an effort to achieve sustainable water use. These phases are similar to the other two conceptualizations discussed above. Yet, this model explicitly linked the social to the natural, where social responses (or adaptations to water scarcity) directly connect to changes in river basin water quantity (Turton 1999). Specifically, the model identifies linkages between the changing perceptions, policies, resource base, and makeup of societal elites and the changing river basin development phases (Turton 1999).

Still others have questioned the linear chronology of river basin development and sought to develop flexible models. One such model "hypothesized that societal responses to water scarcity comprise a set of strategies, defined both at the individual/community level and at the state level, and is elaborated or induced, based on several location-specific factors, without any other assumption about a possible "natural" order or sequencing" (Molle 2003, 10). In other words, societal responses to water scarcity are dependent on both the physical and social landscapes present within a river basin, as well as the historical transformation of the basin. This model revolves around three categories of responses to water scarcity: 1) supply responses, 2) conservation responses, and 3) allocation responses (Molle 2003). Each response has a range of options available at both the local and state scales. For example, supply responses consist of increasing current water supplies. At the state level, increases in water supply may be achieved via constructing new reservoirs. At the local level, agricultural communities, for instance, might drill new wells or create small farm ponds or tanks to store or collect excess water. Conservation responses attempt to increase efficiency of water use. Allocation responses involved in the transfer of water within or between sectors. Furthermore, each response is influenced via physical, economic, and social elements (Molle 2003). The specific development trajectory taken by a river basin results from the extent to which any of these three responses – whether at the local or state scale – are implemented or induced based on the various physical, economic, and social elements driving water allocation change in a river basin (Molle 2003).

The preceding models provide researchers with means for describing the complex process of river basin development over time and the influences of a variety factors that elicit a series of responses to increasing water scarcity, which in turn, ultimately change the allocation system. Figure 3 provides a general illustration of water resources development based on the models discussed above (see Walker 2014).

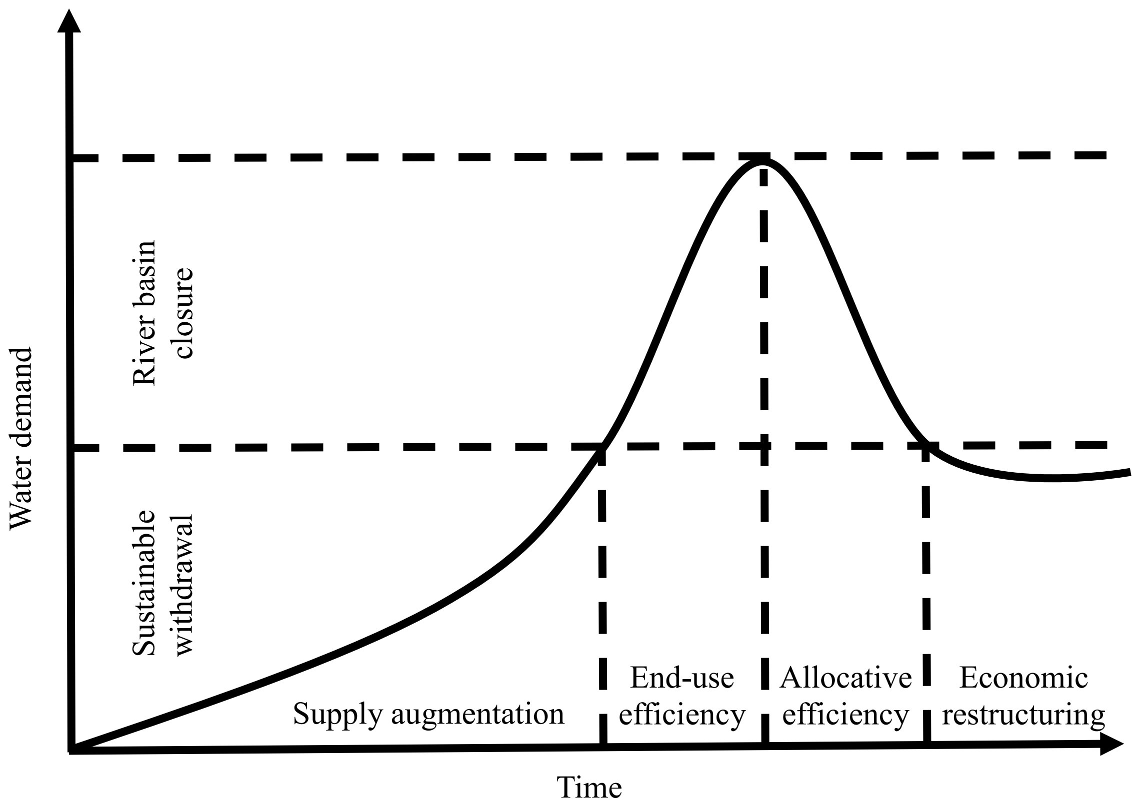

Figure 3. Conceptual model of river basin development and closure (after Walker 2014) due to water scarcity and overcommitting basin water resources (Molle, Wester, and Hirsch 2007).

2.1.2 Models of human-water relations

Some scholars have argued that "water is a 'hybrid' thing that captures and embodies processes that are simultaneously material, discursive, and symbolic" (Swyngedouw 2004, 28). Much of their argument seeks to counter and offer an alternative way of viewing water flows (see, for example, Bakker 2007; Linton 2008, 2010; Loftus 2011; Linton and Budds 2014). These scholars have suggested that viewing water movement via the hydrologic cycle neglects (or overlooks) the human dimensions of water and, instead, focuses on water as a purely physical substance distinct and disconnected from social systems. Yet, the hydrologic cycle, they argue, is a construction of scientific practice, and as such, it represents one understanding of water based on a particular set of historical and geographical conditions in which it was developed (Linton 2008).

Humans, however, over the course of history have modified the hydrologic cycle in a variety of ways (e.g., irrigation and dams) that have thoroughly intertwined water and society. As such, water moves not only through a material dimension but also through social, political, and economic dimensions forming a dialectal relationship between society and nature, where water changes society, and society, in turn, changes water. Thus, the movement of water between human and non-human dimensions produces a socio-natural object or "hybrid" thing (Bakker 2003a; Swyngedouw 2004). In other words, water constitutes a complex mix of political, economic, social, technical, and environmental processes where nature is socially constructed yet also maintains agency.

Viewing water and society as a hybrid, socio-natural thing has led scholars to explore how the materiality – the biophysical and ecological characteristics – of water "shape[s] human perceptions, discursive constructions, and responses to water" (Bakker 2012, 617). This has led to the formulation of the hydro-social cycle as a framework in which to explore water-society relations and as an alternative to the normative flow of water through the hydrologic cycle. The hydro-social cycle explores both "the social nature of [water] flows as well as the agential role played by water, while highlighting the dialectical and relational processes through which water and society interrelate" (Linton and Budds 2014, 170).

The hydro-social cycle when presented as a theoretical framework illustrates the water-society relationship as a dialectic, socio-natural process, where "H_2O" is distinct from "water" (Figure 4). This distinction helps differentiate the hydro-social cycle from the hydrologic cycle: "H_2O circulates through the hydrological cycle, water *as a resource* circulates through the hydro-social cycle – a complex network of pipes, water law, meters, quality standards, garden hoses, consumers, leaking taps, as well as rainfall, evaporation, and runoff" (Bakker 2002, 774, emphasis in original). Linton and Budds (2014, 175) further define the hydro-social cycle "as a socio-natural process by which water and society make and remake each other over space and time," and identify three "key ideas" in the hydro-social cycle.

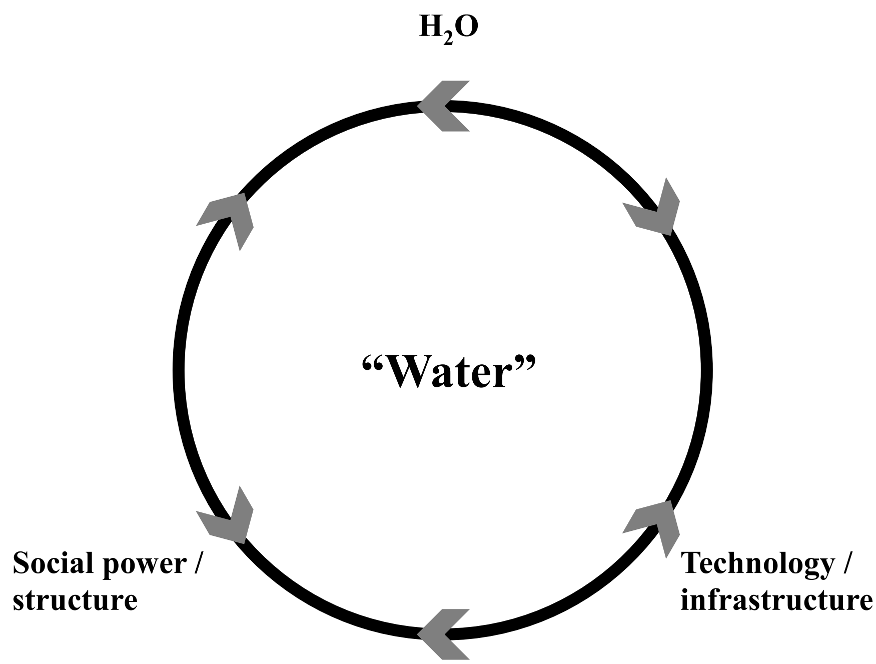

Figure 4. The hydro-social cycle (Linton and Budds 2014).

First, the relationship between society and water is cyclical. In other words, the "need to manage water has an important effect on the organization of society, which in turn, affects, the disposition of water, which gives rise to new forms of social organization and so on…" (Linton and Budds 2014, 175). Second, a series of internal relations mutually constitutes water and society. More specifically, different "social relation[s] produce different kinds of water, and vice versa" (Linton and Budds 2014, 175). Finally, water, as a material substance, "play[s] an active role in the hydro-social process, sometimes structuring social relations and sometimes disrupting them…" (Linton and Budds 2014, 175).

The hydro-social cycle is not unlike other conceptions of human-water relations as advanced by environmental historians beginning in the mid-1980s. For instance, environmental historians have authored histories that conceived of a dialectical relationship between nature and society, between rivers and humans. Specifically, early environmental histories on water suggested that societal interactions with water produce a distinct dialectical relationship, where humans change nature, and nature, in turn, changes humans. Worster (1985, 22), documenting the growth of the western United States through the evolution of increasing technological control over water, framed the dialectic between nature and society "as intertwined in an ongoing spiral of challenge-response-challenge, where neither nature nor humanity ever achieves absolute sovereign authority, but both continue to make and remake each other." Within this dialectical relationship, many outcomes are possible.

Others have extended Worster's challenge-response dialectic through studies of water development along the Columbia River (White 1995) and of the outcomes of irrigation practices in the Snake River Valley (Fiege 1999). White (1995) suggested that the Columbia River operates as an "organic machine," part artifice but still natural, brought into service of regional urban and industrial growth. Spurred by the beliefs (both scientific and technical) of Progressive Era thinkers, such as Lewis Mumford, and shaped by Emersonian values, water projects along the Columbia River were viewed as a necessary and critical element of social and economic growth that would provide a growing nation and its inhabitants prosperity and overall wellbeing (White 1995). Similarly, Fiege (1999) documented the transformation of the Snake River Valley through irrigation practices and emphasized within this transformed landscape nature still exists but in a different form. Indeed, many environmental histories of rivers have recognized that the respective rivers (and water in general) under investigation have agency, through often implicit but sometimes explicit constitution of a hybrid socio-natural relationship between humans and rivers, where it is difficult to discern where nature (i.e., nonhuman) ends and the human begins (Scarpino 1985; Pisani 1992; White 1995; Fiege 1999; Steinberg 2003; Colten 2005, 2014).

A range of ideas exists to explain and describe the development of river basins over time, as well as the changing relationship between humans and water over time. Whether through linear explanations or circular interpretations, the relationship between humans and the development of water resources is complex and complicated. This dissertation research draws from each of the foregoing conceptual model in order to explore the changing relationship between water, humans, and water decisions in the lower Colorado River valley of Texas.

2.2 Drivers and impacts of water reallocation to urban uses

Increasingly, water allocation systems are reallocating water from rural areas in order to meet new demands, and much of the current reallocation of water is from agricultural uses to urban uses (Shupe, Weatherford, and Checchio 1989; Molle and Berkoff 2009; Wagner 2012). The shift of water from older, more traditional uses, including agriculture, to new demands, such as growing urban areas, is not a new phenomenon. Reallocation of water has been ongoing in arid and semi-arid regions of the United States for some time (Shupe, Weatherford, and Checchio 1989).

Provisioning of water for growing urban areas often requires the expansion of the urban hydraulic reach via securing or appropriating water from sources in rural areas. Studies examining urban growth and urban-rural relations relative to water resources have noted an urban bias exists in issues of water development and management, where urban water interests prevail over rural interests (Swyngedouw 1997; Bakker 2003a; Swyngedouw 2004; Kaika 2005; Celio, Scott, and Giordano 2010; Scott and Pablos 2011; Bell 2015). Scholars have also documented a number of socio-spatial patterns of water distribution between urban and rural areas. While their efforts support an urban-rural connection relative to water resources in both developing and developed countries, scholars have proposed a number of ideas in order to explain the linkages binding the urban to the rural and the effects one has on the other. The following sections outline the prevailing ideas within different research paradigms and agendas.

2.2.1 Political ecologies of water allocation

Numerous scholars have approached questions of water allocation through a political ecology lens. These scholars have focused primarily on issues regarding control of water resources and have suggested that access to water is contingent on and constitutive of intertwined historical, political, economic, and environmental factors (see, for example, Swyngedouw 1997; Bakker 2000, 2003b). The most radical among these scholars use the political ecology approach to unravel the many (perceived) injustices of current water power geometries favoring the affluent and well-connected (e.g., those who control resource access) over the marginalized and less affluent members of society (e.g., those that lack resource access) (Loftus 2009, 2012). While critical approaches to water issues occupy the far left portion of the spectrum, a majority of political ecologies – and other human-environment research – of water to some degree seek to understand water issues by exposing, uncovering, and untangling the complex relationships between local and global political, social, economic, and environmental processes (Swyngedouw 1997; Bakker 2003b; Pires 2004; Scott and Pablos 2011; Jepson 2012; Bell 2015; Birkenholtz 2016). In doing so, researchers have uncovered a number of recurrent themes.

One prominent line of political ecological inquiry into water investigates the allocation of water resources for urban purposes and documents the transformation of both urban and rural spaces vis-à-vis water access. In particular, analyses here have explored the causes of unequal distribution of water resources in urban areas and between urban and rural areas. Specifically, studies have documented how expansion of urban hydraulic space has connected, consumed, altered, and transformed rural spaces through increasing control and regulation of rural areas via powerful individuals and institutions and through flows of capital (Swyngedouw 1997; Pires 2004; Scott and Pablos 2011; Bell 2015; Birkenholtz 2016).

These studies have argued that water development and management at the basin scale is typically controlled by those who are economically or politically powerful in urban society (Swyngedouw 1997; Swyngedouw 2004; Bell 2015). For instance, politically powerful urban residents have played an integral role in securing water from rural sources in order to develop urban water delivery systems (Swyngedouw 1997; Bell 2015). In particular, research on the development of the urban water supply system in colonial Lima, Peru, found that farmers in rural areas had to cede their water rights to powerful urban interests (Bell 2015).

Political ecologists have suggested that capital flowing from rural production to support urban interests influences water control and access by and through the circulation money. In this way, political ecologists have linked the development of some urban water systems to the capitalist mode of production with differing outcomes. For example, in Guayaquil, Ecuador, beginning in the late 1800s, rent and taxes extracted from local agricultural production financed the development of its urban water system. Thus, the continual production and profit derived through the "ecological transformation of the countryside" constructed the urban water system and helped urban interests control the area's water supply (Swyngedouw 1997, 313). In a more contemporary study in India, research has documented the flow of capital through rural to urban water transfers. Here, publicly-held, rural water resources are transferred to private interests and then sold for use in growing urban centers. This process has effectively dispossessed rural farmers from their irrigation sources and ultimately their livelihoods (Birkenholtz 2016).

In other cases, growing cities have expanded their hydraulic reach through urban-led institutions that work to appropriate rural water for urban uses (Scott and Pablos 2011). New York City's watershed management program achieves its water quality standards by protecting upstate watersheds – the source of its water supplies. Yet, the mechanisms used to protect the watersheds – land acquisition, conservation easements, setbacks and buffer zones, and land trusts – have limited land use and economic development in the rural portions of the watersheds. Rural communities affected by the program have voiced their concern with elements of the program (Pires 2004).

Moreover, research has also documented cases of water delivery in growing urban areas and how differing types of delivery create an uneven distribution of water resources not only between urban and rural spaces but also across the urban landscape (Bakker 2003a; Loftus 2012). In the global South, water supply networks are distributed unevenly across socioeconomic lines. In both historical and contemporary analyses, urban water networks typically reach affluent urban residents and bypass the poor (Swyngedouw 1997; Bakker 2003a; Swyngedouw 2004; Loftus 2012; Bell 2015). Likewise, water supply, including infrastructure for delivery, for wealthy urban residents tends to be readily available at a reasonable cost, whereas, water supply, if available, for the urban poor is characterized by interruptible service through unimproved systems or delivery via an informal water sector. In more developed countries of the West, water networks typically reach most urban residents; however, exclusionary patterns exist (Jepson 2012).

Thus, the interplay between water, social power, and capital is a hallmark of water resource allocation as operationalized through a political ecology framework. A prominent theme developed within these studies explores how power and influence originating in urban areas dominates water development, allocation, and use, produces unequal distribution of water, and affects land use in the outer reaches of the watershed under investigation.

2.2.2 Socioeconomic effects of water transfers from agriculture

Allocation systems tend to reallocate water resources from agricultural uses to municipal and industrial uses when urban and industry water demands increase. Moreover, during times of water shortage, allocation systems typically curtail surface water previously assigned to agricultural uses in favor of municipal and industry uses

(Molle and Berkoff 2009). Research has shown that the reallocation of agricultural water to other uses directly dictates how much water agricultural communities receive and when, limiting agricultural production and producing multiple effects that ripple across the agricultural community (Celio and Giordano 2007).

First, reallocation of water from agricultural uses to other uses directly affects agricultural productivity. For example, Molle, Hoogesteger, and Mamanpoush (2008) detailed the micro- and macro-level impacts of water reallocation from agricultural communities to urban areas during an extended drought in the Zayandeh Rud river basin of Iran. Agriculture bared the brunt of the water shortage. Normal release to irrigation in the basin was around 75 percent of total water releases; however, the water available for agricultural irrigation decreased in the basin during the drought (e.g., 33 percent of the total in 1998 and 3 percent in 2001). During the drought, crop area in the basin declined by 38 percent. Results were similar during a drought in Mendota, California. Villarejo (1996) found that irrigated cropland in the area declined by 14 percent when authorities curtailed agricultural water during the drought. Decreases in agricultural productivity such as these have been shown to impact food prices (Villarejo 1996) and may affect global food security (Rosegrant and Ringler 1998).

Second, research has also shown that reallocating water from agricultural uses to other uses creates a discernable economic impact on the agricultural community (Howe, Lazo, and Weber 1990; Knapp et al. 2003). Transfers of water rights limits local economic development and contributes to community out-migration (Rosegrant 1997). Moreover, water reallocation away from agricultural uses leads to decreases in the number of farms, decreases in local government revenue, declines in the quality of public services, and reductions in the number of local businesses (Villarejo 1996). Economic trends, such as these, are expected to continue under long-term climate change scenarios as more and more water is redirected away from agricultural users (Xu and Li 2016).

Water reallocation also affects individual farmers. Farmers often use irrigation water for other purposes besides crop production. Curtailment of irrigation water limits farmers' ability to supplement their income through additional activities that require the use of water. Farmers use irrigated water for livestock production, fishing, gardening, as well as other domestic uses (Meinzen-Dick 1997). Their ability to conduct these activities is greatly reduced during times of water scarcity and when water is reallocated away from agriculture.

At the same time, farmers and agricultural communities have implemented various coping strategies in order to overcome the reallocation of water and to limit yield loss during times of drought. In response to changes to the quantity of water and timing of delivery, studies have reported that farmers decreased cropping area and that they increased use of groundwater to offset surface water losses (Villarejo 1996; Celio and Giordano 2007; Molle, Hoogesteger, and Mamanpoush 2008). At the local level, farmers have combined resources to drill new community wells and reallocated available water among themselves (Molle, Hoogesteger, and Mamanpoush 2008). At the individual level, farmers have drilled new wells or deepened older wells, tampered with irrigation systems, moved their farms elsewhere, sold their farms, changed crop patterns, and shifted to other businesses outside of agricultural (Molle, Hoogesteger, and Mamanpoush 2008). Yet, in some cases these coping mechanisms produce further externalities. For instance, research has shown that the level of the local water table dropped because of increased reliance on groundwater sources during times of water scarcity (Knapp et al. 2003; Molle, Hoogesteger, and Mamanpoush 2008).

Many water managers and users view water markets (i.e., the sale and trade of water rights) as efficient mechanisms to reallocate water resources in water scarce river basins. The acquisition of water rights through water markets is driving water reallocation across much of the western United States and, in particular, in areas governed by prior appropriation doctrine where agricultural interests possess the majority of water rights (Shupe, Weatherford, and Checchio 1989; Colby 1993; Xu and Li 2016). In these areas, growing urban populations and an emphasis on the protection of wetlands and wildlife has influenced water rights acquisition. In particular, cities are buying water rights to meet current and future municipal needs.

Research on water markets has suggested that the acquisition of water rights through market transactions and contracts have economic benefits. Chang and Griffin (1992) documented the effects of water markets in the lower Rio Grande valley of Texas. Most water transactions resulted from the sale of water rights held by area farmers to municipalities (45 percent) – an amount equal to 94 percent of all water transfers in the valley or 3.3 billion ft^3 (94,312,569 m^3) of water from 1971 to 1991. Economic benefits were estimated to be around $12,000 per 35,315 ft^3 (1,000 m^3) of water for the municipalities purchasing the water rights. In the Snake River basin of the U.S. Pacific Northwest, Hamilton, Whittlesey, and Halverson (1989) estimated that the benefits of water transfers from agriculture (irrigation) to hydropower industries via a dry-year option contract would be ten times greater than losses in farm income.

Farmers also benefit economically from water transfers. A survey of area farmers in Tamil Nadu, India, indicated that farmers possess a positive view of water transfers. Farmers suggested that water transfers negated labor problems, allowed them to attain higher profits, and generated additional income via the sale of surplus water and the sale of water supplies inadequate for crop irrigation (Palanisami 1994). Thobani (1998) found similar results when farmers sold their water rights in water scarce areas of Chile and Mexico. The selling of water rights lessened withdrawals from groundwater, allowed farmers to repay debts, and in some cases, created employment opportunities (e.g., some farmers went to work on larger farms that bought their water rights).

On the one hand, reallocation of water from agricultural communities to urban areas has been shown to produce several deleterious social and economic ramifications. Transferring water away from agriculture has produced a number of observed impacts on not only agricultural interests but also the surrounding community and its collective social identity and economic development. Yet, research has also shown that regional economic growth may be enhanced through water reallocation. Thus, empirical evidence regarding the impacts of water shifts from agricultural uses to urban uses is mixed and highly complex.

2.3 Other factors affecting water allocation

The literature on water allocation has also indicated that a number of other factors affect the distribution of surface water. Scientific knowledge, policy implementation, technical fixes, and political influence; the physical and ecological characteristics of the river basin; and the construction of discursive environmental systems with regard to water scarcity all play a role in the control over and access to water resources. I explore these factors below.

2.3.1 The role of science and policy in water allocation decisions

Water managers make water allocation decisions based on scientific information and political influence. In some cases, water managers' decisions result in the unequal distribution of water resources across populations. Research has suggested that the use of scientific knowledge and that the deployment of technical fixes drive water allocation decisions, often creating and exacerbating uneven patterns of water distribution (Budds 2009; Walker 2013). In particular, the production and use of scientific data in the form of environmental assessments has been used by policymakers to support their interests and agendas over other competing water interests (Budds 2009). Water demand models have also been used as scientific and objective tools to legitimize water resources management approaches that favor one group of stakeholders over others (Walker 2013).

Other critical inquiries into the production and consumption of scientific knowledge problematize the aspatial notion of scientific facts by bringing to light the myriad contexts and places in which science and knowledge are produced and consumed (Lane 2011). For example, the implementation of science-based water policy has been described as a highly contingent process (Lane 2011). Historical, place-based accounts of policy implementation in the western United States revealed that the implementation of portions of the 1902 Reclamation Act was complicated by local cultural, legal, and historical geographies that disrupted the execution of federal, science-based water management policies developed early in the 20th century (Lane 2011). Yet, specifically in issues regarding water quality, science has led environmental policy and the formation of important state and federal regulations with regard to pollution control (Cumbler 2001).

2.3.2 Environmental processes and considerations in water allocation

In contrast to studies oriented towards the political economic arrangements of water governance and development, other research has foregrounded the environment in their explorations of river basin management relative to urban-rural relations. In particular, Colten (2012) explored how the physical geography of a watershed, as well as the location and historical development patterns of urban centers within a river basin, affects basin-wide water management. For example, modifications to the Illinois River system near Chicago during the late 1800s and into the early 1900s sent the city’s effluent downstream, reaching smaller communities, disrupting commercial fisheries, and reducing water quality (Colten 2012).

Another aspect attended to in the literature suggests that the materiality of water affects management and allocation decisions. Specifically, the physical aspects of water subvert human attempts to govern and control a natural resource that varies spatially and temporally. Yet, natural processes of the hydrologic cycle and extreme environmental phenomena that affect water supply have been leveraged as opportunities to adjust the policies concerning the allocation, access to, and control over water resources. For example, environmental hazards, such as drought and floods, have been used to amend existing water allocation systems (Bakker 2000; Kaika 2003).

2.3.3 The production of water scarcity

The amount of water available to meet demand fluctuates temporally and spatially due to local weather patterns and regional climate. As available water approaches sustainable limits, the ability of allocation systems to meet all demands becomes difficult. These difficulties are magnified when weather patterns and climate trends change suddenly, particularly under drought conditions, and when consumption patterns change in unpredictable ways (Molle and Berkoff 2009). Water scarcity, in particular, places an enormous amount of stress on allocation systems and limits their capacity to meet all water demands.

The literature points to two main drivers of water scarcity: 1) physical scarcity and 2) economic scarcity. Physical scarcity occurs when the development of water resources is approaching or has exceeded sustainable limits. Economic scarcity arises because human, institutional, and financial capital limit access to available water resources. In addition, mismanagement of water resources or extreme environmental conditions, such as drought, influence patterns of water scarcity. Indeed, poor inter-annual management of existing water storages has been shown to leave allocation systems ill-prepared to deal with drought conditions over both short and long terms (del Moral Ituarte and Giansante 2000; Molle, Hoogesteger, and Mamanpoush 2008; Walker 2014).

In a review of intersectoral water reallocation literature, Molle and Berkoff (2009) examined the reallocation of water from agriculture to urban areas and argued that agricultural water demands, while generally greater than other demands, do not compound water supply problems during times of scarcity. Instead, they explained that a number of factors, including poor management of water resources, extreme climatic events, and inadequate preparation, contribute to urban water scarcity. Elsewhere, the timing of important decisions related to the management of water supplies has also been blamed for producing water scarcity. Research has suggested that in times of drought mismanagement of water resources in the beginning stages of a drought led to drastic reductions in available water resources for agricultural interests during peak drought conditions (Molle, Hoogesteger, and Mamanpoush 2008). Similarly, del Moral Ituarte and Giansante (2000) analyzed the management of Spain's water resources during times of drought and found that planners followed historical legacies of water resource management. Planners in Spain focused on fixing structural water deficits through structural responses, while failing to develop drought contingency plans.

Another subset of the literature has critically analyzed normative explanations of water scarcity and challenged the beliefs that water scarcity is a product of mismanagement and extreme environmental events. In particular, research has examined the social construction of water scarcity and water crises. In some instances, the term "water crises" and the appropriate course of action to mitigate, adapt, or solve the (perceived) crisis is carefully constructed in a way that supports the preferred water management agenda (Trottier 2008). Moreover, some researchers have suggested that authorities use the production of water scarcity, particularly in urban areas, as a way to reregulate the hydro-social system in new ways. In an exploration of the outcomes of the 1995 drought in England and Wales, Bakker (2000, 22) suggested that water scarcity was the product of misunderstandings generated through a discourse that privileged "a set of understandings about the environment and consumption patterns that simultaneously concealed or even rejected contradictory evidence." Within this false security, the privatized water industry and regulators focused on issues of water quality instead of issues of water supply. Similarly, Kaika (2003) documented how the discursive construction of drought in Athens, Greece, was used by the state to implement neoliberal reforms in water governance and shift the water sector towards privatization. Thus, the state, as well as corporate actors, plays an important role in the production of waterscapes, influencing water resources governance, decision-making processes, and outcomes and patterns of water resource allocation (Bakker 2002; Gandy 2002; Swyngedouw 2004). Yet, increasingly a growing number of interests and the flow of capital are informing who gets water, when, where, and for what purposes (Gandy 1997). These processes have eroded the historical, centralized control of water resources and dispersed control across a number of entities (Gandy 1997, 2004).

2.4 Discourse and news media

In human geography, the concept of discourse and its various methodological approaches have become an important avenue of inquiry into reframing epistemological questions surrounding the existence of reality, the production of knowledge, and the production of space. Discourse refers to both written and spoken communications, signs and symbols encountered as communicative texts, and assemblages of words, practices, institutions, and things (Cresswell 2012). More directly, a discourse is "a specific ensemble of ideas, concepts and categorizations that are produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities" (Hajer 1995, 44). Analysis of discourse materialized as a critique of normative, dominant modes of research in the social sciences (e.g., positivism) and, in particular, aligns with post-structuralism and harbors a social constructionist notion of reality, where "reality" is assumed to be socially produced (Gill 2000). While there are multiple forms of discourse analysis, many human geographers have examined discursive systems from a Foucauldian-centered perspective.

In his book *Discipline and Punish*, French philosopher Michel Foucault (1977) asserted that discourse produces meaning. In other words, communicative actions produce truth and, in turn, bring “things” into being. Thus, Foucault is interested in excavating and in the archaeology of how “things” come into being through discursive practices. The focus here is less on the specificity of talk and texts and more on the historical formation of discursive systems (i.e., how discursive systems come into being over time and how they produce an understanding of a “thing” that is accepted as truth). In other words, the process through which discourse brings “things” into being is contingent on historical and geographical situations (Cresswell 2012).

Because discourse is highly geographical and it provides an additional reading of events, various forms of discourse analyses have proven to be an attractive research method for human geographers operating within a poststructuralist paradigm (Cresswell 2012). For example, discourse is a product of its context, and the analysis of discourse provides clues to the geographic context in which it was/is produced. Discourse also produces multiple competing truths, meanings, and realities of events, which are contingent upon their situation in space and time. Therefore, discourse is fundamentally a product of geographic and historical contexts. In addition, discourse arises from a specific site, and explorations of where, how, and why a particular discursive system emerges is of geographic importance. Discourse is also a product of place, and people rely on discourse to explain and make sense of the places they occupy. Moreover, discourse analysis provides an alternative version, and a critique, of how social, economic, and political processes inform human-environment interaction than more normative, positivist styles of inquiry.

Dominant environmental discursive systems assert one set of beliefs or truths over other competing discursive narratives. Through these discursive systems specific relations of power develop that are often produced and reproduced, privileging one set of beliefs or truths over others (Peet and Watts 2004). These discourses change over time and are highly influenced by regional history and geography – both human and physical (Bakker 2003b). Science and scientific "facts" are also socially constructed, and discourse analyses have been used to uncover "the plurality of perceptions and definitions of environmental and resource problems," where the production of science or "regulatory knowledge" as an inherently political process is laid bare (Peet and Watts 2004, 15).

Discursive systems arise around environmental issues on or related to the management of natural resources. The news media communicates and disseminates information on important local, national, and international events to the public via a number of outlets, including print, television, radio, and electronic platforms. News media outlets often document and chronicle prominent environmental and resource problems, capturing environmental discourses while offering an important source of information on the issues under discussion. Media coverage of news events, including environmental and natural disasters, plays an important role in shaping public opinion and informing individual knowledge and perceptions of these events (McCombs 2005, 2013). News media coverage "not only can be successful in telling us *what to think about*, but also can be successful in telling us *how to think about it*" (McCombs 2005, 546, emphases in original). At the same time, media coverage of news events has the ability to influence policy formulation. Yet, news media coverage is inherently biased

(Entman 2007). Because of this bias, it is essential to discover the details concerning who and what issues the news media privileges in an effort to understand the complex social relationships and power undercurrents at work in environmental issues.

Americans source information on environmental and natural disasters primarily through television news stations and print newspapers (Boykoff and Boykoff 2007; Baum and Potter 2008). Researchers have shown that exposure to news media generally increases knowledge of the events covered and that the amount of attention an individual gives to the news story influences behavioral choices based on the newly acquired knowledge (The Media Insight Project 2014). The content of media coverage, including how information is communicated and who delivers it, also determines how the public responds to the information presented (Mondak 1995; Slater and Rasinski 2005; De Vreese and Boomgaarden 2006; Slater, Hayes, and Ford 2007). For scientific topics, the public responds positively to accounts provided by scientists and government officials (McManus 2000). In other contexts, the public responds equally or more to first-hand accounts delivered by non-specialized individuals (Lefevere, De Swert, and Walgrave 2012).

Given the influence of news media coverage on shaping peoples environmental perceptions, a number of studies have documented environmental narratives and changing coverage of environmental issues in newspapers. For example, studies have researched media coverage of gentrification (Lavy, Dascher, and Hagelman 2016), floods (Escobar and Demeritt 2014), wildfire (Morehouse and Sonnett 2010), and drought (Sonnett et al. 2006). These and other studies offer a more nuanced interpretation of news media coverage as well as the underlying event or issue covered.

2.5 Conclusion of the literature review

In conclusion, the literature reviewed hereinbefore provides key insights with respect to how the allocation of water resources in urban and agricultural areas throughout a watershed is interconnected and how social, political, economic, and environmental processes shape access to and control over water resources. The socio-natural system that evolves around the allocation of water produces many outcomes, including both temporal and spatial patterns of water distribution, that are contingent on historical trajectories of water development, water management legacies, and river basin geography. Moreover, discursive constructions of water scarcity shape political, social, and economic responses to issues relative to water resources. As river basins begin to close, conflict arises between water users. Whether these conflicts are a result of physical or economic water scarcity, the amplification of discourse surrounding water resources during drought privileges some water users over competing interests and often selects urban-centric management strategies over others. In addition, science and technology has played a prominent role in the deciding who controls and who gets access to water resources.

The materiality of water and the physical geography of the watershed have helped to shape the evolution of state control over water resources as witnessed in the establishment of water institutions and governance mechanisms from the court system to forms of regulatory control. Likewise, the recognition of the importance of water flows for sustaining vital aquatic ecosystems is increasingly complicating traditional allocation systems, pitting environmental demands against traditional water uses (i.e., irrigation, municipal, and industry). Documented in the news media, public discourse around environmental issues and resource access have both influenced and informed who gets water, when, and for what purposes. Taken together, the allocation of water resources has produced a range of social and economic differences between water demands, urban and agricultural areas, resulting in the stratification of society based on access to and control over water.

3 METHODS

This dissertation provides an environmental geography of water use and access and an analysis of discursive systems surrounding water matters in the lower Colorado River valley from 1970 to 2015. My methods identify periods of change in the relationship between urban and agricultural water interests that led to the ascendance of urban water uses, the decline of agricultural water uses, and the resulting competition between urban and agricultural water interests. It takes into account the extent to which political, social, economic, and environmental events informed water management decisions and influenced spatial and temporal outcomes of water use. In order to achieve these goals, this research answered the following questions:

1. What temporal trends and spatial patterns occur in water use and access among urban and agricultural interests in the lower Colorado River valley of Texas from 1970 to 2015?
2. In what years do significant changes occur in water use and access among urban and agricultural interests, and what do these changes reveal about water use and access between urban and agricultural interests?
3. What distinctive periods of water use and access develop in public discourses, and through public discourses, how do urban and agricultural interests enable or constrain access to the water resources of the lower Colorado River given the underlying, changing social, political, economic, and environmental conditions?

In addition, I constructed a conceptual framework – derived from the literature on water use, competition, and access – to guide my analyses and to formulate answers to my primary research questions. The conceptual framework suggests that spatiotemporal patterns of water use and access are a function of political, social, economic, and environmental conditions that predominate in different periods (i.e., Period 1, Period 2, and Period 3) and influence changes in the way water is distributed in the basin. Additionally, embedded within each period are the access mechanisms urban and agricultural interests use in response to the political, social, economic, and environmental conditions. The ending of each period reflects the point at which the structure of the water allocation system is altered in a way that signifies a shift in water use and reflects the movement of water control from one interest group to another (Figure 5).

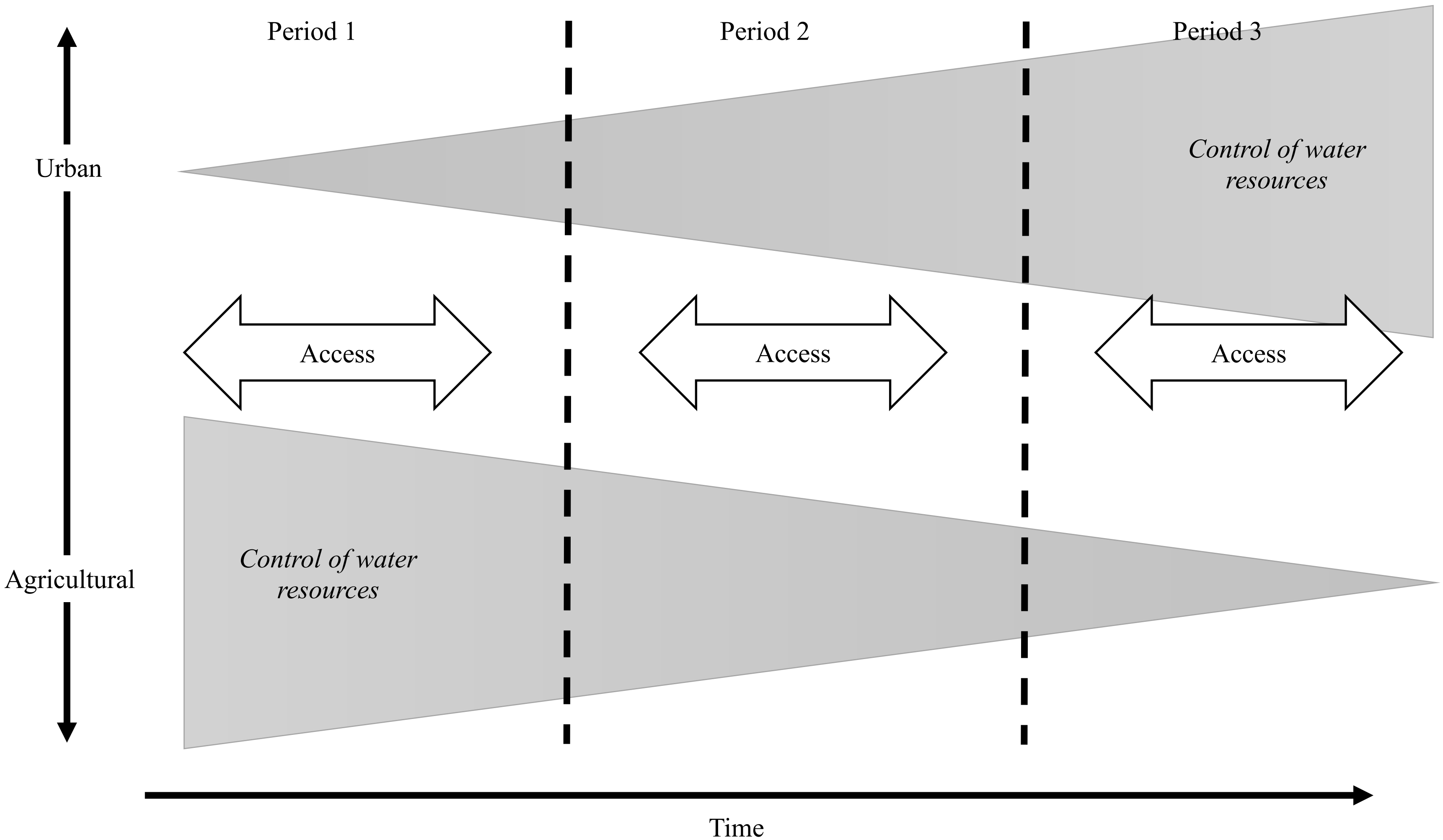

Figure 5. Conceptual framework showing distinctive periods of water use, access, and control in the lower Colorado River valley.

Working within this conceptual framework, I use the river basin as my unit of analysis. The river basin provides a common geographic concept in which to study the management and governance of water resources and the interplay between water users and environmental conditions because of its alignment with legal principles, institutional engagements, management efforts, and current and previous scholarly attention (Colten 2014). Yet, "beyond its relevance as a geographical unit for water resources development and management purposes, the river basin is also a political and ideological construct, with its discursive representations and justifications, closely linked with shifting scalar configurations, both ecological and in terms of regulatory regime or governance" (Molle 2009, 484). In the following sections, I outline my research study area and methods.

3.1 Site and Situation

The study area for this research is the lower portion of the Colorado River valley (Figure 6). A number of cities, including Austin, the capital city of Texas, lay within the lower Colorado River valley, as well as portions of six Texas counties. The six counties are divided between urban counties and agricultural counties. Urban counties primarily consume water for municipal and industrial purposes, whereas agricultural counties consume a significant amount of water for irrigation. The entire Colorado River is approximately 1,439 kilometers (894 miles) long and drains around 107,485 square kilometers (41,500 square miles) (Legasse 2016). It traverses through many of the major physiographic regions of Texas. The upper portion of the river has its beginnings in the High Plains region (Llano Estacado) of northwest Texas before entering the Edwards Plateau region (Texas Hill Country). The lower portion flows through the Texas Hill Country prior to reaching the Balcones Escarpment. In this area of uplift, canyons carved by the river provided the ideal geography for water development projects to protect urban areas from perennial floods and to produce electricity for the surrounding area (Adams 1990). Just downstream from the Balcones Escarpment region, the Colorado River enters Austin and then winds its way southwest through the Blackland Prairies, where it widens, and encounters the Gulf Coastal Plain before discharging into Matagorda Bay and the Gulf of Mexico.

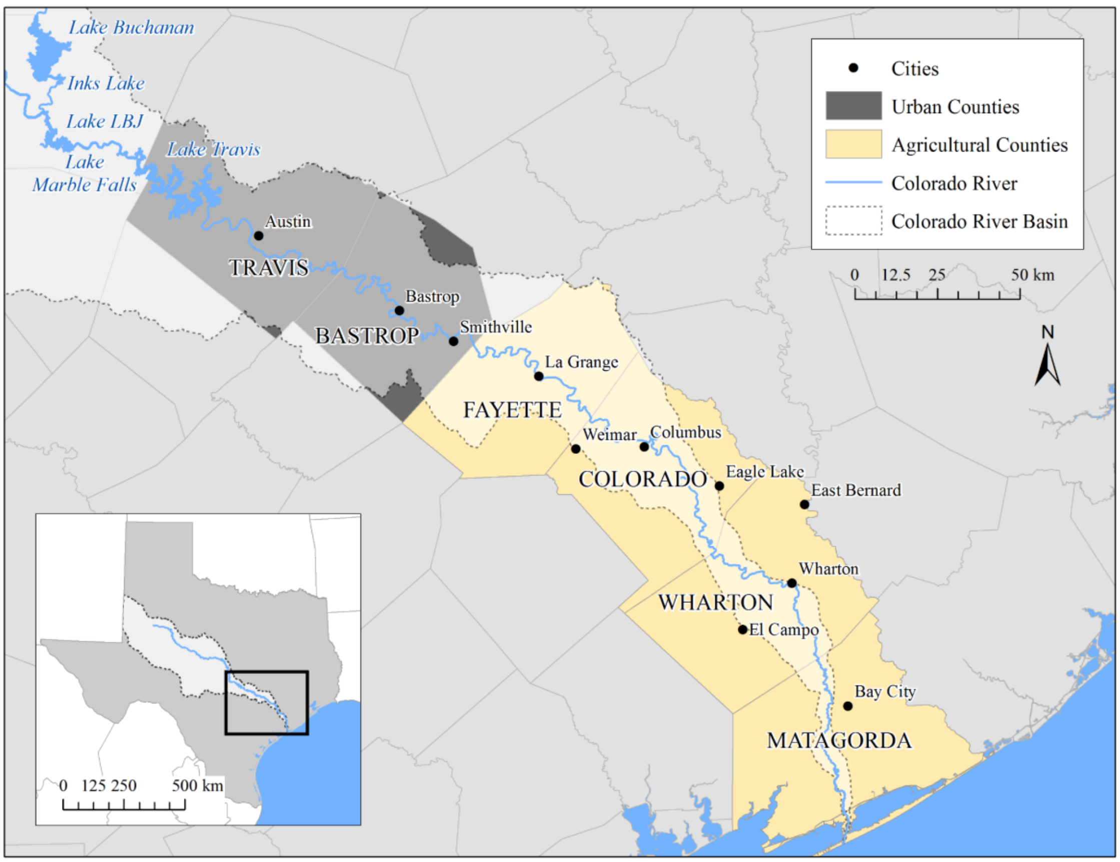

Figure 6. Map of the lower Colorado River valley.

The Lower Colorado River Authority (LCRA) in conjunction with federal and state authorities developed the water resources of the Colorado River between the 1930s and 1960s under a multipurpose management approach. In 1937, the LCRA oversaw the completion of the first dam and reservoir, Lake Buchanan and Buchanan Dam (both named after U.S. Representative James P. “Buck” Buchanan), on the Colorado River just above Austin. In 1961, the last dam and reservoir – Starcke Dam and Lake Marble Falls – joined the Highlands Lake system. By that time, the LCRA, with funding from the U.S. Congress, had created the chain of reservoirs known locally as the Highland Lakes. A product of the conservation movement and New Deal spending, the Highland Lakes system was constructed to alleviate flooding in central Texas, generate hydroelectric power, and provide water for agriculture and municipal needs (Adams 1990).

Precipitation along the course of the Colorado River is highly variable, given that the river crosses the 100th meridian before it reaches Austin. Precipitation totals west of the 100th range in the area of 10 inches to 15 inches per year, whereas totals east of the 100th meridian may be as much as 40 inches per year (Woodruff 1979). The area is prone to cyclical droughts, with approximate decadal intervals related to El Nino-Southern Oscillation (ENSO) events (Barlow, Nigam, and Berbery 2001). The climatological drought of record occurred between 1950 and 1954. The area has just emerged from an extended drought that peaked in 2011 (Combs 2012). During periods of drought, area lake and reservoir levels fall to historic lows, which prohibits water authorities from meeting all water demands.

The lower portion of the Colorado River valley provides an ideal place in which to explore changes in the relationship between urban and agricultural water interests for at least four reasons. First, a major goal of this research is to understand how access to and control over water resources in the lower Colorado River basin has shifted over time from agricultural interests, such as crop production, to primarily urban interests, including drinking water for urban residents and other residential water uses. While the source of the Colorado River is located in West Texas outside of Lamesa (its drainage basin extends into New Mexico), it does not pass through a major metropolitan region until it reaches Austin and its wider conurbation (Figure 7). After leaving Austin, the Colorado River does not encounter any other major metropolitan areas before draining into Matagorda Bay (Sansom 2008). Instead, the lower Colorado River runs near a handful of sparsely populated rural cities and towns (Table 3). This strong urban to rural gradient following the flow of the lower Colorado River – and the accompanying dependence of both urban and agricultural stakeholders on the waters of the lower Colorado River – provides an opportune locale in which to examine the evolving relationship between urban and agricultural surface water allocation and water user interests.

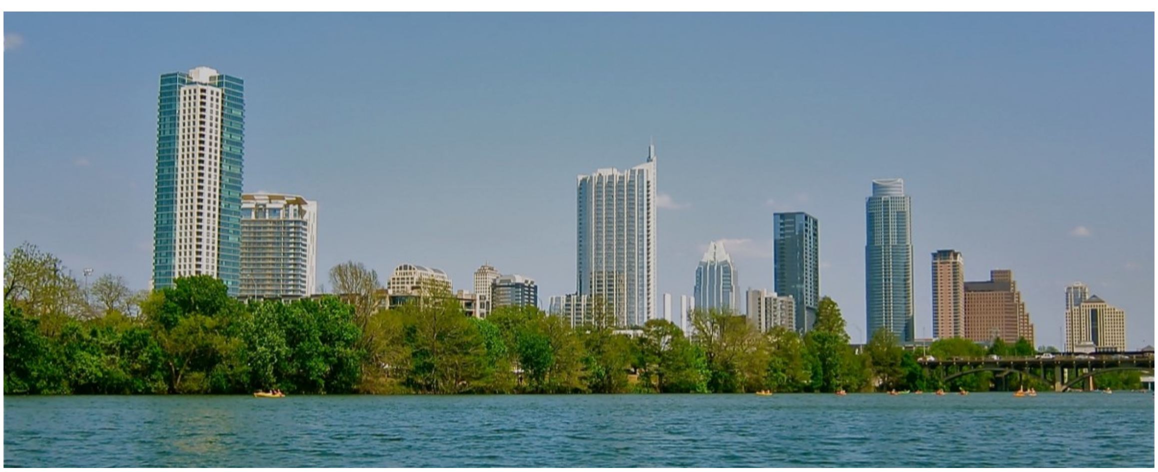

Figure 7. City of Austin skyline from Lake Lady Bird (Photo credit: Brendan Lavy).

Table 3. Population (2010) of select cities along the lower Colorado River.

City	*2010 Population*
Austin	790,390
Bastrop	7,218
Smithville	3,817
La Grange	4,641
Weimar	2,151
Columbus	3,655
Eagle Lake	3,639
East Bernard	2,272
Wharton	8,832
El Campo	11,602
Bay City	17,614

Second, the study area has a long, well-documented history of regional surface water governance, river modifications and infrastructure development, and basin conflict and cooperation (Banks and Babcock 1988; Adams 1990). The Lower Colorado River Authority (LCRA), a quasi-governmental agency created by the Texas Legislature, has developed and managed water supplies in the basin via projects related to flood control, hydroelectric power, and irrigation operations since 1934 (Figure 8). With financial support of the federal government, policymakers modeled the LCRA after the Tennessee Valley Authority (TVA). LCRA was instrumental in the development of water resources in the basin. It oversaw the construction of multiple dams along the Colorado River from 1930s to 1960s (Table 4) (Adams 1990). Today, the LCRA shoulders a diverse portfolio that includes "delivering electricity, managing the water supply and environment of the lower Colorado River basin, providing public recreation areas, and supporting community development" (LCRA 2016a). LCRA owns or co-owns six power plants across central Texas. It also owns, operates, and maintains 14 developed parks, 14 recreation areas, two natural areas, and seven river access sites. Additionally, LCRA serves as the primary authority regarding the allocation of surface water resources collected and stored in the Highland Lakes. It owns the rights to 2.1 million-acre feet of water per year. It also owns three irrigation districts in southwest Texas and operates 11 major pumping plants and a 1,770-kilometer (1,100-mile) network of irrigation canals.

Figure 8. LCRA irrigation operations along the Colorado River near Bay City, Texas (Photo credit: Brendan Lavy).

Table 4. Major dams and reservoirs on the lower Colorado River.

Dam	***Year built***	***Reservoir***	***Max Storage (AF)***	***Purpose***	***Operator***	***Owner***
Buchanan Dam	1937	Lake Buchanan	1,180,000	Hydropower; Flood control; Municipal, industrial, and agricultural water supply	LCRA	LCRA
Inks Dam	1938	Inks Lake	63,500	Hydropower; Buffer dam	LCRA	LCRA
Wirtz Dam	1951	Lake LBJ	223,000	Hydropower; Cooling water for power plant	LCRA	LCRA
Starcke Dam	1961	Lake Marble Falls	8,760	Hydropower	LCRA	LCRA
Mansfield Dam	1941	Lake Travis	3,223,000	Hydropower; Flood control; Municipal, industrial, and agricultural water supply	LCRA	LCRA
Tom Miller Dam	1940	Lake Austin	115,404	Hydropower; Flood control; Municipal water supply	LCRA	City of Austin
Longhorn Dam	1960	Lake Lady Bird	6,850	Cooling water for power plant*; Municipal water supply*	Austin Energy	City of Austin

*no longer used for this purpose

Third, the valley also harbors an active and substantial agricultural community in its lower reaches. Texas generally ranks fourth or fifth in U.S. rice production annually (Baldwin et al. 2011). Colorado, Wharton, and Matagorda counties grow the majority of Texas's rice crop. Rice cultivation in the region began in the late 1800s and continues to play an important role in the culture, society, and economy of Texas's south coastal region (Figure 9). Yet, the number of rice farms in Texas is declining due to price, climatic factors, and higher production costs. From 1992 to 2007, the Texas Gulf Coast rice production region lost 46 percent of its rice area (Baldwin et al. 2011). Rice operations depend on surface water from the Colorado River and water stored in the Highland Lakes.

Figure 9. Rice storage facility near Bay City, Texas (Photo credit: Brendan Lavy).

Finally, a growing interest in the ecological functions of the various Gulf Coastal estuaries in Texas, including Matagorda Bay, by environmentalists and recreationalists has created an awareness of the importance of river inflows to the sustained health and well being of the bay ecosystem. Recent legislation has followed and stipulated environmental flows standards be developed for each Texas river basin (Sansom 2008; Kelly 2011). This adds another water use dimension to water resource management in a fully allocated basin subject to acute, chronic periods of drought.

3.1.1 Texas water law

Texas divides water legally into three media: 1) surface water flowing through a defined channel, 2) groundwater, and 3) overland flow. The state of Texas owns water flowing in rivers and streams. Groundwater is the property of the landowner. Diffused surface water (e.g., rainfall runoff) that is not in a defined channel also belongs to the landowner. However, once diffused surface water enters a watercourse, it passes from private to public property. Surface water law and groundwater law garner the most attention from landowners, water users, and the public.

Civil and common-law principles have shaped a long legal tradition governing the right to use surface water in Texas (Table 5). Currently, surface water law in Texas follows two legal traditions: 1) the riparian doctrine and 2) the doctrine of prior appropriation. Under both of these water rights systems, the right to use water is a usufructory right. Riparian rights allow landowners whose property abuts a riverbank to use or impound 200-acre feet of water annually for domestic and livestock purposes (Kaiser 2011). Appropriative water rights allow permit holders to use a specified amount of surface waters. The doctrine of prior appropriation establishes water rights through a hierarchical system based on seniority of use (or those who claimed the water first, i.e., "first in time, first in right"). All other water users hold junior rights. When water demand outstrips supply, state water authorities may interrupt or cut off junior water rights in favor of senior water rights holders. Water rights allow a user (senior or junior) to divert water from a river or stream. The water right certificate delimits the amount of water available for use. The doctrine of prior appropriation also stipulates that if a permit holder does not use all of the water allocated through the permit, then state water authorities may revoke the permit. Water rights holders may also sell or lease their rights. The Texas Commission on Environmental Quality (TCEQ) grants appropriative water rights through a permitting process (Kaiser 2011).

Table 5. Legal evolution of Texas water law (reproduced from Kaiser 2011).

Sovereign	***Dates***	***Water rights system***
Spain	1600-1821	Spanish civil law
Mexico	1821-1835	Mexican civil law
Republic of Texas	1836-1839	Civil law
	1840-1845	Riparian law
State of Texas	1845-1888	Riparian law
	1889-1912	Prior appropriation in west Texas/riparian law
	1913-1966	Mixed prior appropriation and riparian law
	1967-present	Prior appropriation statewide

In addition to the laws governing water use in Texas, the LCRA manages water supply in the lower Colorado River valley. The LCRA, established by the Texas Legislature through the Lower Colorado River Authority Act of 1934, is composed of ten counties through which the Colorado River flows. LCRA holds 63 percent of all appropriative water rights in the district and acts as a water wholesaler in the basin

(Kaiser 2011). The LCRA may divert and use up to 1.5 million acre-feet per year from lakes Buchanan and Travis and 636,750 acre-feet per year under downstream run-of-river water rights from the Gulf Coast, Lakeside, Garwood, and Pierce Ranch irrigation operations. The LCRA divides water supplies into two preference categories: firm and interruptible water. Firm water is available to customers at all times, even in times of water scarcity. In general, the LCRA enters into firm water contracts with cities, industries, and electric power plants. Interruptible water is only available to customers when area lake levels exceed minimum requirements. In times of drought, the LCRA may curtail or completely cut off water supply to these customers. The LCRA conducts their water allocation decisions based on a state-approved water management plan, which details water allocation priorities during drought periods. The plan also defines when the LCRA may interrupt water delivery and determines the amount of water available for environmental flows. The LCRA also maintains a long-term water supply outlook. The LCRA's Water Supply Resource Plan attempts to project future water demand in the basin (LCRA 2016b).

3.2 Research design and analysis

In order to provide an environmental geography of water use and access in the lower Colorado River valley, to identify periods of change in water use and access that led to the prioritization of urban water interests over agricultural water interests, and to analyze discursive systems for access mechanisms during these periods of change, I used a mixed-methods research design, combining both quantitative and qualitative analyses. Specifically, I employed a sequential explanatory strategy comprised of two successive analytical stages: 1) a quantitative stage followed by 2) a qualitative stage (Creswell

2013). The sequential explanatory strategy uses qualitative analysis to further explain and interpret quantitative data and results (Figure 10) (Creswell 2013, 215).

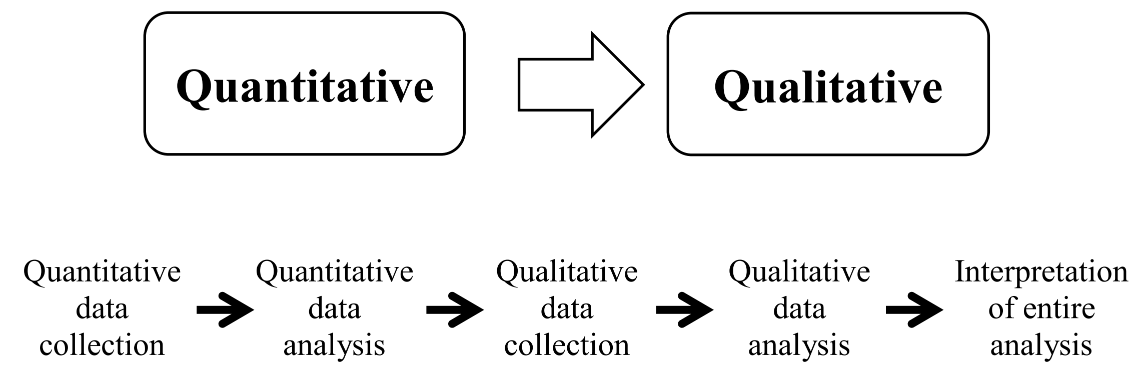

Figure 10. Mixed-methods research design employing a sequential explanatory strategy.

The quantitative stage focused on constructing an environmental geography of water use and access in the lower Colorado River valley from 1970 to 2015. This stage consisted of two primary objectives: 1) to describe spatiotemporal patterns in urban and agricultural uses of the valley's water resources as well as in variables associated with water use and 2) to identify points of change relative to water use and access in the valley over the course of the study period. In the qualitative stage, I documented water governance actions and transactions to provide context on water issues confronting the basin and conducted a qualitative content analysis of news articles to discover the discursive constructions that water interest groups used to enable or constrain access to the basin's water resources. I merged the findings from the two research stages to identify and characterize periods of change in water use and access between urban and agricultural interests (Figure 11). I detail each stage of research in the following sections.

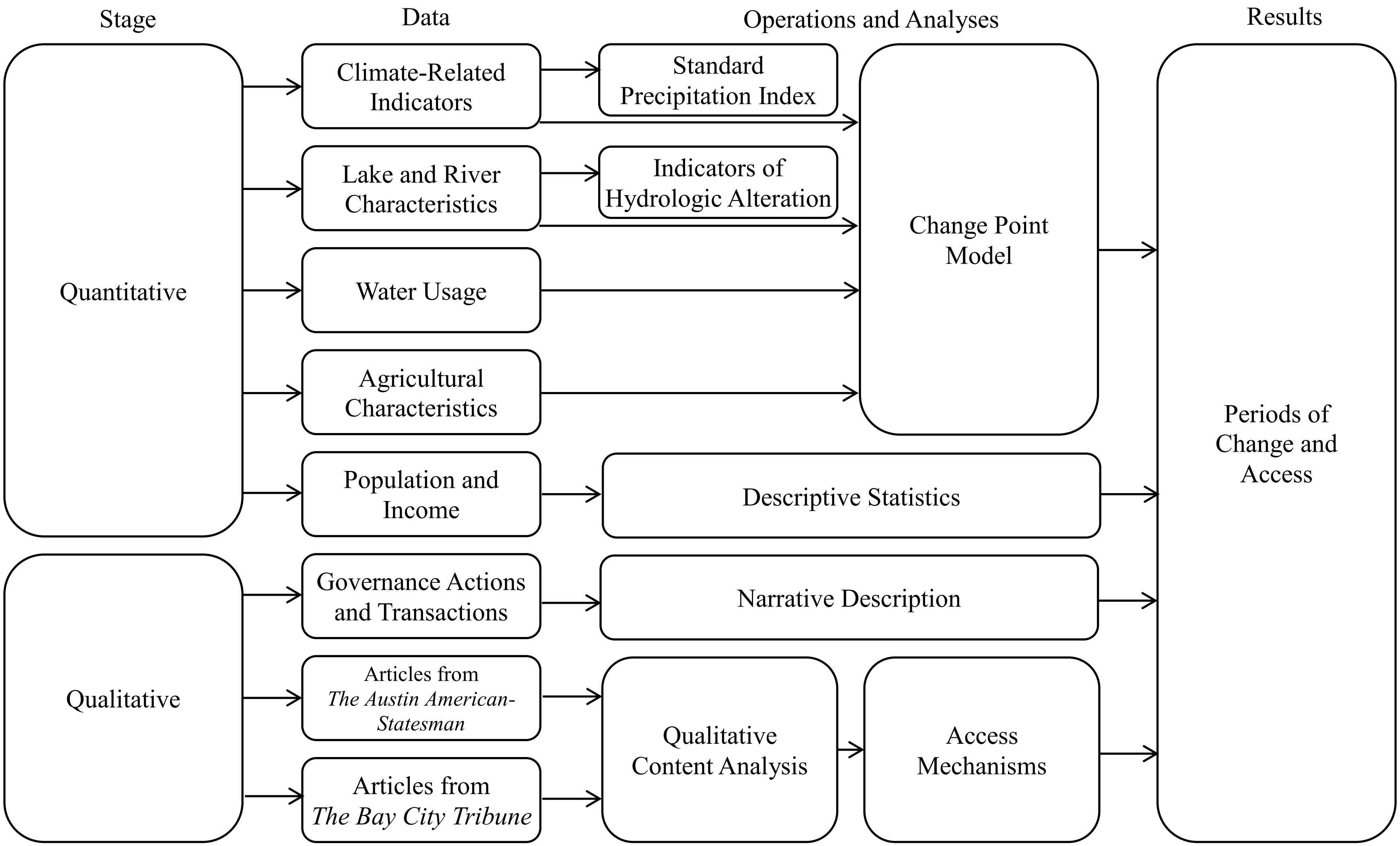

Figure 11. Flowchart describing research methods, operations and analyses, and results.

3.3 Quantitative stage

My first research objective was to describe an environmental geography of water use and access in the lower Colorado River valley of Texas from 1970 to 2015. The primary task was to document spatiotemporal patterns of both urban and agricultural water use over time at the county scale. In order to accomplish this task, I divided the counties in my study area into urban counties and agricultural counties using water use estimates gathered from the Texas Water Development Board (TWDB). I classified counties with a majority of their total water use for agricultural purposes as agricultural counties, and I classified counties with a majority of their total water use for municipal and industrial purposes as urban counties. Next, I operationalized a set of conceptual variables related to water use, access, and control (Table 6). I used these data sets to discover spatiotemporal patterns in water use over time between urban and agricultural counties.

3.3.1 Quantitative data

I based the variables selected for analysis on the primary factors driving competition to access water resources (Molle, Wester, and Hirsch 2007; Hellegers and Leflaive 2015; OECD 2015). I included data, acquired from federal and state institutions, related to local climate trends, basin-wide water usage characteristics, lake level information, agricultural production measurements, and population and income characteristics (Table 6). I aggregated the data sets by year and county. I discuss each data set below.

Table 6. List of conceptual and operational variables for quantitative analyses.

Conceptual variables	***Operational variables***	***Units***	***Source***
Climate-related indicators	Monthly precipitation	inches	NOAA
	Annual mean maximum temperature	degrees Fahrenheit	NOAA
	Summer mean maximum temperature	degrees Fahrenheit	NOAA
Lake and river characteristics	Lake Buchanan (annual mean level)	feet	LCRA
	Lake Buchanan (summer mean level)	feet	LCRA
	Lake Travis (annual mean level)	feet	LCRA
	Lake Travis (summer mean level)	feet	LCRA
	Mean summer river discharge	cubic feet per second	USGS
Water usage	Urban counties water use	thousands AFY	USGS/TWDB
	Surface water use	thousands AFY	USGS/TWDB
	Groundwater use	thousands AFY	USGS/TWDB
	Water use per capita	thousands AFY	.
	Water share	proportion	.
	Agricultural counties water use	thousands AFY	USGS/TWDB
	Surface water use	thousands AFY	USGS/TWDB
	Groundwater use	thousands AFY	USGS/TWDB
	Water use per capita	thousands AFY	.
	Water share	proportion	.

Table 6. Continued.

Conceptual variables	*Operational variables*	*Units*	*Source*
Agricultural characteristics	Total field crops harvested	acres	USDA
	Rice harvested	acres	USDA
	Rice produced	cwt	USDA
	Rice share of harvest	proportion	.
Population and income characteristics	Urban counties population	count	USCB
	Agricultural counties population	count	USCB
	Urban counties per capita income	$000s	USBEA
	Agricultural counties per capita income	$000s	USBEA

3.3.1.1 *Climate-related indicators*

The central Texas region experiences recurring floods and acute, chronic droughts. The region's water supply (collected in the Highland Lakes) varies, depending primarily on precipitation in the upper portions of the Colorado River watershed, which can range from less than 15 inches to 30 inches per year. While the region's water demand is expected to increase, its water supply is expected to decline under current climate change scenarios (TWDB 2017). Empirical evidence suggests that changes in climate influence water use (Franczyk and Chang 2009) and decisions related to water allocation and management (Bakker 2000; Kaika 2003; Linton and Budds 2014). In other words, the amount of water available (i.e., water supply) and water demand guide water usage and influence allocation decisions. Therefore, precipitation and temperature play important roles in determining water supply, water demand, and water usage. In general, precipitation determines water supply, whereas temperature dictates water demand. Both relate to water usage. Under wet conditions and normal temperatures, water use generally decreases, and under drought conditions and warmer temperatures, water use typically increases (Cech 2010). Given the relationship between precipitation, temperature, water supply, water demand, and water usage, I selected climate-related variables in order to ascertain the extent to which they have influenced water use and access in the basin. Because rice is the dominant crop in the agricultural counties of my study area, I collected climate-related data to coincide with the rice-growing season. I gathered climate-related data from a variety of sources, and from these data sets, I defined wet and dry periods and captured summer temperature trends.

I gathered historical precipitation and temperature data reported from Camp Mabry at station site USW00013958 in Austin, Texas, from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC). I chose Camp Mabry because of its relatively long data collection and data coverage over its period of record from 1938 to 2016. Using the temperature dataset, I calculated mean maximum summer temperatures (May, June, July, August) and mean summer temperature trends. Both calculations provided a sense of changing climatic conditions experienced in the upper portions of the lower Colorado River watershed. I used monthly precipitation totals to calculate a Standard Precipitation Index (SPI) for the area in order to document abnormally wet and dry periods within the region (McKee, Doesken, and Kleist 1993, 1995; Agnew 2000). Developed in 1993, SPI is a tool designed to define and monitor drought over several timescales using monthly precipitation data (McKee, Doesken, and Kleist 1993). I used a 12-month timescale because the longer period reflects stream flows, reservoir levels, and groundwater levels and because the 12-month SPI is similar to the Palmer Severity Drought Index (WMO 2012). The index is calculated by fitting long-term, monthly precipitation data to a cumulative probability function with a range of 3 to -3 (Hayes et al. 1999), where a drought event begins when the SPI is continuously negative and reaches an intensity of -1.0 or less and ends when the SPI becomes positive (WMO 2012).

3.3.1.2 Lake and river characteristics

Lakes Buchanan and Travis – the two largest lakes in the system – serve as water storage for the basin. Today, annual water releases from Lake Buchanan feed the irrigation districts in the lower reaches of the river, and water stored in Lake Travis supplies water to the nearby residents of Austin and other central Texas urban populations. Lake levels are an important indicator of the basin's available water supply. As such, I gathered historical lake level information from the LCRA and calculated mean summer averages for both lakes Buchanan and Travis.

The timing and availability of water is critical to rice farmers in the valley. Rice farmers plant crops in mid to late March, and by late April, they flood irrigate their rice fields. Flood irrigation is needed until a week to ten days before harvest, which usually begins in late July. After the initial harvest, rice fields may be flood irrigated again to produce a second (or ratoon) crop. Thus, the rice-growing season dictates the timing of water releases. Water must be available to rice farmers by late April or early May and remain available until late August. In dry years when river flows are low, rice farmers depend on water releases from Lakes Buchanan and Travis in the Highland Lakes system.

I collected mean daily river discharge from the U.S. Geological Survey (USGS) for the period of record (1916-2016) at station site 08161000, corresponding to the Colorado River at Columbus, Texas. I selected this location for two reasons. First, it has a long period of record and sustained data coverage. Second, it is located in Colorado County upriver from the majority of rice farms, and therefore, river flow at this location is less likely to be the result of return flows from ongoing flood irrigation. I analyzed the river flow data using The Nature Conservancy's Indicators of Hydrologic Alteration (IHA), Version 7.1 (2009a). Specifically, I used IHA's calculations of Environmental Flow Components (EFCs) as a proxy measure for hydrological drought in the region. IHA calculates five EFCs: extreme low flows, low flows, high flow pulses, small floods, and large floods (The Nature Conservancy 2009b). Research ecologists use the EFCs to monitor flow regimes in rivers in an effort to assess river functions for the maintenance of dependent ecosystems (Richter et al. 1996). For the purposes of my research, I documented periods of extreme low flow because of its potential impact on rice farming operations. Extreme low flows correspond to the 10th percentile of all low flows (Mathews and Richter 2007). Thus, periods of extreme low flow correspond to hydrological drought and limit water available for flood irrigation. I also documented large floods to provide information on their frequency compared to normal and extreme low flow periods. Large floods correspond to flows that were equal to or greater than the 10-year flood (Mathews and Richter 2007).

3.3.1.3 Water usage information

Information on water use was critical to this research. I obtained water use information from the Texas Water Development Board (TWDB) annual estimates of water use. The TWDB conducts an annual survey of groundwater and surface water use by municipal and industrial entities within Texas. It also collects groundwater and surface water use estimates for irrigation, livestock, and mining. The TWDB issues municipal and industrial surveys annually. The TWBD surveys approximately 4,500 public water systems and 2,500 industrial water users. If selected, the Texas Water Code requires water entities to complete and return the survey in 60 days. The TWDB uses the information gathered through their annual water survey to estimate the amount of water used for municipal, manufacturing, and steam-electric power. It also estimates water used for mining and in secondary processes for oil and gas recovery. The TWDB compiles agricultural water uses from a variety of sources. The TWDB uses annual livestock population estimates produced by the Texas Agricultural Statistics Service (TASS) and estimated water use per animal unit based on research conducted by the Texas Agricultural Experiment Station (TAES) to estimate water used for livestock estimates. The TWDB has used two sources to estimate water used for agricultural irrigation. The TWDB calculated estimates before 2001 using annual crop acreage from the Natural Resources Conservation Service (NRCS) and estimates for 2001 and later using annual crop acreage from the Farm Service Administration (FSA). I collected water use data for each year the estimates were available, beginning in 1984 and ending in 2014.

3.3.1.4 Agricultural characteristics

Agriculture production, particularly rice farming, plays an important role in the economies of the lower basin counties. Water from the Highland Lakes system feeds the irrigation districts, and many rice farmers depend on the surface water releases to flood irrigate their first and second rice crops. Yet, continued urbanization has resulted in less water for agricultural communities (OECD 2012; Wagner 2012). Because of the relationship between water, agricultural production, and the lower counties' economies as well as increasing urban pressure on agricultural water sources, I gathered data related to agricultural production in Fayette, Colorado, Wharton, and Matagorda counties. I collected data related to farming operations and harvested field crops. Since rice is the primary crop in the agricultural counties and is a water intensive crop, I primarily focused on rice. I looked at rice acres harvested and the amount of rice produced. I also calculated rice share of the acres harvested in the counties from 1970 to 2015. I gathered all agricultural information from agricultural censuses conducted by either the U.S. Census Bureau or the U.S. Department of Agriculture's (USDA) National Agricultural Statistical Service (NASS).

The U.S. Census Bureau collected agricultural data from 1840 to 1996. In 1997, the U.S. Congress passed the responsibility for conducting the agricultural census to the USDA's NASS. The NASS conducts the agricultural census every 5 years. It also conducts surveys each year on agricultural production, economics, demographics, and the environment in order to provide annual estimates of important agricultural markers. I gathered data from both surveys and censuses.

3.3.1.5 <u>Population and income characteristics</u>

In addition to climate change, the literature suggests that growing population and commitments to sustaining economic growth drive competition for water resources and that both influence water management and allocation decisions. As such, I gathered population data and per capita personal income (PCPI) information for each county in the study area. I collected county population data and annual population estimates for the years 1970 to 2014 from the U.S. Census Bureau (USCB). I used the population data to calculate county population growth during the study period. I gathered annual PCPI estimates from the U.S. Bureau of Economic Analysis (USBEA). Personal income reflects income received from all sources. The BEA calculates PCPI by dividing personal income by county population derived from annual USBC population estimates. I used the BEA's PCPI as a proxy for county economic growth over the study period.

3.3.2 Quantitative analysis

From the data gathered, I produced an environmental geography of water use and access in the study area from 1970 to 2015. In order to do so, I developed annual time series data sets for each continuous variable collected and analyzed them using statistical analyses. From this, I documented changes in water use and access among urban and agricultural water interests over space and time in an effort to describe the relationship between these interests vis-à-vis changing political, social, economic, and environmental characteristics (after Bakker and Veldkamp 2012; Julian et al. 2012; Jawarneh, Julian, and Lookingbill 2015). I examined the times series data sets using descriptive statistics in order to describe spatiotemporal trends and patterns. I further analyzed the times series data sets using times series analysis to identify significant spatiotemporal changes. Specifically, I used the change point model (CPM) framework to derive important quantitative periods of change relative to the distribution of and competition for water resources between urban and agricultural water interests. I characterized each period of change relative to its dominant, quantitatively-derived characteristics. Then, in the qualitative portion of this research, I used these quantitative periods of change as a starting place to examine public discourses and access mechanisms.

3.3.2.1 Change point detection

I used the change point model (CPM) framework to analyze a selection of the continuous time series variables. The CPM framework developed by Hawkins, Qiu, and Kang (2003) and Hawkins and Zamba (2005) identifies points at which the process that underlies a times series pattern, for a given continuous random variable, undergoes meaningful changes. These changes are detected as shifts in the location or scale parameters of the continuous variable's temporal distribution. The CPM framework was derived from control charts created to monitor industrial and operations processes for quality control via statistical process control (SPC). The goal of SPC is to detect when a process or system has gone out of statistical control (Hawkins and Zamba 2005; Ross

2015). The objectives of SPC "may include providing a signal that the process is out of control, an estimate of when it went out of control, and a diagnosis of the way in which it when out of control – for example, whether the mean shifted, the variance jumped, or either of the quantities started a slow drift" (Hawkins and Zamba 2005, 164). In industrial and operations settings, analysts use this information to diagnose the cause of the change in an effort to bring the process back under control.

Common methods for SPC have included the Shewart, the cumulative sum (cusum), and the exponentially weighted moving average (EWMA) control charts (Hawkins and Zamba 2005; Ross 2015). Shewart control charts detect shifts in mean and standard deviation. The cusum and EWMA control charts detect shifts in mean (Hawkins and Zamba 2005). These methods require that the in-control distribution be known, including the mean and variance. The in-control distribution is determined using a fixed-size sample during what is called Phase I analysis. Once the distribution is known, the process may be monitored sequentially for changes during a subsequent, Phase II analysis (Ross and Adams 2012). Yet, the in-control mean and variance of a system's process are difficult to pinpoint accurately. As such, Hawkins, Qiu, and Kang (2003) developed the CPM framework to largely bypass the need for Phase I analysis. The CPM framework analyzes all process readings to detect the presence of a change point (Hawkins, Qiu, and Kang 2003, 359). Their formulation detects a mean shift in a normally distributed random variable. The CPM framework has been amended to include analysis of nonparametric data sets as well (for example, see Ross and Adams 2012; Ross 2015).

The CPM may be conceived of as follows. For example, consider the continuous time series of annual urban water use (X_1, X_2, … X_n) and assume water use over time follows a single distribution (F_0). The change point model looks for changes in the distribution of the time series or, in this example, changes in urban water use (AFY) that deviate from the initial distribution (F_0). It does so by dividing the time series into two subseries ($x_1, x_2, \ldots x_k$) and ($x_{k+1}, x_{k+2}, \ldots x_n$), and implementing a two-sample test to determine if differences exist between the two subseries. If the differences occur in the statistical properties of the two subseries, then a change point has been located. Thus, the subseries before the change point has a distribution F_0 and the subseries after the change point has a distribution F_1, where F_0 does not equal F_1. From this, two hypotheses emerge. The null hypothesis for this example is defined as (after Hawkins and Zamba 2005; Ross 2015):

$$H_0 : X_i \sim F_0(x; \theta_0), i = 1, \ldots, n$$

where urban water use X at any given year i in the time series follows a single distribution F_0. This distribution F_0 is a function of X_i and a set of unknown parameters θ_i. The alternative hypothesis is defined as:

$$H_1 : X_i \sim \begin{cases} F_0(x;\ \theta_0) & i = 1, 2, \ldots, k \\ F_1(x;\ \theta_1) & i = k+1, k+2, \ldots, n \end{cases}$$

where urban water use X_i follows distribution F_0 with parameter θ_0 before change point k. After change point k, urban water use X_i follows distribution F_1 with parameter θ_1.

This formulation has been extended by Ross (2015) to include sequential monitoring (Phase II analysis) and detection of multiple change points via both parametric and nonparametric methods. I used the *cpm* package in R to look for change points in my continuous time series variables (Ross 2015; R Core Team 2016). Because the time series data sets were not normally distributed, I tested the null hypothesis using the Mann-Whitney *U* statistic. The *cpm* package calculates the Mann-Whitney *U* statistic using the subseries before and after every time interval, evaluating if statistically significant differences occur between each before and after subseries. If the test statistic is significant, a difference has occurred between time intervals and a change point is flagged. If a change point occurs, the *cpm* package in R returns two signals: 1) a detection time and 2) a change point. The detection time refers to "the observation at which a change point was detected" (Ross 2015, 10). The change point refers to "the maximum likelihood estimate (MLE) of the change point τ, defined as the value of k for which $D_{k,n}$ [Mann-Whitney U statistic] is maximum when $n = T$ and T is the detection time" (Ross 2015, 10). Thus, the MLE change point denotes the best estimate of the change point location.

Within the CPM framework, Average Run Length (ARL_0) corresponds to the average number of observations before a Type I Error (or false positive) occurs and is equal to $1/\alpha$. Ross (2015) used Monte Carlo simulation to determine the threshold values for a number of confidence levels in his *cpm* package. In an effort to prevent returning a false positive (i.e., detecting a false change point), I set a conservative 99.9 percent confidence level (or $ARL_0 = 1{,}000$).

The findings explicated through the collection and analysis of the variables under consideration in this portion of my study quantifies change in water use and access in the lower Colorado River basin across the study period. Yet, these findings only capture part of how water has shifted from agricultural uses to urban uses. In the next stage of my research, I use my quantitative findings as an entry point to further analyze and interpret changes in water access and control among urban and agricultural water interests in the lower Colorado River basin. Together, my analyses provide a comprehensive view of a dynamic socio-natural system in which water distribution and access is tightly intertwined with wider political, social, economic, and environmental processes.

3.4 Qualitative stage

The qualitative stage of this dissertation involved an analysis to document and evaluate discursive systems used to access water by both urban and agricultural water interests in pivotal periods of water resource management (i.e., periods of change) as initially identified in the quantitative stage. Specifically, I used a qualitative content analytic method to identify trends and changing patterns in the way access to water resources are presented in news media discourses during the study period. In this stage, I analyzed what mechanisms water interests – urban and agricultural – used to maintain, acquire, or control access to the valley's water resources. I also gave particular attention to how social, political, economic, and environmental events influenced patterns of water resource allocation and access mechanisms. In doing so, I documented a number of governance actions and transactions that affected water use and access in the basin from 1970 to 2015. Finally, I used the results of the quantitative analyses coupled with my qualitative findings to further identify periods of change in water use and access among urban and agricultural interests.

3.4.1 Qualitative data

This stage of my research involved documentation of governance actions and transactions related to water use and access and a detailed analysis of newspaper articles on or related to water resources issues in the lower Colorado River valley beginning with the first year a change point was identified in the quantitative stage. Together, the findings of my qualitative analysis further define periods of change in the relationship between urban and agricultural interests by detailing the mechanisms urban and agricultural interests used to maintain, acquire, or control the basin's water resources as these interests responded to changing water management strategies and environmental stresses.

3.4.1.1 Governance actions and transactions

Governance actions, including the sale, trade, and lease of water rights, shape spatiotemporal patterns of water use and access. Governance actions provide the structure under which authorities make water allocation decisions, and water rights provide owners with the ability to control and maintain access to water. The two are tightly linked. Those that hold water rights generally control access to water and have the power to influence policy outcomes in their favor (Boelens and Doornbos 2001). Together, both policy and those with power, ultimately determine how water resources are developed and who gets water, when, where, and for what. Because of their interconnectedness, I chose to gather governance actions and transactions related to water resources at the state and local levels and document the major water rights holders as well as identify significant water rights acquisitions in the valley. This information included legislation passed and important water development and allocation decisions made, and major water rights holdings and acquisitions via sale, trade, or lease from various sources

3.4.1.2 Newspaper articles

In this final portion of my dissertation research, I used newspaper articles as a data source in which to locate discourses on water matters. Despite inherent biases, newspaper coverage of events and issues represent a form of public discourse. They provide one of the only continuous, consistent, and ubiquitous forms of public sentiment on major local, regional, and global issues. Moreover, historic and current news media reports are widely accessible to the researcher and to the public, and newspaper accounts of events offer an important source of discourse that provides clues to the geographic context in which they were produced. Thus, evaluations of newspaper articles provide a reliable barometer of public perceptions of important issues while illuminating geographic patterns and processes.

News articles on water issues affecting the basin comprised the primary data set for this portion of the study and were collected from two prominent newspapers. In an effort to capture spatial differences between urban and agricultural portions of the study area and to key in on important differences in access mechanisms deployed by the two groups of water interests, I selected articles from an urban-centric, regional newspaper located in Austin, Texas – *The Austin American-Statesman* – and a local, bi-weekly newspaper – *The Bay City Tribune* – situated in the heart of the study area's agricultural producing region. I located articles through newspaper database searches and via microfilm (Table 7).

Table 7. List of documents, sources, and search criteria.

Newspaper	Years	Source	Search Criteria			
			Sections	***Subjects***	***Keyword***	***Length***
The Austin American-Statesman	1994-2015	LexisNexis Academic	News or Main	water rig! OR water reso! OR water su! OR farm! OR rice farm!	Colorado River	>800 words
The Bay City Tribune	1994-2000	Microfilm	Front, 2nd, and 3rd pages	Water issues	None	Any
	2001-2015	NewsBank	News	water rig! OR water reso! OR water su! OR farm! OR rice farm!	Colorado River	Any

I gathered articles from *The Austin American-Statesman* using LexisNexis Academic via a series of targeted searches. LexisNexis Academic maintains complete, searchable archives of *The Austin American-Statesman* from 1989 to present. I collected articles from *The Bay City Tribune* from NewsBank via similar search criteria. NewsBank houses archives of *The Bay City Tribune* from 2001 to present. I acquired news articles prior to 2001 from the Bay City Public Library in Bay City, Texas. The library holds historical archives of *The Bay City Tribune* on microfiche. I collected relevant articles by viewing the front, second, and third pages of each edition.

In order to settle on suitable search terms for each newspaper, I conducted a series of preliminary searches, using a variety of keyword combinations related to water resources. I used searches in LexisNexis Academic for *The Austin American-Statesman* to refine my search criteria. I initially conducted searches using broad search terms. After each search, I surveyed the articles and noted in which sections detailed articles on the water resources of the lower Colorado River valley appeared and where less detailed articles appeared. More detailed and comprehensive articles appeared in the "News," "Main," or "Metropolitan" sections of *The Austin American-Statesman.* Less detailed articles appeared with recurring headlines, such as "Central Texas Digest," "Letters," and "Metro." These articles were typically short and focused on hyper-local water issues, such as boil water notices. Additionally, LexisNexis Academic categorizes articles based on primary subjects contained in the article (e.g., "water resources"). I noted subjects of interest that appeared in articles about the water resources of the lower Colorado River valley. I further refined my searches using key subjects, such as "water resources," "water rights," and "rice farming." My iterative searches returned between 28,310 and

4,340 articles. After each successive search, I continued to review a selection of articles for their overall relevance to water issues in the basin. My final search criteria yielded 945 articles in *The Austin American Statesman* between 1994 and 2015 (Table 7). I further reduced the number of articles by eliminating articles with fewer than 800 words, and the final group of articles from *The Austin American Statesman* consisted of 336 articles. I employed a similar search method to retrieve relevant articles from *The Bay City Tribune*; however, due to the relatively small sample size, I did not limit the length of articles and did not search by subject. The final group of articles from 2001 to 2015 consisted of 156 articles. Articles retrieved from microfilm searches totaled 56. Figure 12 provides a breakdown of articles per year and newspaper. My final database contained 548 articles (Figure 13).

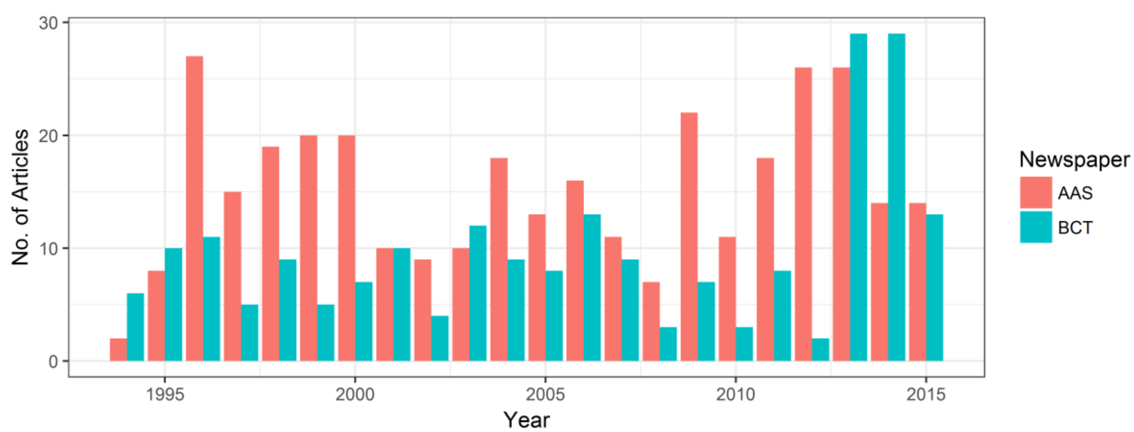

Figure 12. Articles by year from *The Austin American-Statesman* and *The Bay City Tribune.*

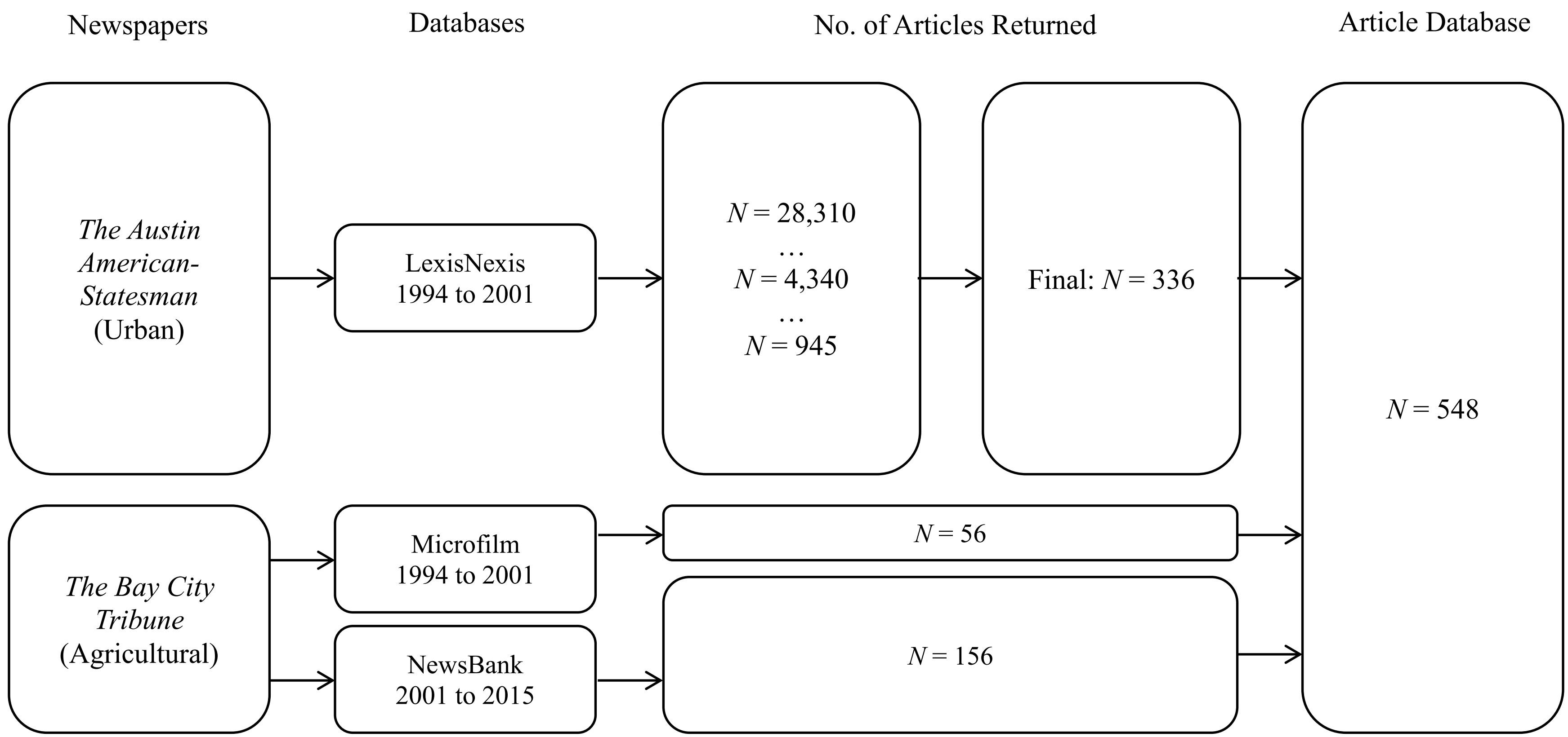

Figure 13. Flowchart describing collection of news articles for qualitative analysis.

3.4.2 Qualitative analysis

My qualitative analysis focus on providing an interpretation of how public discourses used by urban and agricultural interests define periods of change in water use and access and how these discourses are influenced by wider governance actions and transactions as well as environmental stresses. As such, I detailed local- and state-level governance actions and transactions through a narrative description. In this way, the description provides context in which to situate and interpret content found in the newspaper articles.

3.4.2.1 Qualitative content analysis

The bulk of my qualitative analysis, however, centers on analyzing public discourses found in newspaper articles. I used qualitative content analysis to examine the news articles. Content analysis is a form of qualitative analysis used to examine and interpret textual material. Specifically, content analysis produces "replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use" (Krippendorff 2004, 18). Data is derived from the text under analysis and is coded into categories in an effort to find patterns and extract overarching themes (Hsieh and Shannon 2005). While there are many different content analytic research techniques, I used a deductive, qualitative content analytic approach (Mayring 2000). Qualitative content analysis outlines "an approach of empirical, methodological controlled analysis of texts within their context of communication, following content analytical rules and step by step models, without rash quantification" (Mayring 2000, 2). The deductive approach or directed content analysis uses existing theory to "to validate or extend conceptually a theoretical framework or theory" (Hsieh and Shannon 2005, 1281). Under this approach, the text corpus under analysis is connected to a theoretical framework, and the goal of the analysis is to assign a category (derived from the theoretical framework) to a predetermined textual unit (Mayring 2000). In this way, qualitative content analysis provides an orderly, step by step process to describe the meaning of qualitative data via a coding frame derivative of a theory (Hsieh and Shannon 2005; Schreier 2014). The coding frame "is at the heart of the method, and it contains all those aspects that feature in the description and interpretation of the material" (Schreier 2014, 170). The coding frame and coding categories reduce the amount of material, allowing dominant themes to emerge without being hindered by specifics. Moreover, this approach leads to a higher level of abstraction, providing a basis on which to compare different portions of the text (Schreier 2014, 170).

Because this portion of the dissertation employs a qualitative content analysis and not a quantitative content analysis, the primary objective is not to quantify the contents of the news articles; rather, the goal of this portion was to determine key components of access, namely who was participating, how were water resources being accessed, and what do these trends disclose about the changing landscape of water allocation in the basin. It is also important to emphasize that this portion of my research is not a study of how issues related to water resources are covered by news media nor is it a study of the media's role in disseminating information relative to water resources; instead, it uses news media coverage of water issues to ascertain, explicate, and compare the mechanisms water interests deployed to acquire, maintain, or control water access. Therefore, this portion of the research is limited to what the news media reported in two newspapers and to the access mechanisms included in the news media coverage.

For the purposes of this portion of my dissertation, I derived a coding structure from Ribot and Peluso's (2003) theory of access and other factors affecting water allocation, including population growth, economic development, and climate change (OECD 2015) as well as factors specific to the water distribution in the lower Colorado River valley. Together, these theoretical and conceptual frameworks provided the thematic organization for coding news media discourse relative to water resources and access mechanisms. Accordingly, the coding framework allowed me to pinpoint, return, and interpret information relevant to evaluating the extent to which political, social, economic, and environmental events influenced patterns of access and to compare water interest groups' narratives of access. I developed a codebook that details the step-by-step process I used to analyze news media discourse relative to water resource access. The codebook provides the coding structure for analyzing newspaper articles on water resources in the valley (See Appendix for Coding Manual). I used the qualitative data analysis software ATLAS.ti for Mac, version 1.5.3 (2017), to code newspaper articles.

4 QUANTITATIVE RESULTS

This chapter presents the results of my quantitative analyses. First, I document spatial and temporal changes of conceptual variables under analysis in order to illustrate an environmental geography of water resources in the lower Colorado River valley. Next, I present the results of the CPM analysis and offer three periods of change relative to distribution of the basin's water resources. I end with a discussion of my findings and offer concluding remarks. Overall, my analyses – both descriptive and statistical analyses of fluctuating time series data – reveal a basin attempting to balance the distribution of water against the competing demands of urban population growth and continued economic development, all of which are influenced by recurring statewide and regional droughts.

4.1 Water usage information

Urban and agricultural demands and, to a lesser extent, power production demand drives water use in the lower Colorado River valley. Yet, important spatial differences and temporal patterns emerge. This section presents both spatial and temporal patterns of water use by demand and source (i.e., surface water and groundwater) at the county scale. I primarily explain differences and trends observed in municipal and agricultural annual water use, but where necessary, I discuss important distinctions that arise in water use across counties in the study area. Finally, I group the counties in the study area into two groups – 1) urban counties and 2) agricultural counties – based on the observed water consumption patterns.

4.1.1 Spatial and temporal patterns

From 1984 to 2014, the counties in the lower Colorado River valley average annual water use equaled 155,126 acre-feet per year (AFY). Together, the six counties drew roughly two thirds of their water from surface water resources in the valley, and the remaining third, they pulled from groundwater sources. Peak water consumption in the study area occurred in 1988 (1,242,845 AF), and in general, combined water consumption in the study area has trended downward with a few anomalies (Figure 14). In particular, water consumption spiked in 2011 (1,181,772 AF), and in 2014, water use reached its lowest point of the study period (591,498 AF).

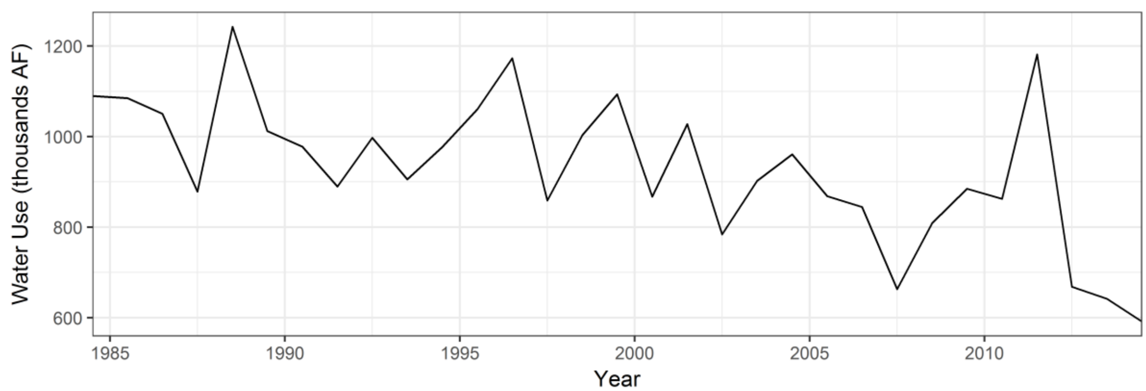

Figure 14. Water use (combined surface water and groundwater) in thousands of acre feet (AF) in the study area from 1984 to 2014.

Annual water use varied greatly by individual county (Table 8). The downstream counties of Colorado, Wharton, and Matagorda used the most water annually. Wharton County had the highest annual water usage (306,616 AFY) followed by Matagorda (223,908 AFY) and Colorado (190,131 AFY) counties. Colorado and Matagorda counties predominately drew water from surface water sources, whereas Wharton County pulled from groundwater and surface water resources almost equally. Water consumption has also steadily declined in these counties. Peak water usage for Wharton County occurred in 1988 (466,687 AF), for Matagorda County in 1995 (341,588 AF), and for Colorado County in 1985 (278,596 AF) followed closely by 1988 (276,097 AF).

Table 8. Mean annual water usage, standard deviation (SD) for mean annual water usage, and total water usage measured in acre feet (AF) per county from 1984 to 2014.

	All water demands (AF)					
	Groundwater			***Surface water***		
County	***M***	***SD***	***Total***	***M***	***SD***	***Total***
Travis	13,988	4,866	433,624	155,785	28,544	4,829,322
Bastrop	10,163	3,700	315,044	5,342	1,495	165,605
Fayette	3,980	492	123,381	18,549	8,036	575,015
Colorado	34,573	10,390	1,071,750	155,558	48,662	4,822,299
Wharton	155,431	33,453	4,818,350	153,481	56,944	4,757,908
Matagorda	33,306	11,086	1,032,492	190,602	64,121	5,908,653

Upstream, the most populated county, Travis, ranked fourth in average annual water use (169,772 AFY). Travis County relies mostly on surface water sources. Since 1984, water consumption in Travis County has been steadily increasing. Peak water demand in Travis County occurred in 2011 (234,968 AF), which was almost double its low usage in 1987 (122,884 AF). Finally, Fayette (22,529 AFY) and Bastrop (15,505 AFY) counties used considerably less water annually than their upstream and downstream neighbors. Bastrop County water usage peaked in 2011 (28,398 AF) with a low in 1986 (10,670 AF). Fayette County's water usage has been mostly steady throughout the study period with its peak in 2011 (56,543 AF).

4.1.2 Municipal demands

Across the six counties in the study area, those with larger populations (Table 9) devote more of their water resources to cover growing municipal water demand (Table 10). Municipal demand primarily drives water use in the two upstream, more populated counties of Travis and Bastrop. From 1984 to 2014, municipal water use in Travis County averaged 147,566 AFY. The average municipal share of water in Travis County during this time was 86.8 percent. Travis County pulls much of its municipal water from surface water sources (92 percent), including from the Colorado River and waters impounded in the Highland Lakes system. Lakes Travis and Austin, just north of Austin, serve as the primary sources for municipal water use in Travis County and, in particular, the city of Austin. In Bastrop County, annual municipal water use is much lower (8,250 AFY) but still accounts for the majority (53.8 percent) of water demand. Most of this water, however, originates from groundwater sources. Bastrop County sits on top of the Carrizo-Wilcox Aquifer.

Table 9. County population as of the 2010 U.S. Census.

County	*2010 Population*
Travis	1,030,443
Bastrop	74,336
Fayette	24,538
Colorado	20,877
Wharton	41,316
Matagorda	36,721

Table 10. Mean annual water usage, standard deviation (SD) for mean annual water usage, and total water usage measured in acre feet (AF) for municipal demand per county from 1984 to 2014.

	Municipal (AF)					
	Groundwater			***Surface water***		
County	***M***	***SD***	***Total***	***M***	***SD***	***Total***
Travis	11,971	4,218	371,098	135,595	26,580	4,203,440
Bastrop	8,249	2,134	255,716	1	2	35
Fayette	3,168	250	98,197	1	8	42
Colorado	3,038	255	94,164	0	0	0
Wharton	6,206	313	192,395	0	0	1
Matagorda	5,088	425	157,720	0	2	12

The four downstream, primarily agricultural counties of Fayette, Colorado, Wharton, and Matagorda devoted much less of their total annual water usage for municipal purposes than their upstream neighbors (Table 10). Annual municipal water use in Fayette County averaged 3,169 AFY, an amount equal to 16 percent of its annual water use. The municipal share of annual water use in Colorado (1.8 percent), Wharton (2.1 percent), and Matagorda (2.5 percent) counties was smaller. In all cases, these four counties drew more than 99 percent of their municipal water from groundwater sources (i.e., the Gulf Coast Aquifer).

4.1.3 Irrigation demands

Irrigation demand drives water use in the three downstream counties (i.e., Colorado, Wharton, and Matagorda counties) (Table 11). From 1984 to 2014, irrigation water use in Colorado County averaged 163,830 AFY, and the irrigation share of water used during this time averaged 86.4 percent annually. Wharton County devoted almost 97 percent of its annual water use to irrigation with an average amount equal to 299,960 AFY. The irrigation share of water used in Matagorda County was slightly lower at 77.2

percent annually. Yet, irrigation water demand averaged 178,611 AFY. Of the three downstream counties, Wharton County used an equal amount of surface water and groundwater for irrigation, whereas Colorado and Matagorda counties pulled irrigation water mostly from surface water resources.

Table 11. Mean annual water usage, standard deviation (SD) for mean annual water usage, and total water usage measured in acre feet (AF) for irrigation demand per county from 1984 to 2014.

	Irrigation (AF)					
	Groundwater			***Surface water***		
County	***M***	***SD***	***Total***	***M***	***SD***	***Total***
Travis	853	609	26,441	1,852	2,012	57,422
Bastrop	989	1,394	30,661	347	344	10,754
Fayette	406	332	12,583	306	223	9,475
Colorado	28,561	10,653	885,399	135,269	39,751	4,193,326
Wharton	147,971	33,300	4,587,105	151,989	56,053	4,711,656
Matagorda	23,316	11,905	722,811	155,295	70,143	4,814,143

Conversely, the irrigation share of water used in Travis (1.5 percent) and Bastrop (7.4 percent) counties made up a relatively minor proportion of their annual water use. Travis County's average irrigation water use during the study period was 2,705 AFY, and Bastrop's was 1,336 AFY. Fayette County devoted the least amount of water for irrigation purposes. It averaged 712 AFY of water for irrigation.

4.1.4 Power generating demands

Outside of municipal and irrigation water demands, power production processes also compete for the valley's water resources (Table 12). Approximately 17.2 percent of Matagorda County's annual water demand arises from power production. This demand comes primarily from the South Texas Project Electric Generating Station (STPEGS). A nuclear power facility, STPEGS lies along the banks of the Colorado River between Bay City and the Matagorda Bay estuary system. Operations at STPEGS came online in 1988. The facility generates 2,700 megawatts of energy via two pressurized water reactors. It maintains a 7,000-acre (2,800 ha) cooling water reservoir on its premises and holds Colorado River water rights equal to 102,000 AFY (STPEGS 2017).

Table 12. Mean annual water usage, standard deviation (SD) for mean annual water usage, and total water usage measured in acre feet (AF) for power generating demand per county from 1984 to 2014.

	Power Generation (AF)					
	Groundwater			***Surface water***		
County	***M***	***SD***	***Total***	***M***	***SD***	***Total***
Travis	19	37	578	5,112	2,081	158,468
Bastrop	110	611	3,400	3,992	1,351	123,737
Fayette	3	5	86	16,294	8,136	505,115
Colorado	0	0	0	0	0	0
Wharton	0	0	0	0	0	0
Matagorda	1,125	348	34,866	30,418	23,731	942,970

In Fayette County, steam-electric power generation consumes most of its annual water supply (69 percent). The majority of which is pulled from surface water sources (96.4 percent). Annual water share for municipal (16 percent) and irrigation (3 percent) purposes come in a distant second and third, respectively. The primary consumer of water in Fayette County is the Fayette Power Project (FPP). A three-unit coal-fired power plant, FPP produces around 1,636 megawatts of electricity. Austin Energy, Austin's publicly-owned utility provider, and the LCRA co-own two of the three units. The LCRA owns the third unit (LCRA 2017b).

4.1.5 Other demands

Manufacturing facilities, livestock operations, and mining operations also vie for the basin's water resources (Table 13). A number of sand and gravel mining operations exist in Colorado County. These operations mostly rely on surface water. In Travis and Matagorda counties, manufacturing facilities use both surface and groundwater in their production processes.

Table 13. Mean annual water usage, standard deviation (SD) for mean annual water usage, and total water usage measured in acre feet (AF) for other demands per county from 1984 to 2014.

	Others (Manufacturing, livestock, and mining) (AF)					
	Groundwater			***Surface water***		
County	***M***	***SD***	***Total***	***M***	***SD***	***Total***
Travis	1,145	421	35,507	13,226	3,435	409,992
Bastrop	815	658	25,267	1,003	165	31,079
Fayette	404	138	12,515	1,951	248	60,469
Colorado	2,974	703	92,187	20,289	13,231	628,973
Wharton	1,253	677	38,850	1,492	1,427	46,250
Matagorda	3,777	1,907	117,095	4,888	2,255	151,528

4.1.6 Urban versus agricultural water use

For the purposes of this research, I divided counties in the study area into two groups – 1) urban and 2) agricultural counties – based on the county-level water consumption patterns presented above. Travis and Bastrop counties make up the urban counties group. Both counties predominantly used water for municipal purposes. Fayette, Colorado, Wharton, and Matagorda counties comprise the agricultural counties group. The counties of Colorado, Wharton, and Matagorda used water primarily for agricultural purposes. Fayette County is somewhat of an outlier. The majority of its water use has historically gone to power generation operations. Because a small proportion of its water use is devoted to municipal purposes, however, I included Fayette County with the agricultural counties.

Total water consumption – from both groundwater and surface water supplies – in the urban counties of Travis and Bastrop has increased during the study period (Figure 15 A) and in the agricultural counties of Fayette, Colorado, Wharton, and Matagorda, water consumption has declined (Figure 16 A). Water use in urban counties peaked in 2011 (263,366 AF) and reached a low in 1987 (134,369 AF). Similarly, water consumption in agricultural counties climaxed in 1988 (1,094,249 AF) and hit a low in 2014 (386,041 AF). From 2011 to 2012, water use declined 52 percent in the agricultural counties. This represents the greatest annual percentage decline over the course of the study period. During the same period, water consumption in urban counties declined by only 14 percent. Surface water and groundwater usage has increased in the urban counties (Figure 15 B and C). Per capita water use in urban counties, however, declined slightly over the study period (-1.67 percent) (Figure 15 D). Surface water use in agricultural counties decreased (Figure 16 B). Agricultural counties used groundwater at a consistent rate with lower annual usage in the mid-2000s (Figure 16 C). Per capita water consumption in agricultural counties fell (-2.95 percent) (Figure 16 D). Urban counties increased their share of water from a low of 12 percent in 1988 to a high of 35 percent in 2014 (Figure 15 E). Yet, agricultural counties consumed the majority of water in the basin (Figure 16 E).

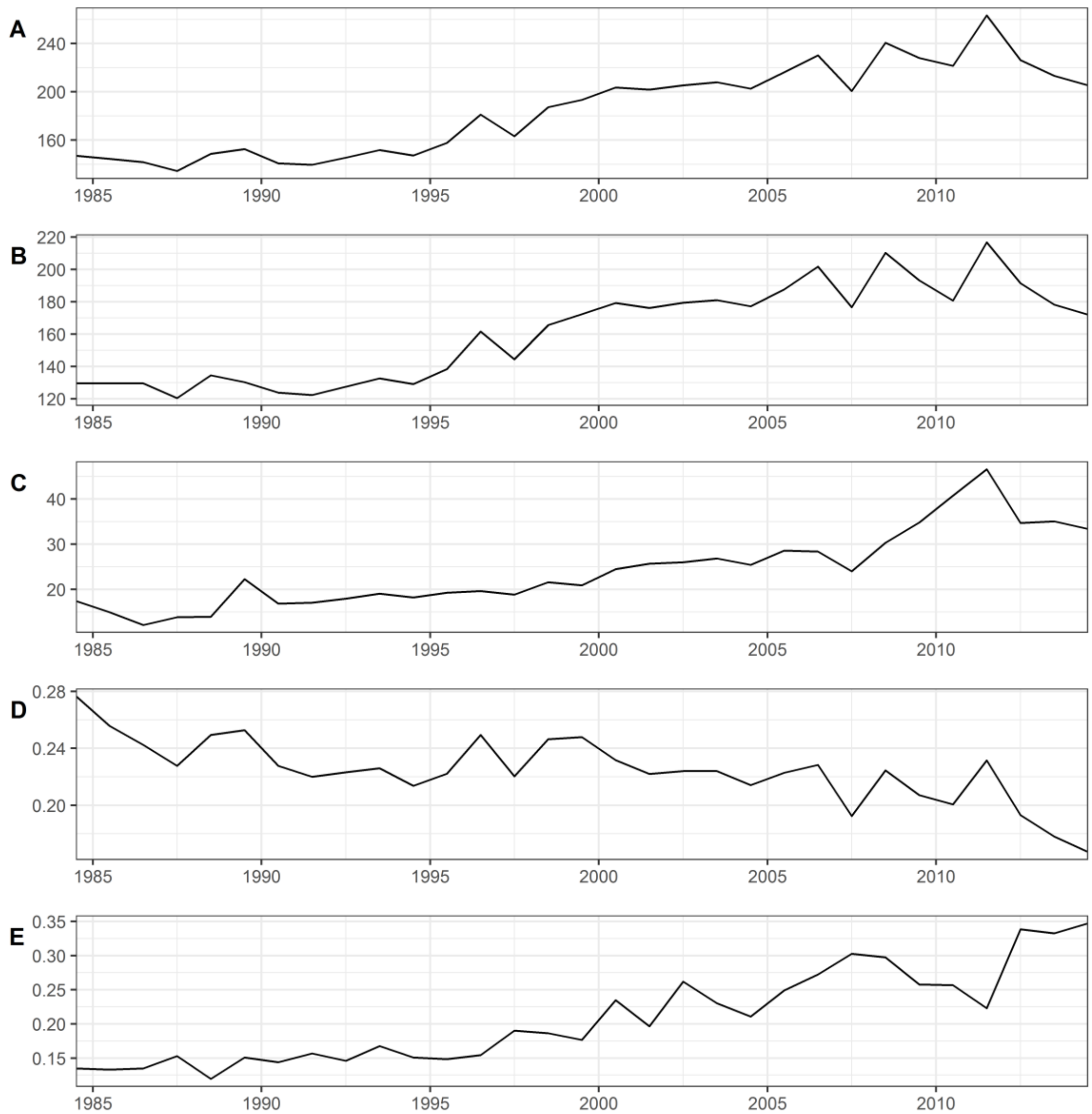

Figure 15. Annual water use by urban counties from 1984 to 2014: A) total, B) surface water, C) groundwater measured in thousands of acre feet (000s AF); D) per capita water use measured in acre feet (AF); and E) proportion of total water used.

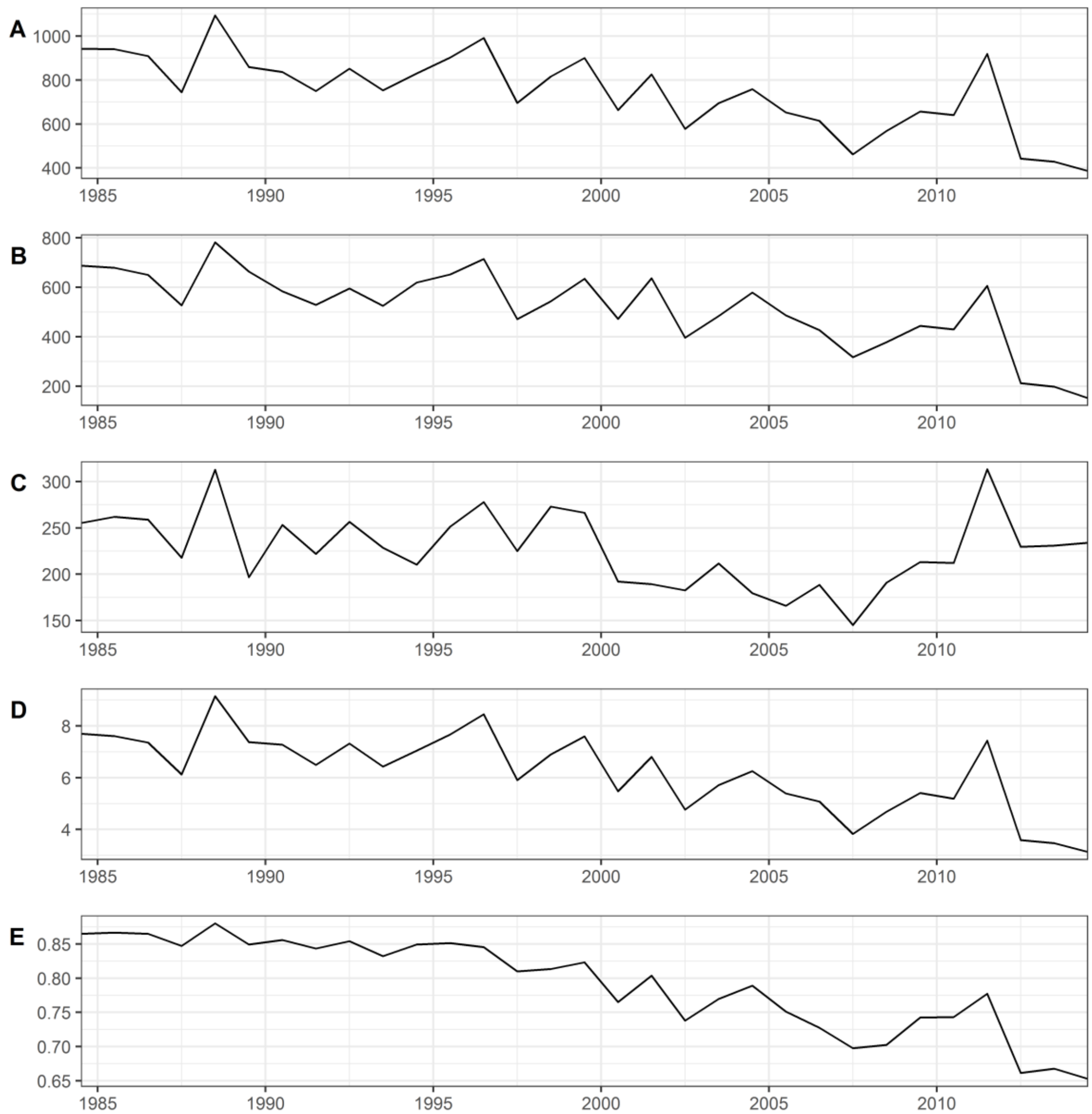

Figure 16. Annual water use by agricultural counties from 1984 to 2014: A) total, B) surface water, C) groundwater measured in thousands of acre feet (000s AF); D) per capita water use measured in acre feet (AF); and E) proportion of total water used.

4.2 Population and income characteristics

Population in urban counties increased during the study period (Figure 17 A). Both Travis and Bastrop counties had an average annual growth rate above 3 percent for the years 1970 to 2014. Travis County, home to Austin the Capital of Texas, is the study area's most populated county. In 2014, Travis County had a population of 1,229,214. From 1970 to 2014, urban counties increased their share of the study area's population from 76 percent to 91 percent. Population in agricultural counties remained relatively flat in comparison to urban counties (Figure 17 B). The average annual growth rate for the four agricultural counties was below 1 percent. Agricultural counties share of the study area's population declined from 24 percent in 1970 to 9 percent in 2014.

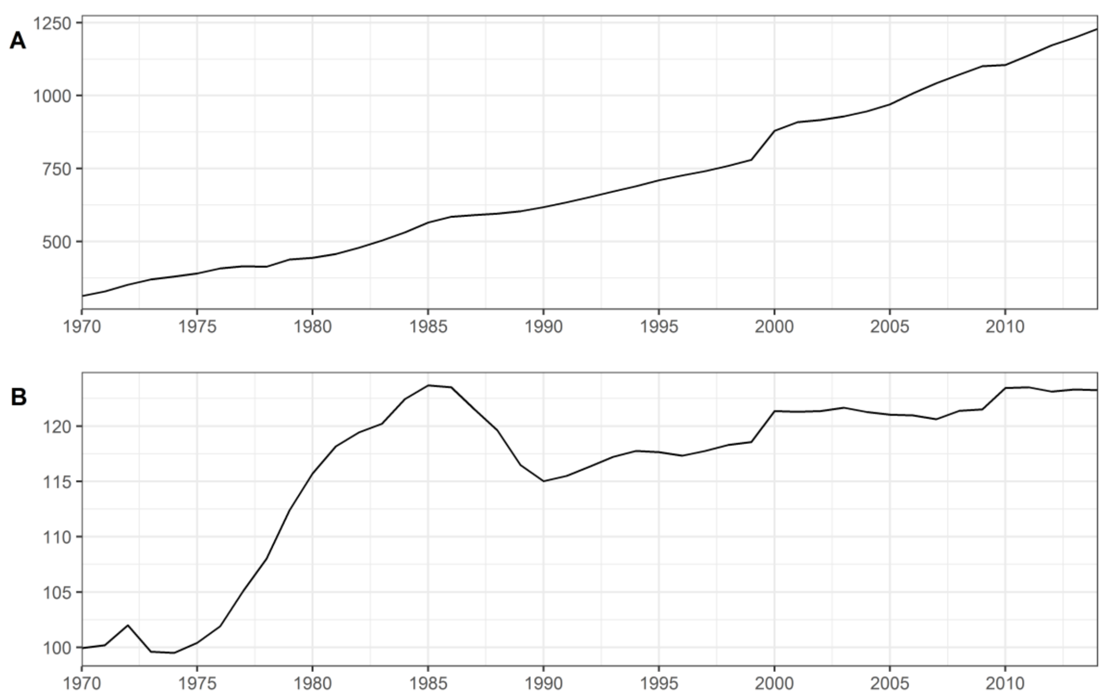

Figure 17. Population growth measured in thousands (000s) from 1970 to 2014 in A) urban counties and B) agricultural counties.

Measures of wealth also vary between the urban and agricultural counties. Personal income in Travis and Bastrop counties has increased exponentially over the study period. In 2014, the counties of Travis and Bastrop had a total personal income of USD $64,701,254. The agricultural counties had a total personal income of USD $5,158,099. Per Capita Personal Income across the counties is more closely aligned. In 1970, PCPI equaled USD $3,126 in urban counties and USD $2,628 in agricultural counties. By 1984, PCPI totaled USD $42,265 in urban counties and USD $42,696 in agricultural counties.

4.3 Lake and river characteristics

Lakes Buchanan and Travis function as water storage reservoirs and provide water for municipal, industrial, agricultural, and environmental uses throughout the lower Colorado River valley. The LCRA manages the lakes together as one system, and they hold around 2.01 million AF of water. Of this amount, 434,154 AF per year is reserved for firm water supply, and under normal conditions, up to 278,500 AF per year is available for interruptible supply contracts, operating in the Gulf Coast, Lakeside, and Pierce Ranch irrigation operations (LCRA 2015b).

The LCRA considers Lake Travis full when its elevation reaches 681 feet above mean sea level (amsl). At this level, Lake Travis impounds 1,134,956 AF of water. On 25 December 1991, it reached a historic high of 710.44 feet amsl, and on 14 August, 1951 it reached a historic low at 614.18 feet amsl (LCRA 2017c). Lake Buchanan reaches capacity when waters climb to an elevation of 1,020 feet amsl, with Buchanan Dam holding back 875,588 AF of water. Lake Buchanan fell to a historic low of 983.7 feet amsl on 9 September 1952 and reached a historic high of 1,021.4 feet amsl on 20 December 1991 (Table 14) (LCRA 2017a).

Table 14. Lowest lake levels for lakes Travis and Buchanan (LCRA 2017a, 2017c).

	Lowest Lake Travis Elevations			*Lowest Lake Buchanan Elevations*		
Rank	***Drought***	***Date***	***Height (ft amsl)***	***Drought***	***Date***	***Height (ft amsl)***
1	1947-57	Aug. 14, 1951	614.18	1947-57	Sept. 9, 1952	983.7
2	1963-64	Nov. 8, 1963	615.02	2008-16	Sept. 20, 2013	985.27
3	2008-16	Sept. 20, 2013	618.64	1963-64	Sept. 20, 1964	986.63
4	1983-84	Oct. 7, 1984	636.58	1983-84	Oct. 7, 1984	987.97
5	1999-2000	Oct. 15, 2000	640.24	1999-2000	Oct. 15, 2000	994.73
6	2005-06	Dec. 13, 2006	643.55	2005-06	Jan. 1, 2007	997.97

During the study period, lake levels varied from year to year (Figure 18). The average annual lake level for Lake Buchanan varied from a low of 988.26 amsl in 2014 to a high of 1,018.82 amsl in 1987 (Figure 18 A). The average summer lake level (May, June, July, and August) for Lake Buchanan fluctuated from an average low of 989.16 in 2013 to an average high of 1,018.99 in 1976 (Figure 18 B). Lake Travis reached its average annual low (626.25 feet amsl) in 2014 and its high (682.04 feet amsl) in 1992 (Figure 18 C). The average summer lake level for Lake Travis fluctuated from a low of 626.14 feet amsl in 2013 and a high of 684.21 feet amsl in 1997 (Figure 18 D).

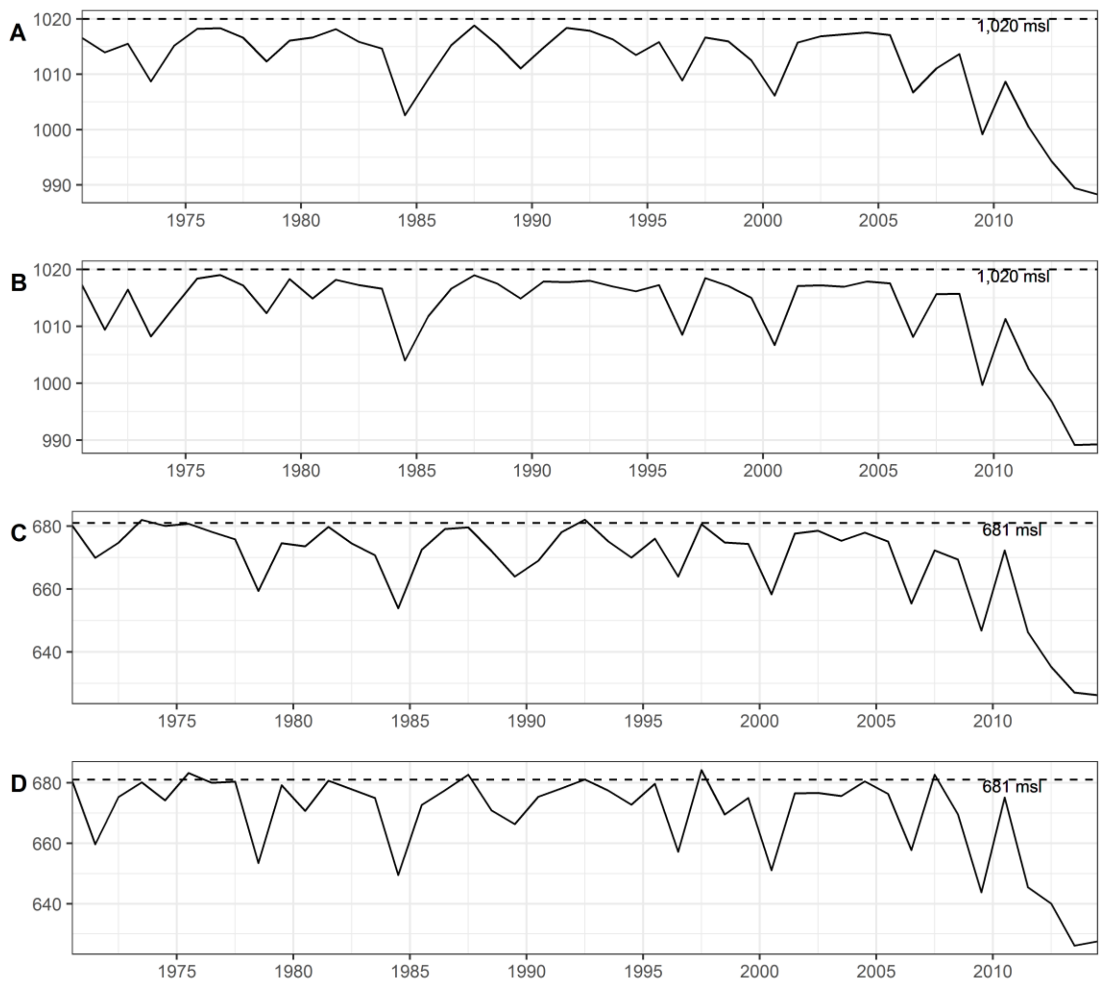

Figure 18. Lake Buchanan A) annual mean level and B) annual summer level and Lake Travis C) annual mean level and D) annual summer level from 1970 to 2014. Each lake level measured in feet above mean sea level (msl). Dashed line represents the level (msl) when the lake is at capacity.

Discharge measurements on the Colorado River at Columbus, Texas, are highly variable. Calculations of IHA's Environmental Flow Components after 1960 returned a number of flood events and extended periods of extreme low flow (Figure 19). Until 2011, extreme low flow periods ended around April, coinciding with the beginning of the rice crop season. After 2011, extreme low flow periods extended into the first and second crops seasons. Mean summer (May, June, July, and August) discharge exhibits a similar trend. The lowest discharge readings occurred in 2012 (444 cfs), 2013 (744 cfs), and 2014 (1,042 cfs). The highest mean summer discharge rate occurred in 2007 (9,931 cfs) (Figure 20). The average mean summer discharge for the study period is 3,258 cfs. Omitting the top five highest and lowest discharge years, the Colorado River averaged a mean summer discharge of 2,761 cfs.

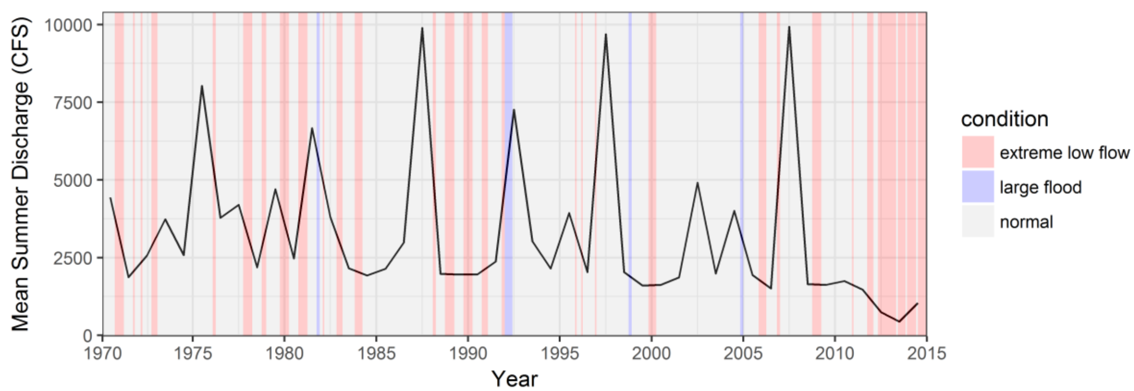

Figure 19. Mean annual summer discharge (cfs) on the Colorado River near Columbus, Texas, from 1970 to 2014 overlaid against IHA calculations for periods of extreme low flow, large floods, and normal conditions.

4.4 Climate-related indicators

Central Texas summer (May, June, July, and August) temperatures increased over the study period (Figure 20 A). The Austin area recorded its lowest summer temperatures in the 1970s. In 1983, the average summer temperature was 76.2 degrees Fahrenheit. The warmest temperatures in Austin have occurred in the latter fourth of the study period. The average summer temperatures in 2008, 2006, and 2011 were 82.3 degrees Fahrenheit, 83 degrees Fahrenheit, and 84 degrees Fahrenheit, respectively. Maximum summer temperatures follow similar trends (Figure 20 B). The highest maximum summer temperature reached 99.1 degrees Fahrenheit in 2011.

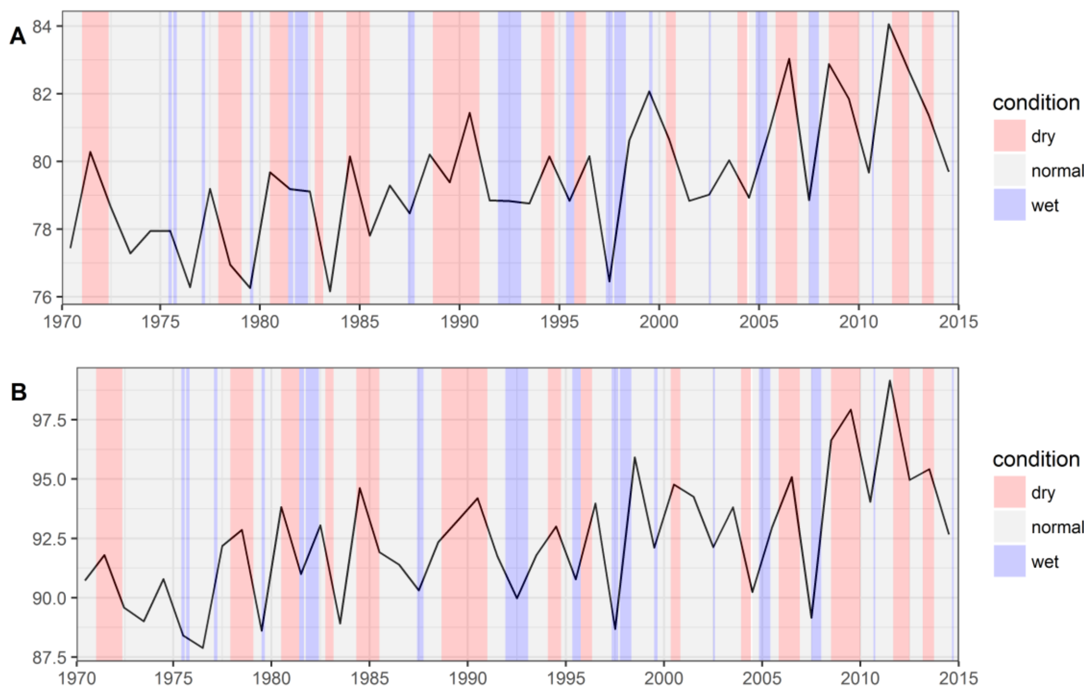

Figure 20. A) Mean summer temperature and B) mean summer maximum temperature measured in degrees Fahrenheit from 1970 to 2014 overlaid on SPI calculations for normal, dry, and wet periods.

The region also witnessed a number of wet and dry periods (see Figures 20 A and B). Calculations from the SPI indicated severe dry periods in the early and late 1970s as well as the early 2000s and early 2010s. Additionally, extended dry periods occurred from 1970 to 1972, 1988 to 1990, and 2008 to 2009. The SPI results also showed a number of short duration wet periods with more sustained wet periods from 1991 to 1993, 1997 to 1998, and most recently, 2015 to 2016.

4.5 Agricultural characteristics

The number of farms in the agricultural counties fluctuated throughout the study period (Table 15). It is difficult to compare agricultural census farm counts after 2002 with previous censuses. In 2002, the USDA implemented a new methodology to count the number of farms in the United States. The USDA reweighted the 1997 counts to enable comparability between 2002 and 1997; however, they did not reweight prior census counts (USDA 2004). Despite this correction and before NASS implemented its new calculation techniques, the number of farms in the four agricultural counties declined from 1969 to 1997. Farm counts reached a low of 5,700 in 1982 but rose slightly to 6,336 in 1997. Under the adjusted calculation technique, the total number of farms also declined from 1997 to 2012. Yet, the number of farms in Matagorda and Wharton counties declined, whereas the number of farms in Fayette and Colorado counties increased. The number of farms in Matagorda and Wharton counties reached their highest count in 1969 before experiencing a gradual decline. Fayette and Colorado counties gained farms from 1969 to 2012, after low counts in 1974 and 1978.

Table 15. Number of farms by agricultural census (*calculated using new method).

Census Year	*Fayette*	*Colorado*	*Wharton*	*Matagorda*	*Total*
1969	2,708	1,410	2,005	902	7,025
1974	2,368	1,295	1,413	753	5,829
1978	2,379	1,289	1,328	704	5,700
1982	2,610	1,424	1,258	703	5,995
1987	2,750	1,589	1,272	721	6,332
1992	2,642	1,547	1,273	738	6,200
1997	2,659	1,562	1,347	768	6,336
1997*	2,994	1,767	1,564	885	7,210
2002*	2,973	1,770	1,538	991	7,272
2007*	2,991	1,790	1,506	903	7,190
2012*	2,882	1,575	1,553	856	6,866

The total annual field crop production also declined (Figure 21 A). From 1970 to 1982, the total field crops (i.e., corn, cotton, rice, sorghum, and soybeans) harvested in the agricultural counties grew to a high of 629,800 acres. Since 1982, total field crops harvested have decreased reaching a low of 290,400 acres in 1987. Both rice yield and acres of rice harvested decreased from highs in the early 1980s. Rice farmers harvested a record number of acres in 1981 (196,600 acres). Since 1981, the number of rice acres harvested declined to a low of 26,600 acres in 2014 (Figure 21 B). Rice production reached a high of 10,364,000 cwt in 1981 and lows of 2,616,000 cwt, 2,371,200 cwt, and 2,125,000 cwt in 2012, 2013, and 2014, respectively (Figure 21 C). Rice yield corresponds to the number of acres harvested. Similarly, the rice proportion of total field crops harvested declined. In 1970 and 1971, rice acres harvested accounted for almost half of the total field crops harvested (Figure 21 D). Yet, by 1999 the proportion of rice acres harvested dropped below 30 percent.

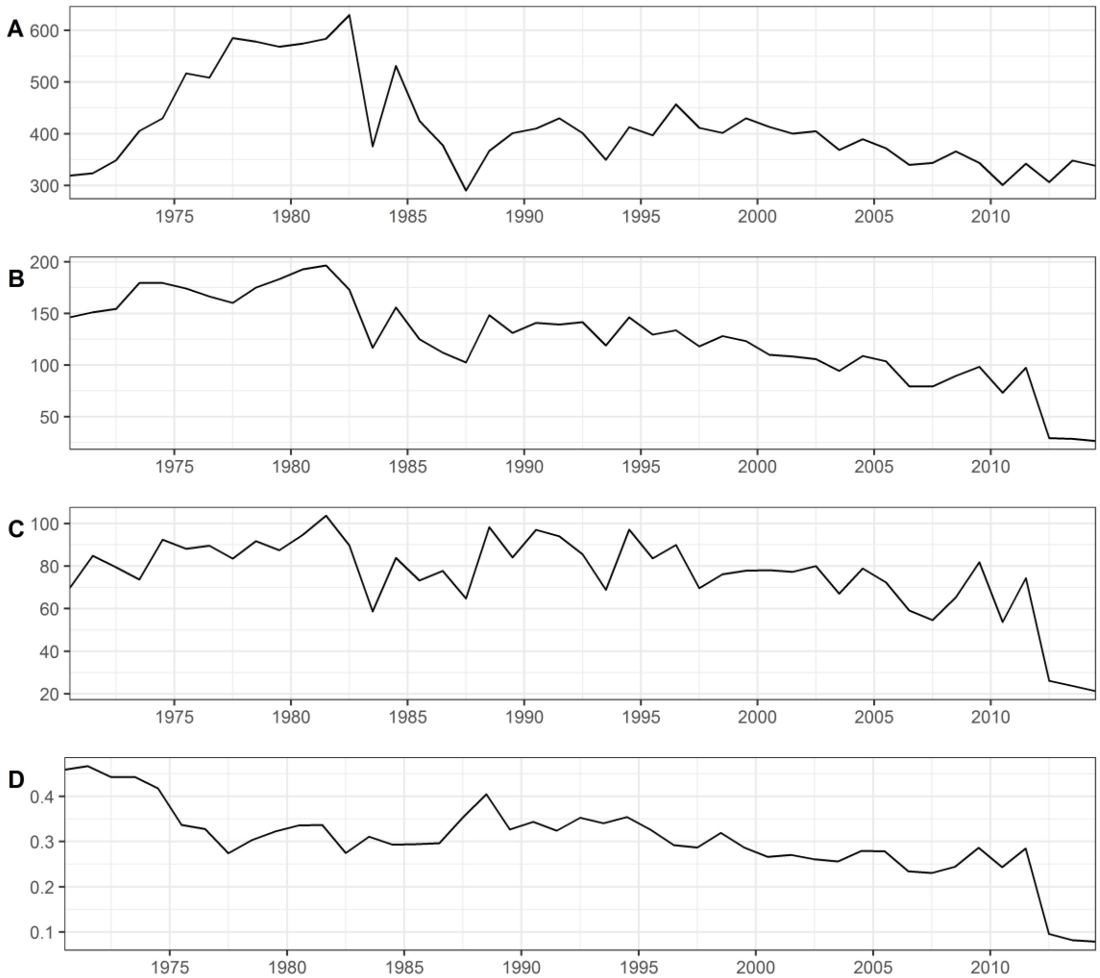

Figure 21. Annual agricultural characteristics by agricultural counties from 1984 to 2014: A) total annual field crop acres harvested, B) rice acres harvested measured in thousands of acres harvested (000s acres), C) rice production measured in thousands of hundredweights (000s cwt), and D) rice proportion of total field crop acres harvested.

4.6 Change points

The change point model offered a more analytically-replicable, data-driven method to discern salient periods of change in the water use and access in the lower Colorado River valley. Results of the CPM analysis of time series variables detected a number of annual change points (Table 16). The first change point occurred in 1974 and the last in 2007. The CPM returned no change point for urban counties per capita water use. For the remaining variables, the CPM analysis returned at least one change point. Multiple change points were detected in two variables: 1) rice acres harvested (1982 and 1999) and 2) rice share of the total field crops harvested (1974 and 1995).

Table 16. Results of the CPM analysis with the year(s) a change point was detected within time series variables.

Conceptual variables	***Operational variables***	***Units***	***Change points (year)***
Climate-related indicators	Annual mean maximum temperature	degrees Fahrenheit	1997
	Summer mean maximum temperature	degrees Fahrenheit	1997
Lake and river characteristics	Lake Buchanan (annual mean level)	feet	2005
	Lake Buchanan (summer mean level)	feet	2005
	Lake Travis (annual mean level)	feet	2005
	Lake Travis (summer mean level)	feet	2007
	Mean summer river discharge	CFS	2007
Water usage information	Urban counties water use	thousands AFY	1994
	Surface water use	thousands AFY	1994
	Groundwater use	thousands AFY	1997
	Water use per capita	thousands AFY	none
	Water share	proportion	1996
	Agricultural counties water use	thousands AFY	1999
	Surface water use	thousands AFY	2001
	Groundwater use	thousands AFY	1999
	Water use per capita	thousands AFY	1999
	Water share	proportion	1996
Agricultural characteristics	Total field crops harvested	acres	2002
	Rice harvested	acres	1982, 1999
	Rice produced	cwt	1996
	Rice share of harvest	proportion	1974, 1995

4.6.1 Climate-related indicators

For both climate-related variables, the results of the CPM analysis rejected the null hypothesis. The critical value of *U* was exceeded and reached a maximum value in 1997, indicating a shift occurred in the times series data sets for the mean annual maximum and the mean maximum summer temperature (Figure 22 A and B). Since 1997, temperatures in central Texas increased.

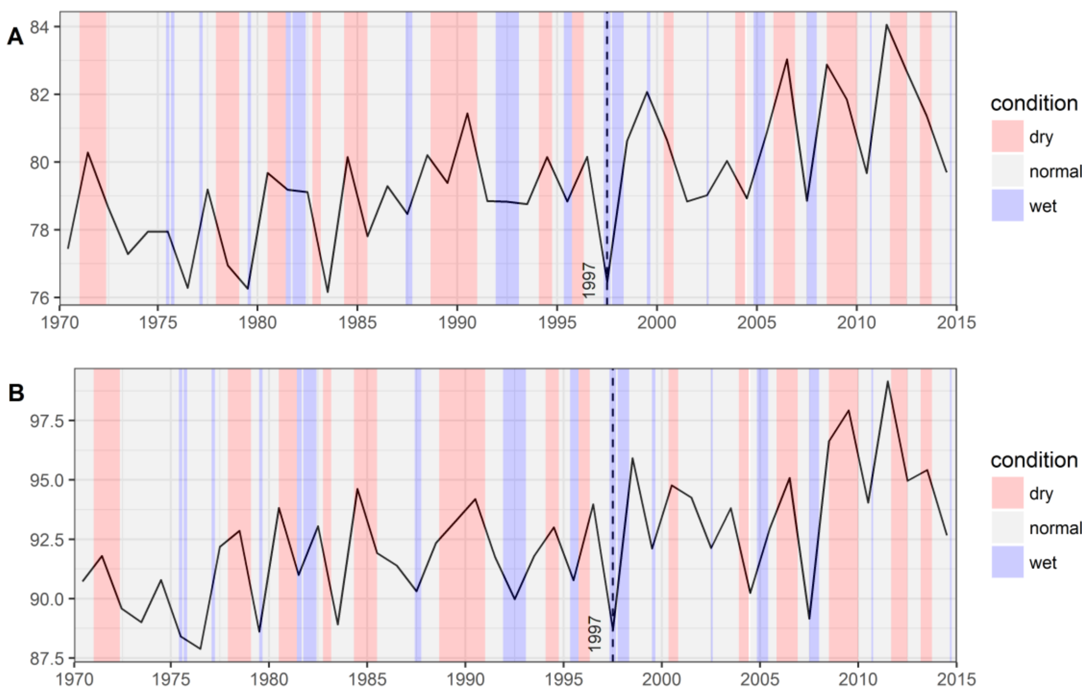

Figure 22. Change points for climate-related indicators: A) mean annual maximum temperature and B) mean maximum summer temperature measured in degrees Fahrenheit.

4.6.2 Lake and river characteristics

The null hypothesis was rejected for all lake and river characteristics tested. The annual mean levels for lakes Buchanan and Travis exceeded critical values for *U* in 2005 (Figure 23 A and C). The summer mean level for Lake Buchanan signaled in the same year (Figure 23 B). Yet, critical values of *U* for Lake Travis's summer mean level (Figure 23 D) and for the mean summer river discharge (Figure 24) near Columbus, Texas, were exceeded two years later in 2007. All significant shifts in the times series data sets detected by the CPM indicated decreases in the lake levels and river discharge.

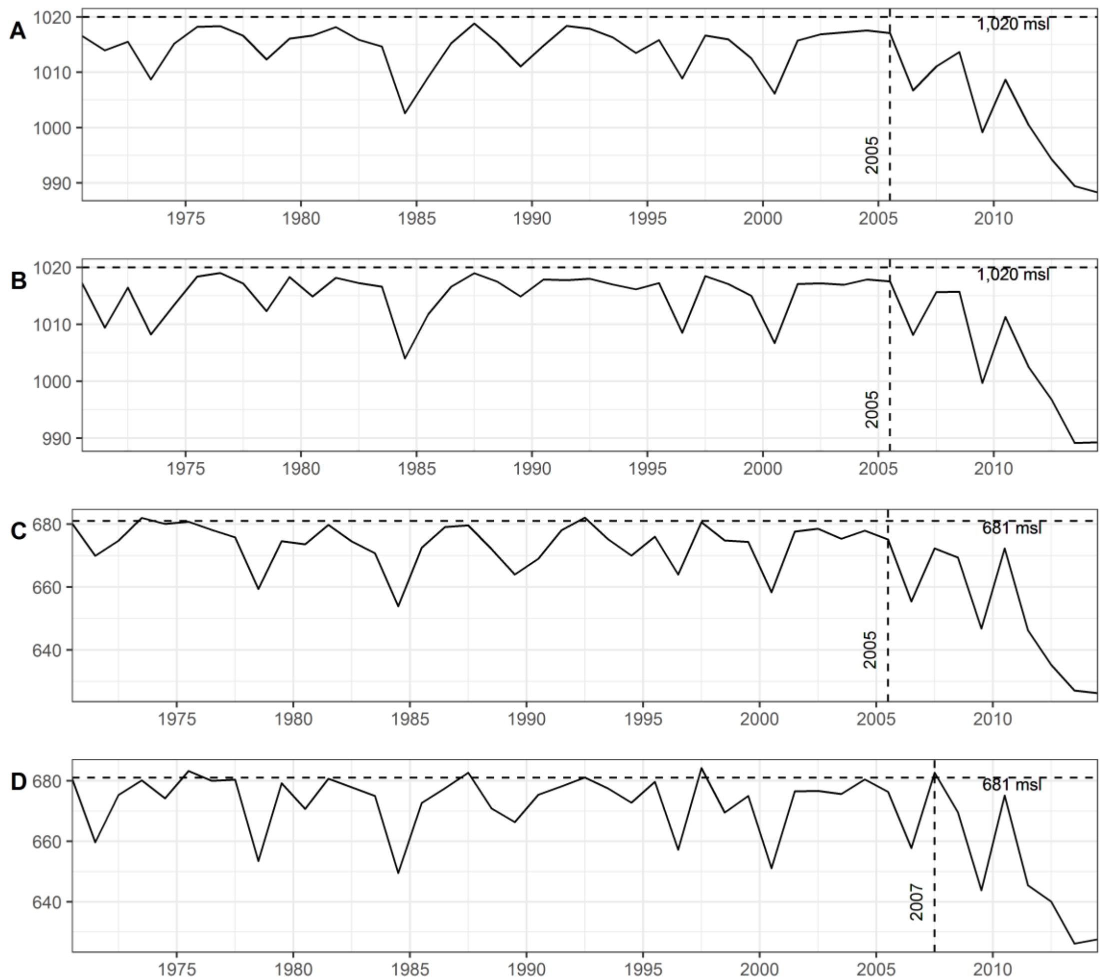

Figure 23. Change points for lake characteristics: Lake Buchanan A) annual mean level and B) annual summer level and Lake Travis C) annual mean level and D) annual summer level from 1970 to 2014. Each lake level measured in feet above mean sea level (msl). Horizontal dashed line represents the level (msl) when the lake is at capacity.

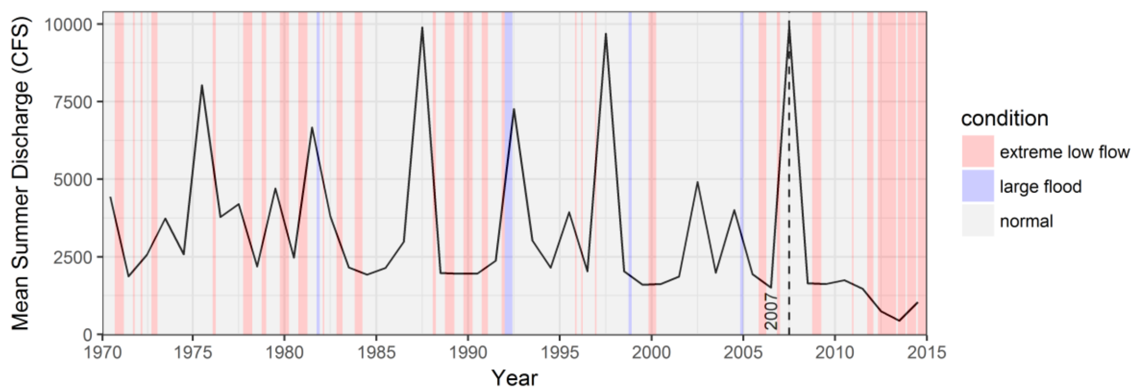

Figure 24. Change point for river characteristics: Mean annual summer discharge (CFS) on the Colorado River near Columbus, Texas, from 1970 to 2014 overlaid against IHA calculations for periods of extreme low flow, large floods, and normal conditions

4.6.3 Water usage information

Critical values of *U* were exceeded for a number of the water usage variables and the null hypothesis was rejected. Urban counties water use (from groundwater and surface water sources) signaled in 1994, indicating an increase in water usage (Figure 25 A). Surface water use by urban counties also returned a change point in 1994, corresponding to increasing usage (Figure 25 B). Similarly, groundwater use in urban counties reached its maximum *U* value in 1997 (Figure 25 C). Per capita water usage in urban counties failed to reject the null hypothesis; however, per capita consumption generally declined during the study period (Figure 25 D). Urban counties share of water signaled in 1996, marking the point where urban counties began to increase their consumption of the basin's water resources and the decline of the agricultural counties water consumption (Figure 25 E). Agricultural counties water consumption declined during the study period. Water use, groundwater use, and water use per capita reached maximum *U* values a couple of years later in 1999 (Figure 26 A, C, and D, respectively), paralleling decreased water usage. Surface water use signaled two years later in 2001 (Figure 26 B).

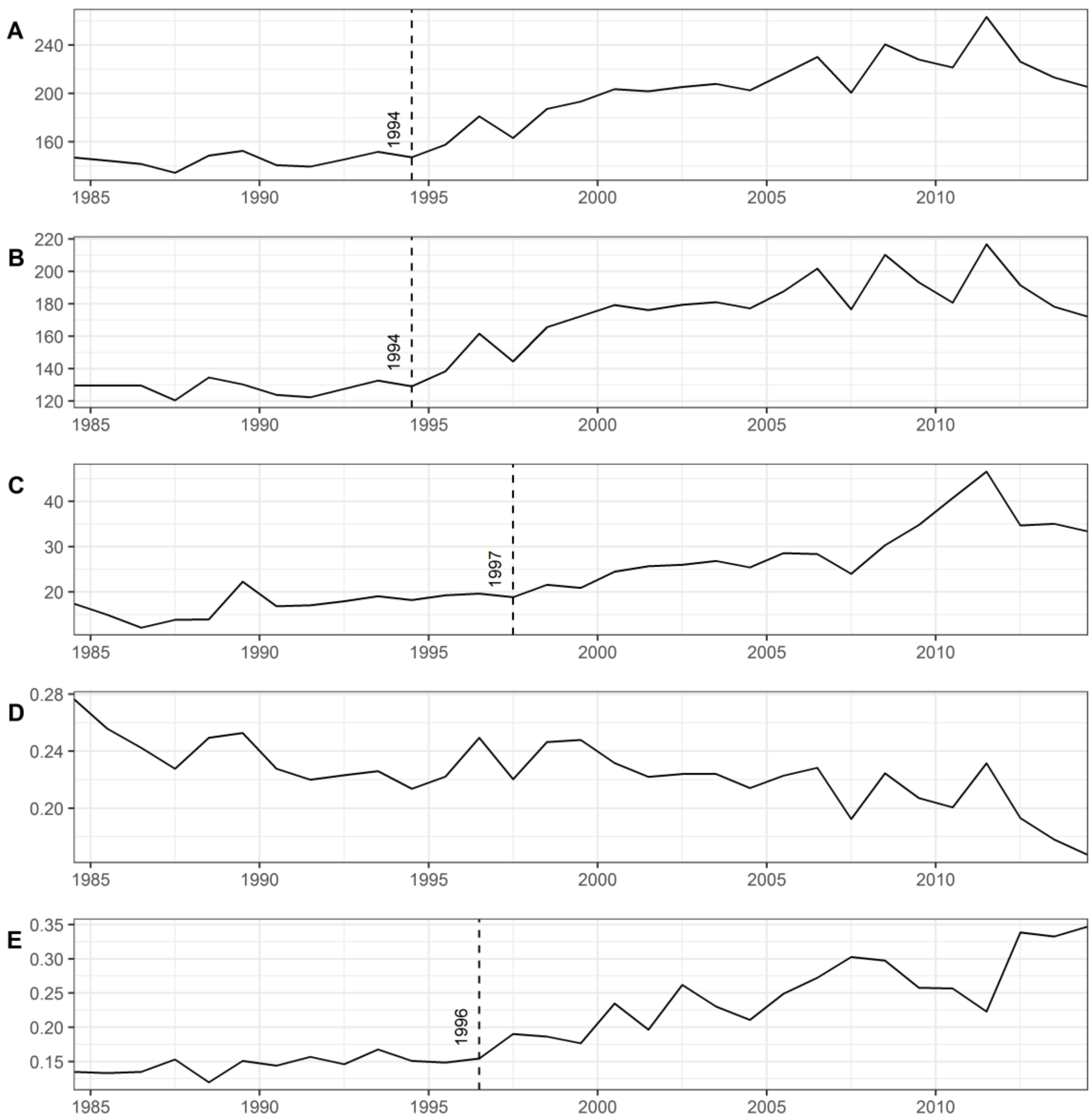

Figure 25. Change points for annual water use by urban counties from 1984 to 2014: A) total, B) surface water, C) groundwater measured in thousands of acre feet (000s AF); D) per capita water use (no change point detected) measured in acre feet (AF); and E) proportion of total water used.

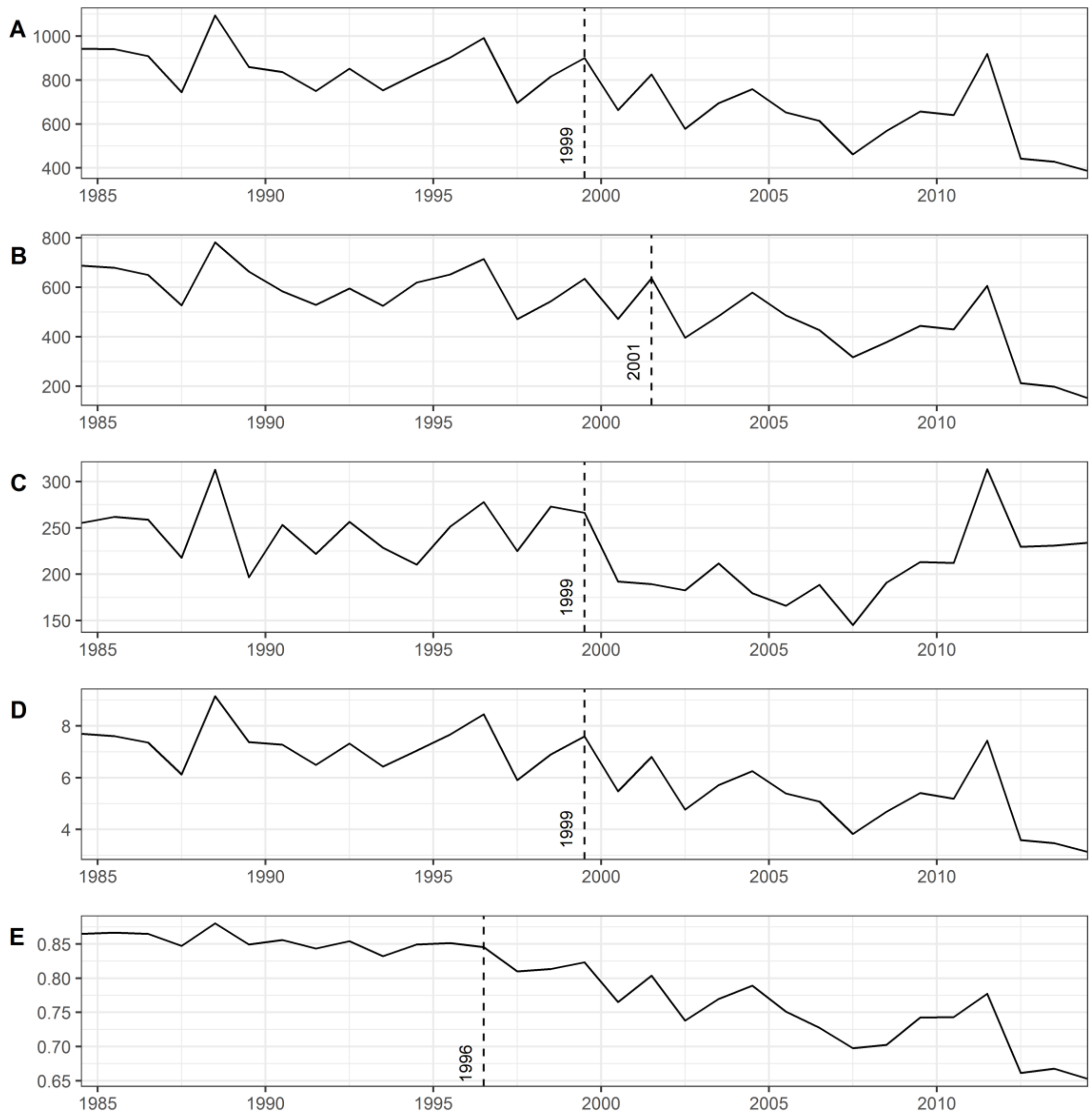

Figure 26. Change points for annual water use by agricultural counties from 1984 to 2014: A) total, B) surface water, C) groundwater measured in thousands of acre feet (000s AF); D) per capita water use measured in acre feet (AF); and E) proportion of total water used.

4.6.4 Agricultural characteristics

A number of change points occurred in the agricultural variables. Agricultural production in the valley has ebbed and flowed but, in general, has declined since 1970. The critical value of *U* was exceeded and reached a maximum value in 2002, signaling a downward shift in total crop acres harvested (Figure 27 A). Rice acres harvested signaled in 1982 and 1999, revealing three successive periods of decline (Figure 27 B). Similarly, the proportion of rice harvested to other field crops harvested signaled in 1974 and 1995, showing three periods of decline (Figure 27 D). In 1996, the critical value of *U* was passed, and the amount of rice produced declined after a relatively stable period (Figure 27 C).

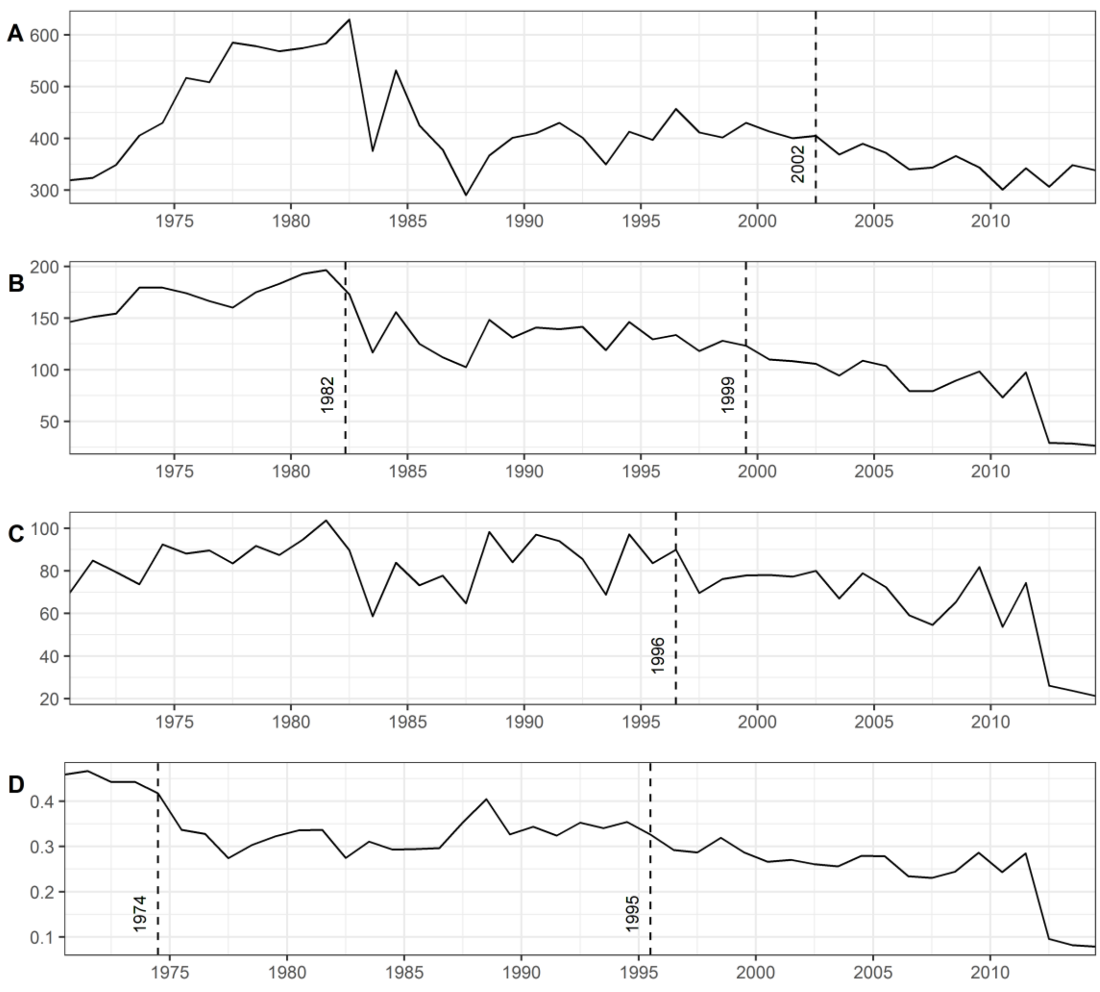

Figure 27. Change points for annual agricultural characteristics by agricultural counties from 1984 to 2014: A) total annual field crop acres harvested, B) rice acres harvested measured in thousands of acres harvested (000s acres), C) rice production measured in thousands of hundredweights (000s cwt), and D) rice proportion of total field crop acres harvested.

4.7 Quantitative periods of change

The results of the CPM analyses allowed me to further define spatial patterns of water use between urban and agricultural water interests while locating significant temporal changes in water use. Based on the CPM results, I initially grouped variables with coincidental annual change points (i.e., those that occurred close together) in an effort to identify periods of change in water use and access for further examination. I deemed the early change points detected in the agricultural variables as outliers and did not included in the identification of periods of change for this analysis. Three distinctive groupings of change points emerged beginning in 1994 (Table 17). Increasing water use by urban counties and a shift in local climate conditions characterized the first period. Declines in both agricultural counties water use and crop production defined the second period of change. Significant drops in lake levels, lower river discharge, and an extended dry period marked the third period. Thus, the results of the quantitative portion of my research demonstrate the utility of the CPM analysis to detect significant changes in water use and consumption. By grouping coincidental change points, I was able to define periods of change for further examination in the qualitative stage of my study.

Table 17. Groupings of change points identified as periods of change in water use and access.

Period of change	*Time series variable*	*Change point (year)*
Period 1 (1994 to 1997)	Urban counties water use	1994
	Urban counties surface water use	1994
	Rice share of harvest	1995
	Urban counties water share	1996
	Rice produced	1996
	Annual mean maximum temperature	1997
	Summer mean maximum temperature	1997
	Urban counties groundwater use	1997
Period 2 (1999 to 2002)	Agricultural counties water use	1999
	Agricultural groundwater use	1999
	Agricultural water use per capita	1999
	Rice harvested	1999
	Agricultural Counties surface water use	2001
	Total field crops harvested	2002
Period 3 (2005 to 2007)	Lake Buchanan (annual mean level)	2005
	Lake Buchanan (summer mean level)	2005
	Lake Travis (annual mean level)	2005
	Lake Travis (summer mean level)	2007
	Mean summer river discharge	2007

4.8 Discussion and conclusions of quantitative findings

For this portion of my study, I gathered a set of conceptual variables and analyzed them in order to provide an environmental geography of water use and access in the lower Colorado River valley from 1970 to 2015. Specifically, I examined many of the variables under consideration using descriptive statistics and the change point model.

Using information from the set of conceptual variables, I documented general spatiotemporal trends relative to water use in the basin and revealed the interconnectedness between variables. Overall, water use decreased in the basin; however, demand increased in dry periods but significant declines in urban and agricultural water use occurred after 2011. Urban counties water use continually increased while agricultural counties consumption decreased. Yet, agricultural counties still use the majority of the basin's water resources. Urban counties increased their share of the valley's population, placing more demand on water resources. Population growth in agricultural counties peaked in 1985 and leveled off thereafter, and the amount of farms in agricultural counties declined, leading to increases in urban counties share of water.

Additionally, warming temperatures and increasing dry periods affected lake levels and to some extent river discharge. Lake level declines were partially a function of the drought. The LCRA, however, contributed to the lake level declines when they fulfilled all interruptible contracts in 2011. The result of these releases, without adequate rainfall to fully recover lake capacities, contributed to the diminishment of the region's available water supply. Additionally, the LCRA's decision to cut off water to agricultural interests in 2012, 2013, 2014, and 2015, caused the significant, extended periods of low flow beginning in 2012. These actions are further detailed in the qualitative findings.

Finally, the CPM results showed a number of change points in variables occurred in near each other. By grouping change points, three quantitative periods of change emerge and suggest, beginning in 1994, urban water uses were on the rise, followed by declines in agricultural water usage, before, the basin entered into an extended period of water scarcity. I refine and extend these periods of change in the following chapter.

5 QUALITATIVE FINDINGS

In the preceding chapter, I documented spatial and temporal trends of water use in the basin through a descriptive analysis of basin-wide water usage characteristics, lake level information, agricultural production measurements, and population and income characteristics. I then analyzed a number of these variables using the change point model (CPM) (Ross 2015). I used the results from these two analyses to identify changes in water use as well as changes in who uses water and for purposes. From the quantitative results, three distinct periods emerged (Table 17). I used these quantitative periods as a foundation for further inquiry. In the following chapter, I present the findings of my qualitative analyses. First, I provide a description of the primary governance actions and transactions that took place during the study periods. Next, I document access mechanisms through a qualitative content analysis of newspaper articles in *The Austin American-Statesman* and *The Bay City Tribune*.

5.1 Governance actions and transactions

During the study period from 1970 to 2015, a number of local, regional, and state water management proposals, decisions, and actions shaped the distribution and allocation of water resources in the lower Colorado River basin (Figure 28). In this section, I provide an overview of the predominant proposals, decisions, and actions undertaken in the basin. Instead of providing a chronology of major governance and management actions, I group them into three primary themes: 1) state water legislation and planning, 2) regional water management strategies, proposals, and decisions, and 3) water rights purchases and water resource contracts undertaken in the lower Colorado River basin.

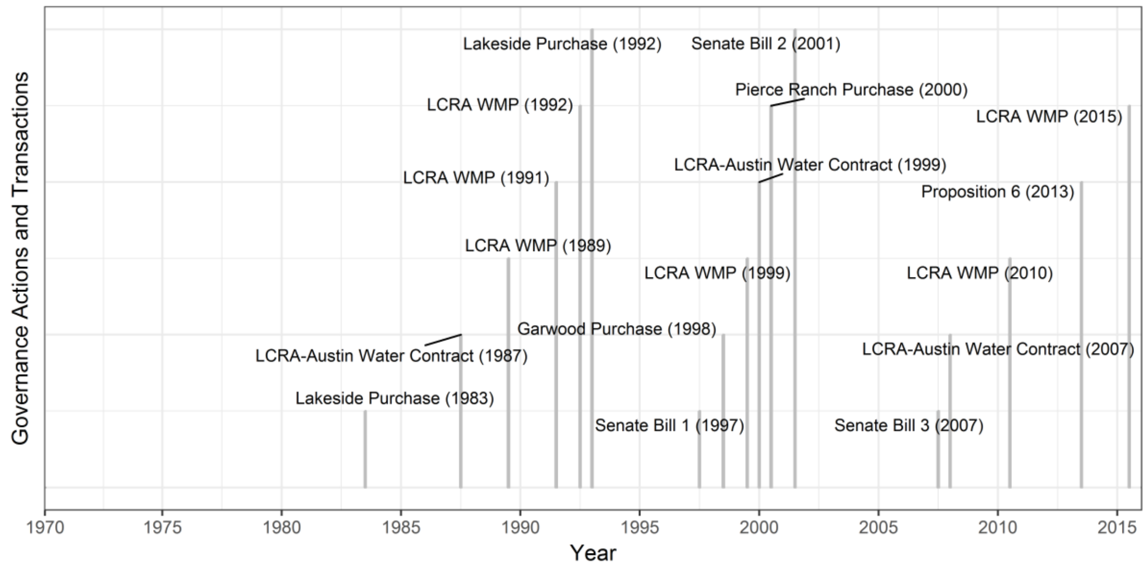

Figure 28. Timeline of governance actions and transactions from 1970 to 2015.

5.1.1 State-level water governance

After an extended and extensive period of water resource development, spanning from the early 1950s to the late 1970s, the State of Texas through the Texas Water Development Board (TWDB) adopted its third state water plan in 1984. State-level water planning attempts to identify solutions to the state's water supply problems and set goals for maintaining and developing the state's water resources. The 1984 plan is noteworthy for its inclusion of water conservation strategies to meet future water demand. The previous two state water plans in 1961 and 1968 had recommended the continual development of the state's water resources through dam and reservoir construction. Today, Texas ranks first among states in the number of dams (Graff 1999), and as of 2017, Texas had constructed 7,395 dams. Of these, over 70 percent were built between 1950 and 1979 (USACE 2017). After 1980, Texans have built 857 dams (USACE 2017).

The departure from the dam and reservoir construction era (or the period of supply augmentation) resulted in a period of end-use efficiency, marked by conservation efforts outlined in the state water plan of 1984. Yet, the 1984 plan still advanced reservoir development and dam building across the state to shore up water supplies and meet future water demands. The addition of conservation and reuse provided an added source of water supply. Nevertheless, the 1984 plan set a precedent for future plans, and in 1990 and 1992, the TWDB amended and adopted the state water plan. Each revision updated the previous plan and focused planning efforts on key water management areas, including financing water infrastructure and environmental protection, crafting programs for economically disadvantaged areas, managing groundwater and floodplains, providing flood protection, conserving and reusing water resources, developing water management strategies for drought periods, and exploring environmental water needs (Texas Department of Water Resources 1984; TWDB 1990, 1992). Subsequent state water plans (in 1997, 2002, 2007, and 2012) increasingly called for more water conservation (TWDB 1997, 2002, 2007, 2012). Indeed, water conservation has been the stated primary strategy to bolster the state's water supplies since 1997 (Rogers and Clancy 2014).

The state water plan, however, has continued to pursue more traditional water development strategies over time, including expanding existing supplies, constructing new reservoirs, transferring water between basins, and reallocating existing supplies. The 2012 state water plan called for 26 new major reservoirs that would generate an additional 1.5 million AF of water per year by 2060. Each proposed reservoir would possess a storage capacity greater than 5,000 AF (TWDB 2012). One of the recommended reservoirs was an off-channel reservoir in Wharton County to bolster water supplies in the lower Colorado River basin.

The Texas Legislature passed three major pieces of legislation beginning with Senate Bill 1 in 1997. Senate Bill 1 established sixteen water planning groups throughout the state. The main thrust of Senate Bill 1 was to create a consensus-driven approach to water management across the state by including local stakeholders in the decision making and planning processes (Sansom 2008). Each water management group consists of 20 members. The members represent the full range of water interests and develop a 50-year regional water plan every five years (TWDB 2016). The TWDB synthesizes the groups' plans into the state water plan. During the regional planning process, the public is encouraged to participate. The counties in the study area are part of the Lower Colorado River Planning Area (or Region K). Region K consists of the following counties: San Saba, Burnet, Llano, Mills, Blanco, Gillespie, Hays (partial), Williamson (partial), Travis, Bastrop, Fayette, Wharton (partial), Colorado, and Matagorda. The western portion of Wharton County is part of the Lavaca River Planning Area (or Region P).

The second major piece of legislation was Senate Bill 2 passed by the Texas Legislature in 2001. Senate Bill 2 created groundwater management areas (GMAs) "in order to provide for the conservation, preservation, protection, recharging, and prevention of waste of the groundwater, and of groundwater reservoirs or their subdivisions, and to 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, groundwater management areas may be created…." (*Texas Water Code* 2001). In the bill, the Texas Legislature tasked the TWDB to help with the delineation of

GMAs for the state's major and minor aquifers (Sansom 2008). The TWDB established 16 GMAs, which serve as planning areas and for the coordination of smaller groundwater conservation districts. As a follow up to Senate Bill 2, in 2005, the Texas Legislature passed House Bill 1763, which said that groundwater conservation districts that manage groundwater resources from the same aquifer must coordinate their management efforts. The counties in the study area fall into a number of different GMAs and many possess their own groundwater conservation districts.

The Texas Legislature passed the third and final major piece of legislation in 2007. Senate Bill 3 called for the protection of environmental flows in the state's rivers and estuaries (Sansom 2008) and required groundwater districts to produce groundwater management plans (Rogers and Clancy 2014). Additionally, in 2013, Texans voted in favor of Proposition 6. Proposition 6 called for the state, using monies from its Economic Stabilization Fund (ESF), to create the State Water Implementation Fund for Texas (SWIFT) and the State Water Implementation Revenue Fund for Texas (SWIRFT). These funds are used to finance priority projects outlined in the state water plan.

Together, the state water plans along with Senate Bills 1, 2, and 3, and Proposition 6, shaped the course of surface water and groundwater management in the state and the lower Colorado River valley during the study period.

5.1.2 Regional water management plans and projects

The LCRA and Region K produced a number of water management plans during the study period. These plans provided the guidelines for water allocation in the lower Colorado River and the management of water stored in the Highland Lakes system. Additionally, the LCRA explored the possibility of transferring water to the City of San

Antonio through a collaborative effort with the San Antonio Water System (SAWS). In the following subsection, I highlight important components of the various regional water management plans and explain the LCRA-SAWS project.

The LCRA has produced five water management plans since its first plan in 1989. The TCEQ approved updates in 1991, 1992, 1999, 2010, and 2015. The plans outline the LCRA's policies and procedures for managing water in the lower Colorado River basin. The primary components of the water plans, which are of interest to this research, include the details outlining the delivery of water for customers holding firm and interruptible water contracts.

The LCRA distinguishes between two water types: 1) firm and 2) interruptible water. Cities, industry, and power plants possess firm water contracts, which guarantee water supply even during periods of drought. Agricultural interests enter into interruptible water contracts on a yearly basis. The LCRA may be curtail or cut off interruptible water supply completely during times of drought. Because this is the primary mechanism by which flows to both urban and agricultural interests are determined, I highlight the changes in interruptible supply over the study period as outlined in the water management plan's section on drought management and drought contingency plans.

In the 1989 plan, the LCRA outlined its drought management and drought contingency plans in regards to interruptible water contracts (LCRA 1989). Open supply for interruptible water contracts would occur if on January 1 combined water storage in lakes Buchanan and Travis equaled 1.4 million AF. Curtailment of interruptible water contracts would ensue in stages if the combined storage of lakes Buchanan and Travis were less than 1.4 million AF on January 1. Finally, complete cut off of interruptible water contracts would occur when the combined water storage of lakes Buchanan and Travis were equal to or less than 325,000 AF on January 1. In contrast, the LCRA would ask customers holding firm water supply contracts to implement voluntary water use reduction measures if the combined storage of lakes Buchanan and Travis were less than 1.4 million AF on January 1. Should the combined water storage of lakes Buchanan and Travis reach 900,000 AF or less on January 1, firm water customers would need to implement mandatory water use reduction measures in an effort to reduce their water consumption by 10 to 20 percent. If a drought occurs that is worse than the drought of record, the LCRA would implement pro rata curtailment for firm water users in order to reduce water use by 20 percent.

These curtailment and cutoff guidelines for firm and interruptible water customers remained unchanged through subsequent revisions to the water management in 1991, 1992, 1999, and 2010 (LCRA 1991, 1992, 1999, 2010). However, combined water storage in lakes Buchanan and Travis, during an extended, intense drought period from 2008 to 2015, dropped, and in 2013, the lakes were only 43 percent full (AARO 2015). Because of the drought and ongoing water scarcity in central Texas, the LCRA filed an emergency order with the TCEQ to adjust its water management plan. Specifically, the order called for the cutoff of interruptible water supply contracts. The TCEQ approved the emergency order. The LCRA filed similar emergency orders in 2013, 2014, and 2015 and received TCEQ approval.

Recognizing the difficulty and uncertainty of filing annual emergency orders, the LCRA set out to update its water management plan in an effort to provide more flexibility to its curtailment procedures, and in 2015, the TCEQ approved the LCRA’s newest water management plan. The 2015 water management plan made significant changes to the way in which the LCRA manages interruptible water contracts. The changes implemented in the 2015 plan were largely a response to severe drought conditions that occurred in central Texas from 2008 to 2015. First, the LCRA moved the date to determine the water available for interruptible water contract holders from January 1 to March 1. They also added an additional evaluation date of July 1. These dates correspond to the timing of water for first and second rice crops in the lower Colorado River agricultural operations, making the determination of water available for first and second crops separately. On both dates, the LCRA categorizes the water supply condition as either 1) normal, 2) less severe drought, or 3) extraordinary drought. The LCRA determines the water supply condition measuring the combined storage of lakes Buchanan and Travis as well as inflow into the lakes. From these measures, the LCRA makes a determination on the amount of interruptible water available.

Curtailment of water proceeds on the following basis. First, the plan ended open water supply, and under normal conditions, the plan outlines stages of water curtailment for first and second crop seasons. When the combined storage of lakes Buchanan and Travis is greater than or equal to 1.4 million AF with sufficient inflows into lakes Buchanan and Travis and no other conditions were in effect before the evaluation date, conditions are considered normal. Curtailment begins when combined storage falls below 1.3 million AF for the first season and 1.55 million AF of the second season. Additionally, if at any point during the crop season the combined storage of lakes Buchanan and Travis reach 900,000 AF, the LCRA will stop all water releases. Under the less severe drought condition, curtailment also advances in stages; however, curtailment begins when combined storage falls below 1.599 million AF for the first season and second season. If at any point during the crop season the combined storage of lakes Buchanan and Travis reach 950,000 AF, the LCRA will stop all water releases. The less severe drought condition is entered when the a) combined storage of lakes Buchanan and Travis is less than 1.6 million AF and inflows into the lakes Buchanan and Travis are less than 50,000 AF or b) combined storage of lakes Buchanan and Travis is less than 1.3 million AF and inflows are less than the 33rd percentile of inflows into lakes Buchanan and Travis (LCRA 2015b, 4-5). No water releases occur under the extraordinary drought condition. The extraordinary drought condition is met when a) combined storage is less than 1.3 million AF, b) the drought period is 24 months, and c) an inflow test meets a drought worse than a drought of record (LCRA 2015b, 5-6). Additionally, the LCRA also uses a "look ahead test." Should the LCRA decide "that the combined storage [of lakes Buchanan and Travis] would drop below 900,000 AF in the upcoming crop season or below 600,000 AF within 12 months," it will not release interruptible water under the normal or less severe drought conditions (LCRA 2015b, ES-3). Finally, the 2015 water management plan leaves in place the curtailment guidelines for firm water customers.

In addition to the water management plans produced by the LCRA and Region K, a legal battle between the Sierra Club and the U.S. Department of Interior generated a number of water development proposals and strategies that affected water interests in the lower Colorado River valley. In 1991, the Sierra Club sued the U.S. Fish and Wildlife Service (USFSW). The suit, filed in the U.S. District Court for the Western District of Texas in Midland, Texas, alleged that the USFSW violated the U.S. Endangered Species Act of 1973 (ESA) because it had not adequately safeguarded the federally-listed endangered and threatened species in the Edwards Aquifer (Sierra Club v. Babbitt 1993). The plaintiffs requested that the USFWS establish withdrawal limits from the Edwards Aquifer in order to provide adequate spring flows for the survival of the aquifer's endangered and threatened species. In January 1993, the court ruled in favor of the plaintiffs.

In response to the court's ruling, the Texas Legislature passed Senate Bill 1477, the Edwards Aquifer Authority Enabling Act of 1993, creating the Edwards Aquifer Authority (EAA) (Votteler 2001; Gulley and Cantwell 2013). The legislature tasked the EAA with managing the water resources of the Edwards Aquifer via the issuance of groundwater permits and establishing maximum pumping levels from the aquifer. The overall management goals sought to maintain healthy ecosystem functioning and the survival of the aquifer's endangered and threatened species.

Until the *Sierra v. Babbitt* decision and the subsequent establishment of the EAA, the City of San Antonio relied wholly on the Edwards Aquifer for its water supply. After *Sierra v. Babbitt* and the establishment of groundwater pumping permits, San Antonio had to reduce its reliance on the aquifer and seek out new water supplies for its rapidly-expanding urban population. One such plan called for an inter-basin water transfer from the lower Colorado River basin to San Antonio (TTWP 1994).

In 1992, the cities of Houston, San Antonio, and Corpus Christi, and a handful of regional water authorities, including the LCRA, initiated the Trans-Texas Water Program (TTWP). The TTWP offered solutions to increase water supplies in these rapidly growing urban agglomerations. Two plans, in particular, received the most attention from the water interests in the lower Colorado River valley. These plans called for the transfer of surface water resources from the lower Colorado River basin to help meet the growing water demands of San Antonio and to relieve the water deficit created by the newly established Edwards Aquifer pumping limits (TTWP 1994).

One of the plans called for the withdrawal of water from Lake Austin and transfer to San Antonio via a series of water pipes. The other proposed diverting water from the Colorado River at Columbus, Texas, which is located downstream from Austin and just upstream from the basin's agricultural operations (TTWP 1994). Water interests along the lower Colorado River initially resisted the plans developed by the TTWP. Yet, less than a decade later, in 2001, the Texas Legislature passed House Bill 1629 allowing the exploration of an inter-basin transfer project through a collaborative effort between the LCRA and the San Antonio Water Supply (SAWS). The LCRA entered into an agreement with the SAWS the following year to study the feasibility of diverting water from the lower Colorado River to augment San Antonio's water supply (SAWS 2002).

Among other strategies, the study proposed the development of a number of reservoirs in the lower reaches of the Colorado River to increase overall water supply (Hall, Manning, and Guy 2006, 2007; Manning, Guy, and Butler 2008). In 2009, the LCRA terminated the agreement and no water was diverted from the lower Colorado River to San Antonio. The San Antonio Water System sued the LCRA, and the LCRA settled the suit in 2011 with a payment of USD $30 million.

5.1.3 Water rights purchases and contracts

Since the 1970s, the LCRA has made a number of significant water rights purchases and entered into three noteworthy firm supply water contracts with the City of Austin. These purchases and contracts reveal an increasing control over the water resources of the lower Colorado River valley by both the LCRA and Austin. In the following subsection, I outline the details of LCRA's water rights purchases and its contracts with Austin.

Before the beginning of the study period, the LCRA purchased the Gulf Coast Irrigation district in 1960. The Gulf Coast Irrigation District consists of two sections – east and west of the Colorado River – and resides in Wharton and Matagorda counties. This purchase amounted to water rights in excess of 250,000 AF. The bulk of these water rights possess a priority date of 1 December 1900.

Within the study period, the LCRA purchased water rights from Lakeside Irrigation District in 1983 and 1992, Garwood Irrigation District in 1998, and Pierce Ranch in 2000. The LCRA purchased the Garwood rights for approximately USD $75 million (Kaiser 2011). With the purchase of the Pierce Ranch water rights, the LCRA secured the last group of privately held senior water rights in the basin. Additionally, the purchase of the Pierce Ranch solidified LCRA's control over all the major irrigation districts in the basin, and agricultural operations, in particular rice farmers, now had to enter into contracts with the LCRA to purchase interruptible water. As of 2011, the LCRA had amassed rights to 63 percent of the lower Colorado River basin's water (Kaiser 2011), a majority of which are the most senior rights in the basin. In contrast, the next largest water rights holder, the City of Austin, possesses 4.9 percent of the basin's water.

There are few major water rights holders outside of the LCRA and Austin (Table 18). The City of Corpus Christi owns the rights to 35,000 AF from the lower Colorado River valley. Corpus Christi purchased these rights from the Garwood Irrigation

Company before the LCRA's deal with the company. Finally, the STPEGS possesses a number of water rights; however, the facility is co-owned with the LCRA.

Table 18. Major water rights holders in the lower Colorado River basin as of 2015.

Holder	***Water rights (acre feet)***
Lower Colorado River Authority (LCRA)	
Lakes Buchanan and Travis	1,500,000
Garwood	133,000
Gulf Coast	262,500
Lakeside	186,250
Pierce Ranch	55,000
Total (LCRA)	2,136,750
Austin	340,000
Corpus Christi	35,000
South Texas Project	102,000

The LCRA is the primary water wholesaler in the basin, and the City of Austin has become its primary customer. While agricultural operations have used more water than the residents of Austin, water deals with the capital city financed the LCRA's accrual of water rights in the lower basin.

In 1987, the City of Austin and the LCRA entered into an agreement for the delivery of 250,000 AF of firm water from lakes Buchanan and Travis through 2023 (LCRA and the City of Austin 1999). The 1987 agreement amended a previous agreement entered into in 1966. The LCRA and Austin amended the agreement again in 1999. On the heels of the LCRA's purchase of the Garwood water rights, the LCRA secured a new water deal with the City of Austin. The city agreed to pay the LCRA USD $100 million to extend water delivery from lakes Buchanan and Travis to 2050. The agreement upped the amount of firm water available to 325,000 AF. The agreement said that the first 150,000 AF of water was free and set a water rate of USD $105 per AF for the use of water over 150,000 AF to 201,000 AF. The agreement, however, specified that payment would not commence until Austin's annual average water use for two consecutive years exceeded 201,000 AF (LCRA and the City of Austin 1999). The deal reserved a large amount of water for Austin and its future demands even in drought periods. In 2007, Austin and the LCRA extended the agreement until 2100 under a formal water partnership (LCRA and the City of Austin 2007).

5.2 Qualitative periods of change

In an effort to reflect the larger political-ecological conditions in the basin, I discuss how and why I modified the periods of change while providing situational context for each period informed by governance action and transactions presented above and characterized by the quantitative results. Next, I document the primary, recurring access mechanisms that water interest groups used to enable or constrain access to the basin's water resources during each period of change. I conclude with a discussion of the periods and their primary narratives of access. Overall, I found that governance actions and transactions influence access mechanisms, that recurring droughts play a conspicuous role in access mechanisms, that competition for water drives access mechanisms, and that access mechanisms vary by water interest group and throughout the study period.

My initial article database consisted of 548 articles. After reviewing the articles, I excluded 176 articles. These articles, while captured in my searches, were not germane to the subject or geography of my study or were duplicates. The final number of articles that I coded was n = 372. Of these, 196 were from *The Austin American-Statesman* and the remaining 176 were from *The Bay City Tribune.* Based on my coding of articles, three distinct periods emerged. These periods arrange the groupings identified through the CPM analysis differently but were formed using the CPM results as a backdrop. The periods reflect the predominant access mechanisms that emerged from the narratives presented in the collection of newspaper articles and defined during the coding process. The end and beginning of each period signals a shift in public discourse related to water access and together tell the story of how the allocation of water resources in the valley has shifted from agricultural interests to urban interests.

The initial groupings of variables attained through the CPM analysis provided an entry point into the qualitative analysis portion of my research. I started coding articles from both newspapers – *The Austin American-Statesman* and *The Bay City Tribune* – beginning with 1994, which corresponds to when the frequency of change points intensified. After coding articles and taking into consideration how political and management actions informed public discourses during the study period, I adjusted the initial groupings. Based on my interpretation of the broad discursive systems advanced across the text corpus (i.e., newspaper articles), the new, adjusted periods of change reflect the three most prominent political-ecological conditions informing the underlying discourses and the resulting patterns of water use and access. Before exploring the results of my qualitative analysis in detail, I provide below a brief overview of each period of change, in order to frame their salient features, which includes information from the CPM results joined to the underlying political-ecological contexts.

The first period of change, local control, occurred between 1994 and 1999. In this period, local control superseded outside state and regional encroachment. I identified this period by initially grouping the early signaling variables returned by the CPM analyses.

Change points in period 1 show significant increases in urban water use, a significant decrease in rice production, and a significant increase in central Texas temperatures. The public discourse during this period was informed by a unique set of political-ecological conditions. Through a number of proposals, endorsed by state and regional actors, outside interests attempted to acquire water resources from the lower Colorado River basin, and public discourse revolved around these actions. Both urban and agricultural interests came together to maintain control of the valley's water, and at the same time, an emerging drought forced basin water interests to initiate conservation measures.

The second period of change, strategic alliances, occurred from 1999 to 2007. This period is characterized by water rights purchases, local and outlying community collaboration, and requests for fact gathering. I identified this period by grouping the next set of variables that signaled in the CPM analysis. In this period, agricultural counties' water use as well as the amount of crop acres harvested began to decline significantly. Toward the end of the period, lake levels and river discharge began to decline due to an emerging drought and an assortment of water management decisions made at the basin scale. During this period, the LCRA purchased significant water rights and entered into a number of large water contracts with Austin and developing Hill Country urban areas. Public discourses within period 2 reflected the increasing control of the basin's water resources by the LCRA and the rise in Austin of water issues before the beginning of the 2008 to 2015 drought.

The third and final period of change, urban ascendance, began in 2007 and ended in 2015. It is marked by increasing conflict between urban and agricultural water usage. This period begins as the last quantitative variable signals, indicating the beginning of the

2008 to 2015 drought, and as Austin and the LCRA strengthened their relationship and entered into a water partnership. The period is characterized by increasing competition for the lower Colorado River's water resources during the drought. Public discourse reveals a number of variegated responses from water interests to a host of idiosyncratic management decisions as the drought worsens. In many cases, the drought surpasses the drought of record, persisting into late 2015, driving further changes to the hierarchical structure of water access in the lower Colorado River valley.

I develop the narratives of access for each period of change below. I begin by presenting the major story lines within both newspapers for each period of change. Next, I detail the narratives of access used to either constrain or enable access to water. Taken together, I describe the narratives water interests used to derive benefits from the basin's water resources; how social, political, and environmental events influenced those narratives; what dominant narratives emerged in each period; and how these narratives evolved and transformed over time and, in turn, reflect changes in water distribution in the lower Colorado River valley. It is important again to emphasize that this portion of my research is not a study of media coverage of water issues. It uses historical media coverage of water issues to identify and relate the mechanisms that water interests deployed to constrain or enable access to the basin's water resources.

5.2.1 Period 1 (1994-1999) – Local control access narratives

The CPM analysis indicated that urban counties (Austin and Bastrop) were increasing their use of the basin's water resources between 1994 and 1998, and at the same time, temperatures in the area were increasing. Media coverage echoed these trends. Articles in *The Austin American-Statesman* (n = 26) covered the increasing pressure of growing urban populations in search of ways to access the basin's water resources. Articles from *The Bay City Tribune* ($n = 32$) were primarily concerned with agricultural interests. Yet, the main storyline for each paper focused on the external (i.e., state, regional, and local) pressures vying for a stake of the lower Colorado River basin's water resources. The drought of 1996 also received coverage in both newspapers. The issues covered within period 1 include TTWP's proposals, Corpus Christi's purchase of a portion of the Garwood Irrigation District's water rights, and the 1996 drought.

As urban counties in the lower Colorado River were increasing their water usage, federal, state, and nearby municipalities attempted to gain access to the basin's water resources. Beginning in 1994, the cities of San Antonio and Corpus Christi were seeking to increase and supplement their own water supplies. The TTWP had also issued its first proposals to bolster water supplies in San Antonio and other nearby municipalities identified as water scarce urban areas.

The TTWP report identified a number of ways in which that water authorities and municipalities might harness central and southern Texas water resources to meet the region's growing population needs from San Antonio to Houston. The recommendations largely focused on technical, policy, and management solutions, such as inter-basin water transfers and water conservation measures, to meet the region's increasing water demands. One of TTWP's proposals suggested piping water to the city of San Antonio from the lower Colorado River basin at Lake Austin or directly from the river at a diversion point near Columbus, Texas.

At the same time, the establishment of the Edwards Aquifer Authority and pumping restrictions placed on the aquifer had forced San Antonio to explore alternative options to augment its water supply. In 1995, a court-appointed monitor in the *Sierra v. Babbitt* suit offered a proposal similar to the TTWP proposals to ease San Antonio's reliance on the Edwards Aquifer. The proposal called for pumping water from the Colorado River near Smithville, Texas, and piping it to San Antonio.

In the mid 1990s, the City of Corpus Christi estimated that its water supply would run out by 2000, and it entered into negotiations with the Garwood Irrigation Company to purchase the rights to 35,000 AFY of Colorado River water. In 1996, the City of Corpus Christi finalized its deal with the Garwood Irrigation Company. Shortly, after the water rights purchase, Corpus Christi began the process of receiving approval for an inter-basin transfer from the state. Corpus Christi would pipe water from the Colorado River to Lake Texana in the Lavaca River basin for eventual municipal use.

Additionally, in 1996, Texas experienced a drought that resulted in widespread agricultural losses (WGA 1996; Hayes et al. 1999). The drought also affected municipalities in central Texas, including Austin. As the levels of lakes Buchanan and Travis fell (see Figure 19), the LCRA and the City of Austin requested that area residents voluntarily conserve water.

Consequently, in period 1 from 1994 to 1999, the water resources of the lower Colorado River basin were under threat from outside water interests and depletion by an emerging, acute, but short-lived drought. The narratives of water access that emerged during period 1 were mainly a response to these events. Basin water interests deployed a number of mechanisms in an effort to control and maintain their own access to the basin's water resources at a time when their own water usage (especially in urban counties) was increasing. Within this period, I identified three primary access mechanisms that water interests used to constrain access to the basin's water resources. Basin water interests used authority, knowledge, and social relations access mechanisms.

Access to authority was a common and recurrent theme in the news media. The TTWP proposals offered a number of options to enable the City of San Antonio and other municipalities to benefit from the water resources in the lower Colorado River valley, and it ostensibly had the backing of state-level water regulators, namely the TWDB. Yet, reaction to the TTWP report and its proposals from Austin and other lower Colorado basin interests was swift and merciless. Basin water interests expressed their opposition to the proposals. Within mechanisms of access, authority figures serve as important "nodes of direct or indirect forms of access control" (Ribot and Peluso 2003, 170), and authority figures especially were vocal in their opposition to the proposals.

In period 1, authoritative figures in the lower Colorado River valley firmly and uniformly decried external efforts to access its water resources. Elected officials, water interest representatives, and water authorities voiced their disapproval of inter-basin water transfers to San Antonio and Corpus Christi. For example, a local Travis County judge explained, "It's an awful idea. San Antonio has sucked its aquifer dry, its voters won't support a new reservoir and now the state wants to give them our water? It's outrageous" (Wright 1994). Opposition narratives were not limited to judges. Local community groups and associations formed to oppose the proposals. An association representative noted, "No one wants to see anyone die of thirst. But the problem is, you don't take water away from someone else who needs it" (Wright 1994). The LCRA also fought back against the proposals. The general manager of the LCRA reinforced these comments, and based on LCRA's estimates of available water in the lower Colorado

River basin, suggested “there is no water to spare [in the lower Colorado River basin]” (Wright 1994). The proposals made the front page of *The Bay City Tribune* as well. In an early edition, an LCRA spokesperson commented:

> “When you’re talking about diverting water for a tourist attraction like Sea World or pumping water into the San Antonio River for the Riverwalk, I think you would have to contend that most river authorities would want to see a very serious conservation program in place” (Clamon 1994b).

This opposition narrative continued throughout the first period as other authority figures in the basin came to the defense of its water interests. Months later, in response to the Smithville proposal recommended by the court-appointed monitor in the Edwards Aquifer case, the LCRA general manager explained again, “We’re not a surplus basin, in our opinion. I don’t fault [the court monitor] for making the recommendation. We’re going to have to get together and find some more creative solutions” (Haurwitz 1995). The Austin Mayor was less restrained in his comments on the proposal. He stated, “Keep their hands off. That kind of policy is inherently unfair to all the people who choose to live and work up and down the Colorado River” (Haurwitz 1995).

These examples illustrate the ability of basin water interests, both urban and agricultural, to turn to authoritative figures in an effort to maintain access to the basin’s water while at the same time constraining external water interests. Their voices in the public discourse convey the importance of keeping water within the lower Colorado River basin while signifying their influence on matters related to who gets to benefit from the waters of the lower Colorado River. These examples also indicate an alignment of water interests in the basin whereby both urban and agricultural water interests were defended in the basin. In other words, basin water interests essentially operated as one unit to deter and constrain outside encroachment. The Austin mayor’s above comment while trenchant and defiant hints at this additional, recurrent narrative that basin water interests used frequently to rebuff the advances of San Antonio and other municipalities on the basin's water resources.

The narrative emerged around social relationships between urban and agricultural water interests in the basin and ties to their individual social identities. The ongoing discourse suggested that basin water interests were united in opposition to outside encroachment, and together, the narratives of access illustrated an alignment of basin interests to constrain outsiders from accessing (and benefiting) from the valley's water resources.

Evidence of basin alignment was frequent in *The Austin American-Statesman* as opponents to the San Antonio transfer proposal became more vocal. Within these comments, both urban oriented water interests, including recreational interests, and agricultural interests operated as one system, defending each other's water supply. One article explained, "Opponents say piping water from the [Highland Lakes] to San Antonio would hurt the area's tourism and recreation-based economy" (Wright 1996). Members of the Highland Lakes Association also recognized the importance of the Highland Lakes for supplying irrigation water to agricultural interests while voicing their opposition to the San Antonio inter-basin transfer proposals. One association member noted:

> "The irrigation rights are senior priorities for the Lower Colorado River Authority. It's been this way since before the dams were built. That's just a fact of life for people in Lake Travis. We've just learn to live with it" (Breeding 1996).

Despite the uneven tone, this statement reflects the status quo of how the Highland Lakes system functions and more broadly, the legalities of water rights in Texas. It also recognizes the hierarchical structure of water allocation in the basin and more importantly, that basin interests, whether urban, industrial, or agricultural, come first. Additionally, the LCRA general manager noted again its opposition, and in his defense, singled out the basin's agricultural interests to make his point, saying, "… the agency [LCRA] would oppose a withdrawal of 75,000 acre-feet because it would devastate rice farmers in Matagorda and Colorado counties, along the Gulf of Mexico" (Haurwitz 1995).

Lower Colorado River water interests were also aligned in opposition to Corpus Christi's purchase of water rights from the Garwood Irrigation Company. At the time, Austin's mayor explained of the proposed purchased and water transfer, "It's more than just the nose of the camel under the tent. It's bad policy, and we oppose it. It affects not only Austin but the communities all around Austin. It is our drinking water" (Dworin 1996). The LCRA also voiced its opposition to the Corpus Christi deal. Their water resources planner said, "The biggest impact will be for the people who are downstream of Garwood [irrigation operations]. We're already in short supply in the basin, and taking more water out would only make it worse" (Dworin 1996).

Many of those speaking out against the various transfer proposals also used scientific knowledge and information about the amount of water available in the basin to defend its water resources. As such, basin estimates became another recurring theme in the overall opposition narrative. In addition to the LCRA's general manager's comments about not being a surplus basin, the manager also explained to *The Austin American-Statesman*, "… the river agency [LCRA], which manages the Lower Colorado River, opposes diverting water to San Antonio because its projections indicate there is no water to spare" (Wright 1994). This became a common refrain by the LCRA leadership (Wright 1994; Haurwitz 1995). While staying closer to home, *The Austin American-Statesman* also explained, "[Opponents] also say that studies show Austin, which draws its water from Lake Austin, and other lake-area communities will need all the water in the future" (Wright 1996). The LCRA also challenged TWDB estimates for the lower Colorado River basin, particularly with concern for agricultural water demand. The LCRA leadership suggested, "[TWDB] figures show more a decline in demand than our figures do. We are right at a good conservation level right now" (Clamon 1994a). Additionally, the LCRA suggested that results from an inflow study would "provide a solid basis for rejecting the proposed inter-basin transfers" (McCormick 1995).

Through the coding process, a clear strategy emerged in the public discourse as basin interests attempted to constrain access to its water resources. As San Antonio and Corpus Christi among others attempted to capitalize on the state recommendations and use their connections to state authorities to acquire lower Colorado River water, local authorities vocalized their opposition to these outside interests in an effort to control and maintain access and rights to the basin's water resources. In particular, local authority figures, representing the full range – and interconnectedness – of water interests from urban to agricultural uses, defended the basin's water supplies from outside interests. As many of the above statements suggest, county, city, and basin officials repeatedly voiced their distaste for the inter-basin transfers and backed up their claims with basin water supply estimates. In doing so, they also seemed aware of the many demands on the water resources of the lower Colorado River and noted how each entity would be affected. The formation of social relationships was also used as a means to maintain water access for all water demands and to constrain outside access from benefiting from the valley's water resources.

When the drought of 1996 began to impact central and south Texas, it served to catalyze water interests in the basin even further. Water interests formed alliances across the basin, bolstering social relationships even more but not necessarily bringing together urban and agricultural interests. Municipalities in Travis and Williamson Counties formed an "Alliance of Cities," composed of Central Texas elected officials, that considered pursuing legislation to limit inter-basin transfers in an effort to ensure that water would stay within the basin of origin (Dworin 1996). Agricultural counties also joined forces. A coalition of county governments from the agricultural areas of the lower Colorado River basin also formed to combat the inter-basin transfer proposals (Hart 1995; Gonzales 1996). Thus, basin interests at both ends of the lower Colorado River came together to protect the valley's water resources.

Additional narratives of access that surfaced during the drought decreased in scale from regional to local and focused on the ways in which water authorities might increase basin water supplies and limit water use in the basin. Here, recurrent access narratives revolved around enabling or constraining basin water use through a number of strategies. The most consistent access narrative that developed during the drought at the local level was the need to conserve.

Articles in *The Austin American-Statesman* outlined various conservation strategies adopted by local cities. Municipalities in central Texas, including Austin, urged residents to reduce their water usage. As a voluntary conservation program, the city of Austin asked its residents to water only once every five days. Additionally, the city used the drought conditions as a strategy to communicate its conservation message, while conceding that it had ample supplies to meet the needs of Austin's growing population. The voluntary conservation of water by residents would, as one Austin Water spokesman explained, "… level off those peaks [caused by residential lawn irrigation], [so] customers can save money through conservation and the utility can delay building another [water treatment] plant, which will keep [water] rates down" (Lindell and Todd 1996). Other conservation efforts also emerged. The elected officials of the Alliance of Cities came together again and "agreed … to put aside years of intercity squabbling to adopt a unified water conservation program" (Lindell 1996). The program attempted to educate municipal residents on water conservation strategies. The alliance's chief goal was to cooperate in solving regional water supply issues during a drought. One municipal mayor and member of the alliance remarked, "This is something new to us. This (agreement) is probably the first step" to working together to find solutions to shared water problems (Lindell 1996). At the other end of the basin, articles in *The Bay City Tribune* suggested the drought had little effect on water supplies in the area.

Access mechanisms captured in public discourse reveal how water interests attempted to limit access to the basin's water resources at both a regional and local scale. At the regional scale, authoritative figures denied outside interests' access to the basin's water resources through repeated, vocal opposition. They also drew on social relations to form a cohesive alignment of basin interests to combat the outside threat. Conservation became the primary mechanism to limit access to the basin's water supplies at a more local scale during the drought. The narratives delivered through the news media made each of these strategies apparent. Figure 29 documents the access mechanisms and conditions characteristic of period 1.

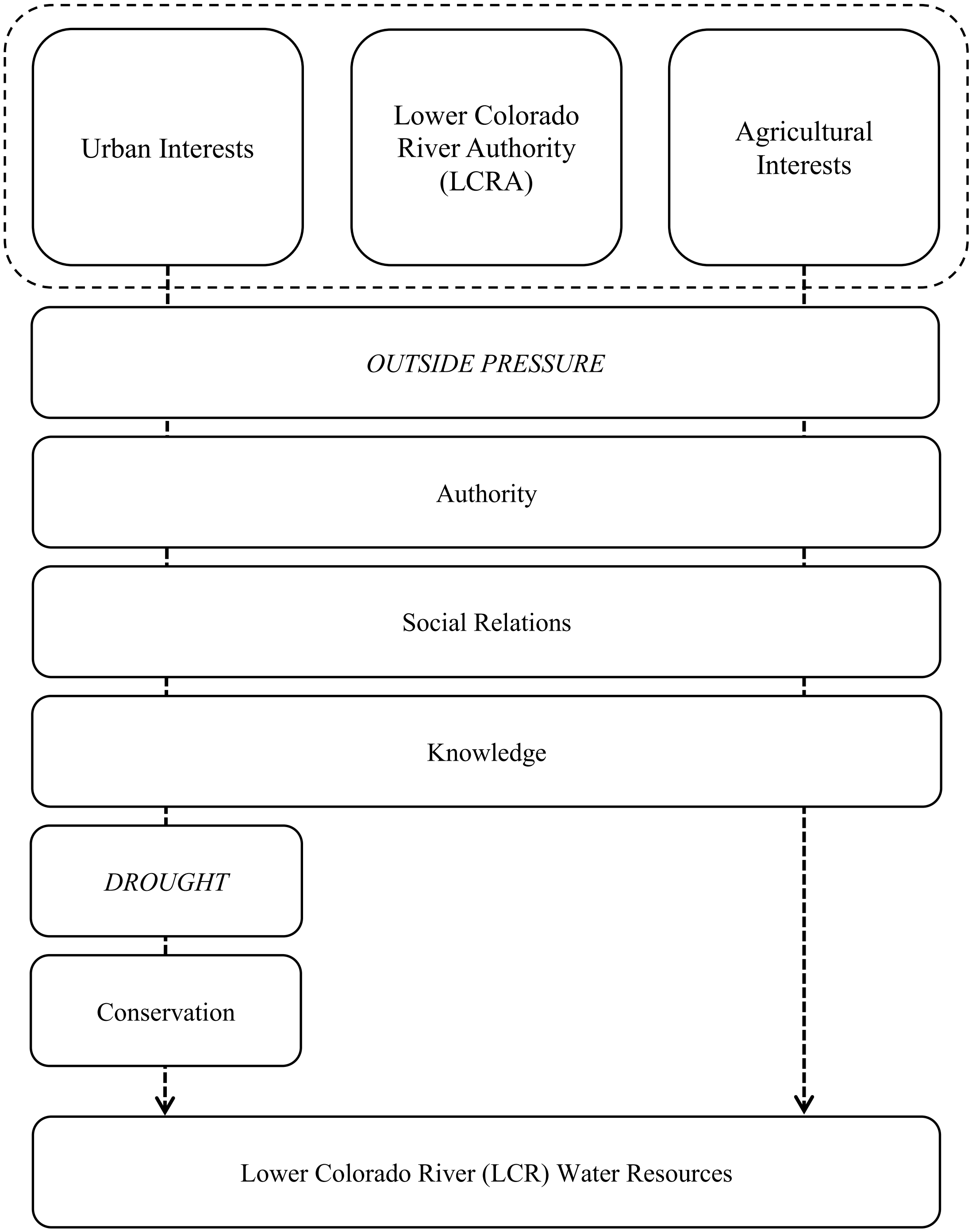

Figure 29. Period 1, local control access mechanisms and intervening conditions on the path to the water resources of the lower Colorado River.

5.2.2 Period 2 (1999-2007) – Strategic alliances access narratives

The CPM analysis signaled a decrease in agricultural counties' (Fayette, Colorado, Wharton, and Matagorda) water usage and agricultural production from 1999 to 2002. Additionally, lake levels fell in 2005 and 2007, and discharge on the Colorado River near Columbus, Texas, decreased in 2007. Media coverage of water issues in the lower Colorado River basin from 1999 to 2002, however, revealed less about agriculture's water loss and more about the increasing, competing demands on the basin's limited supplies as well as the consolidation of water resources by area interests. This narrative continued into 2007 and ended with the partnership between the LCRA and the City of Austin and the beginning of area drought conditions. Based on continuity among narratives of access described below, I defined period of change 2 to extend from 1999 to 2007.

During this time, articles in *The Austin American-Statesman* (n = 89) focused on the delivery of water to new developments in the northwest portion of Travis County and surrounding areas (i.e., the Hill Country) and the 1999 and 2007 Austin-LCRA water deals. Articles from *The Bay City Tribune* (n = 66) reported on ongoing management efforts and policy proposals to secure freshwater inflows for the Matagorda Bay estuarine system. Both newspapers reported on the LCRA's purchases of water rights and other large water deals in the basin. The LCRA was responsible for the delivery of water to new Hill Country developments and the conversation around freshwater inflows. The primary storylines, in period 2, reflected the LCRA's growing presence in issues regarding the distribution and management of the basin's water supply.

The narratives of access within period 2 also reflect the LCRA's increasing status in the basin's water issues. Yet, the narratives also reveal a developing fracture between basin water interests. In period 2, basin water interests are no longer aligned in opposition to outside interests as the threat has dissipated. Instead, urban and agricultural interests focused individually on constraining the LCRA's water decisions or on improving their positions within the larger water supply hierarchy taking shape. The narratives of access that appear within period 2 are characterized by competition between water interests for control of the basin's water resources and, as a consequence, signify an important shift not only in the consumption of water but in the control of the basin's water resources. Access mechanisms used to maintain or control water resources are reflected in narratives situated around capital, social relations, and knowledge and information.

Access to capital together with the formation of social relations was a repeated narrative theme in the articles from *The Austin American-Statesman* and revolved around water purchases and water contracts. Access to capital has been identified as a major factor influencing who is able to benefit from natural resources (Ribot and Peluso 2003). In terms of water, those with finances to purchase water rights or enter into large contracts have the ability to control (and derive benefits) from the valley's water. For example, a series of water rights purchases allowed the LCRA to increase its control over the basin's water resources. During this period, the LCRA also entered into a number of water contracts with the City of Austin and other growing urban populations, granting them access to a share of the basin's water resources. Thus, the primary narratives of access in the news articles discussed the LCRA's purchases and contracts and the benefits they created.

First, just before the CPM analysis signaled that agricultural counties water use had started to decline in 1999, the LCRA purchased the rights to 133,000 AFY from the Garwood Irrigation Company for USD $75 million in 1998. At the time, the purchase was the largest sum ever paid for a group of water rights in Texas history. With the purchase, the LCRA tripled its water reserves, and its manager stated that "water will not be a restriction to population and industrial growth in the 21st century, even during a repeat of the worst drought on record" (Haurwitz 1998). State officials lauded the purchase and pointed to it as an example of the type of cooperation and innovative planning espoused in the 1997 Senate Bill 1.

Agricultural interests in the basin also cheered the LCRA's Garwood rights acquisition. A Matagorda County water consultant commented on the deal:

> "The better news is that this water will stay in our basin, rather than be purchased by outsiders and possibly be taken away in the future. There were instructions from Bill Lear (Garwood owner) that there be provisions for rice irrigation, that their interests be protected" (Newell 1998).

The LCRA increased its water rights holdings again in 2000. For USD $17 million, it purchased the rights to 55,000 AFY from Pierce Ranch. LCRA's general manager remarked that the Pierce Ranch deal was "a very important piece, and the last piece, in the whole puzzle," and an executive manager stated, "This is a long term investment" (Haurwitz 2000). Indeed, the Pierce Ranch water rights were the last large group of privately-held water rights in the basin, and through its purchase, the LCRA acquired a majority of the basin's water rights (Kaiser 2011). Agricultural interests touted the purchase as "a landmark deal for the LCRA, the state's water-planning efforts, and for Matagorda County" (Bagent 2000).

After the Garwood purchase, the LCRA and Austin entered into a 50-year water supply contract for USD $100 million in 1999. The contract ensured the delivery of water to the city until 2050. City officials applauded the deal. One city council member remarked, “What we are buying here is not just water. What we are buying is control over our destiny” (Lindell 1999). A number of other deals and contracts were brokered between the LCRA and surrounding municipalities. The river authority agreed to sell and deliver water to Pflugerville, Leander, Georgetown, Dripping Springs, and other emerging Hill Country developments. Some of these deals were met with opposition; however, the LCRA contracts were critical to the expansion of Hill Country developments.

At the same time, the LCRA began to consider ways to develop the basin’s water supplies in the lower portions of the valley as they increased water delivery to growing residential areas in Travis County. To explore the potential to further develop the basin’s water resources, the LCRA also entered into a contract with the San Antonio Water System (SAWS) (Price 2006). In the contract, the two water authorities agreed to examine potential storage options as well as costs associated with the delivery of water from the Colorado River to San Antonio. The feasibility study cost approximately USD $42 million (Price 2006). After signing the contract, the LCRA general manager stated, “Every part of our region will benefit, from the Highland Lakes to the rural communities to farmers in the coastal region” (Staff Reports 2001b).

The contract, based on a plan drawn up by the Region K Planning Group, provided a solution to three area water problems. First, it would supply water to San Antonio. Second, it would ensure irrigation water for agricultural interests even under drought conditions. Finally, it would maintain the levels of lakes Buchanan and Travis. The plan hinged on the further development of the lower Colorado River's water resources. Through state funding, the LCRA and SAWS would construct a series of off-channel reservoirs in the lower portion of the basin to store excess water during high flow periods.

Whereas basin interests mounted a vociferous campaign to deny San Antonio access to a portion of the basin's water resources in period 1, basin interests now seemed unified in exploring the possibility of an inter-basin transfer as long as it benefited the lower Colorado River valley. The contract stipulated that San Antonio would not be allowed to take more than 150,000 AFY and prohibited it from pumping any groundwater from the basin's coastal region (Staff Reports 2001a). The plan would have "increase[d] the amount of water supply available in the lower Colorado River basin by up to 330,000 acre-feet annually" (Mashood 2012).

Agricultural interests were firmly behind the plan and contract. One agricultural interest stated, "The outcome would be that our region would get water for rice irrigation and there would be additional water available for San Antonio" (McClanahan 2001b). He followed his own comments with the following statement, "The projection is that if we don't do something, we won't have enough water, so I'm very much supportive of the contract. But we have [groundwater] concerns and we're hoping that (LCRA) will be looking out after our interests" (McClanahan 2002). As the feasibility study progressed, the LCRA held numerous town hall meetings in the lower basin counties. Despite some confusion over the siting of the proposed reservoirs, counties in the lower basin remained in favor of the planning efforts.

Finally, the LCRA and Austin entered into another significant contract at the end of period 2 by signing another historic water deal in 2007. The deal set up a water partnership between Austin and the LCRA, ensuring Austin's water supply until 2100. Through the partnership, the LCRA and Austin together, controlled the vast majority of water in the basin. The partnership also signaled a maturing relationship between the two entities. One Austin official noted, "The idea [behind the partnership] was that we would solve our problems locally. It's cutting edge for the city and the LCRA to do something as collaborative as this" (Price 2007).

Thus, the flow of capital through the basin allowed the LCRA to amass a significant amount of the basin's water rights and assume control over water supply in the basin. Its contract with San Antonio and other municipalities signaled the LCRA's increasing control over the basin's water resources. But its partnership with the City of Austin in 2007 solidified its position atop the water supply hierarchy. Reflecting on the LCRA-Austin deal, one former LCRA board member remarked, "If water is the new oil, LCRA is chief of the emirates" (Price 2007). Another added:

> …the agreement … put[s] LCRA in the driver's seat on water supply and maybe even water quality in the region. That gives me a good deal of concern, because the City of Austin is politically a lot more responsive to the concerns of their citizens than LCRA is responsive to concerns of their consumers" (Price 2007).

Notwithstanding LCRA's movement to shore up control of the basin's water resources through water rights purchases and water contracts, both urban and agricultural interests explored ways to maintain or acquire water resources on their own. In doing so, both brushed up against the increasing power of the LCRA while displeasing other water interests.

During this period, the city of Austin explored other options for securing water. Options ranged from purchasing land and developing groundwater supplies in surrounding counties to reclaiming and reusing its wastewater. Austin filed an application with the TCEQ to reclaim and reuse its wastewater 2002. The LCRA, in particular, contested Austin's request. The general manager said, "This is not just an Austin issue. It's a huge change. It will have huge impacts on those who have relied on the status quo" (Scheibal 2002). Rice farmers' reacted similarly to Austin's request for indirect use of its wastewater. Agricultural interests felt that Austin's reclamation would lower flows to agricultural counties during the year. One agricultural county water representative stated, "We're very concerned that anything that could take water out of the natural flow of the river could certainly be detrimental from an irrigation standpoint" (Smith 2004).

At the opposite end of the valley, a recurring narrative of access specific to agricultural interests appeared. Agricultural interests interrogated the LCRA over environmental inflow estimates included in its draft water management plan. Agricultural interests felt that environmental inflows would siphon water from irrigation operations and insisted that the LCRA complete more studies before making a final determination and including it in their water management plan. One agricultural interest explained his opposition:

> While adequate freshwater inflow needs (FIN) must be accommodated. There is a serious question of the adequacy of the presented data as it is used in forming a conclusion. Since we are confronted with allocating a limited resource whose misappropriation to FIN would result in serious economic losses to irrigation interests, we must have adequate proof of need. If an allocation is made that will deprive irrigators of water for crops, the effect will be immediate and highly predictable, but due to limited data we may not know for some time if we have benefited [Matagorda] Bay (McClanahan 2001c).

He added, “We really don’t know the actual requirement of bays and estuaries, but we do know the consequences of less water for rice” (McClanahan 2001a). Thus, the agricultural interests managed to persuade the LCRA to conduct a long-range FIN study by appealing to both the economic interests of the lower basin and questioning the knowledge produced through the LCRA’s studies.

The narratives of access that characterize period 2 reflect the ongoing effort of the LCRA to control the valley’s water resources. The LCRA, through water purchases and water contracts, becomes a full-fledged water wholesaler and begins to exert control over water access among the various water interests. Urban interests maintain and acquire significant amounts of water by entering into a water contract with the LCRA and finally by partnering with the river authority. Agricultural interests, however, attempted to maintain access to their share of the water by challenging the LCRA’s FIN studies and reacting to Austin’s indirect use plan. Overall, both urban and agricultural interests successfully retained access to their portions of the basin’s water supply. Yet, social relationships shifted in telling ways. Agricultural interests increasingly were called on to defend their interests in the basin, whereas urban interests benefited from their relationship with the LCRA. Figure 30 visualizes the access mechanisms and conditions characteristic of period 2.

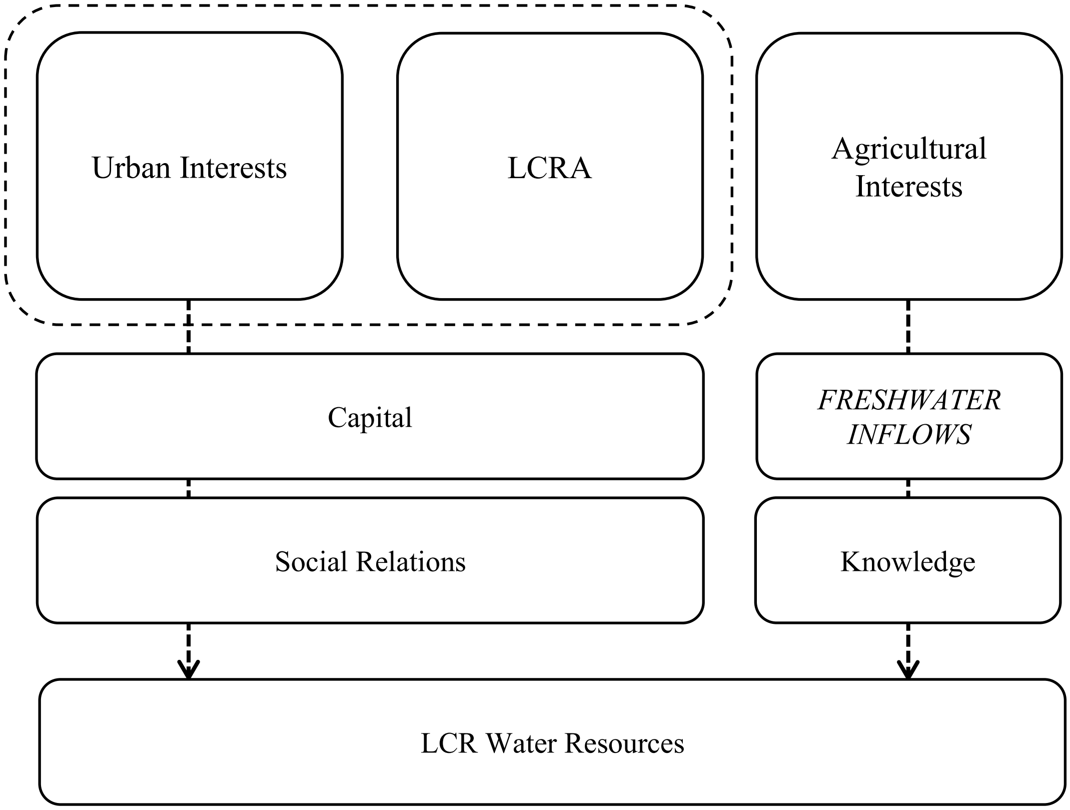

Figure 30. Period 2, strategic alliances access mechanisms and intervening conditions on the path to the water resources of the lower Colorado River.

5.2.3 Period 3 (2007-2015) – Urban ascendance access narratives

The last signal from the CPM analysis occurred in 2007 when the mean level of Lake Travis decreased significantly. This also signaled the beginning of an extended, acute drought in Texas (Combs 2012) and marks the beginning of the third and final period of change. The period extends from 2008 to 2015 and corresponds to the timing of severe drought conditions in the area. This period is characterized by increasing internal competition for the basin's water resources under environmental stress.

The state entered into an extended period of drought in 2008 (Nielsen-Gammon 2011; Combs 2012). Precipitation in early 2010 initially eased drought concerns; however, in the period immediately following a number of records fell. In 2011, March through May and June through August produced record low precipitation totals. Similarly, the 12-month rainfall total for October 2010 through September 2011 fell below the previous record set during Texas's drought of record in the 1950s. Across the state, average summer temperatures beat previous records (Nielsen-Gammon 2011). The drought diminished water stored in the Highland Lakes. Inflows into lakes Buchanan and Travis from March 2008 to October 2014 were 43 percent lower than during the drought of record (AARO 2015). The drought lasted until 2015, and in February of the same year, the LCRA concluded that the drought was the worst on record (LCRA 2015a).

The dwindling water resources in the lower Colorado River valley created by the drought and to some extent mismanagement by the LCRA greatly increased competition for the basin's water resources and divided the basin's water interests. The LCRA fulfilled all interruptible water contracts in 2011 despite the ongoing drought and the protests of urban interests. As the drought worsened and urban interests exerted increasing political pressure on the LCRA, it cut off irrigation water to agricultural counties in the years 2012, 2013, 2014, and 2015. Urban counties lobbied in favor of the cutoffs, and the cutoffs, in turn, angered agricultural counties.

During period 3, articles in *The Austin American-Statesman* (*n* = 81) concentrated on the growing tensions between urban water users and agricultural water users and described local water restrictions and conservation efforts during the drought. Articles from *The Bay City Tribune* (*n* = 78) reported on the various strategies agricultural counties mounted in an effort to maintain access to their share of the basin's water resources. Thus, the narratives of access that developed during this period reflect increasing competition between urban and agricultural interests for the basin's water resources. The narratives each water interest deployed differed, and the access mechanisms each used suggest a broad shift in who controls the valley's water supply. The overall narrative suggests that during this period urban counties acquired the ability to control and dictate water distribution throughout the basin. To do this, urban interests used authority figures to bolster their access claims. Agricultural interests, however, remained on defense, and their narratives of access reflected social relations, social identity, and market access mechanisms.

Access to authority again became a recurrent theme in the larger narrative but urban water interests used it expressly and most successfully to control the basin's water resources. Two state legislators serving the residents and businesses in portions of Travis County protected urban water interests. Threatening the LCRA with legislation to limit its authority in water matters, the legislators opposed the river authority's initial recommendation to release water to its agricultural customers in 2012. They suggested that if the LCRA released water for irrigation operations downstream, the release would create the worst drought on record and would not leave enough water to meet its firm water supply commitments to urban counties. They vowed to fight the LCRA's initial recommendation to release water to rice farmers. To emphasize the seriousness of their threats, one legislator commented, "We are ready to go to the mat on this" (Toohey and Price 2012). Moreover, in a letter written to the LCRA, with portions published in *The Austin American-Statesman* and *The Bay City Tribune*, the legislators said they would "pursue legislation that prohibits such decisions in the future and would actively support court action to stop the river authority" (Toohey and Price 2012). The legislators also publically labeled the LCRA's decision as "irresponsible", and Austin's mayor added that the decision was "inconceivable" (Toohey and Price 2012). The legislators' efforts were effective. The LCRA with approval from the TCEQ cut off water to irrigation operations in 2012.

The legislators continued to put pressure on the LCRA the following year. The legislators filed a bill in 2013, requiring the "supply of interruptible water must be cut off entirely before the [LCRA] curtails supplies of firm water or requests that firm water customers institute voluntary drought contingency measures" (Halvorson 2013d). The proposed legislation made it out of committee but did not receive a reading in the legislature; however, their efforts on behalf of urban water interests continued to be successful. The LCRA pursued emergency orders to cut off water to agricultural interests in 2013, 2014, and 2015, and the TCEQ approved the orders each year. As a result the LCRA did not release water from the Highland Lakes system to downstream customers in those years. The TCEQ's approval of multiple emergency orders by the LCRA suggests that urban interests' access to authority worked to constrain agricultural water interests.

Down river, agricultural interests, their water security under pressure from urban interests, deployed an array of access mechanisms to maintain their share of the basin's water resources. I identified three primary and recurring narratives of access that agricultural counties used to constrain urban interests during this period. Agricultural interests relied increasingly on social relations, social identity, and market access mechanisms to defend their water supplies. Agricultural interests directed these narratives of access at the LCRA's decisions to curtail water for agriculture and urban interests' support of them.

In an effort to unseat urban interests and combat the LCRA's emergency orders, agricultural interests formed a number of new social relationships. Agricultural interests merged with environmental interests in an effort to maintain access to the basin's water resources. At the time, environmental interests were particularly concerned with the impact the water cutoffs would have on the migratory waterfowl population. Many migratory waterfowl species rely on the wetlands created by rice farming operations for their winter habitat. Furthermore, interest in the Matagorda Bay estuarine system and the aquatic wildlife dependent on fresh water inflows, such as the endangered Ridley's Kemp Sea Turtle, concerned environmentalists. The endangered turtles' main food source is blue crab, which thrive in the brackish waters of the bay. Environmentalists were concerned that the lake of freshwater inflows would lead to a decline in the blue crab population and subsequently, harm the survival of the Ridley's Kemp Sea Turtle.

Based on their similar concerns, agricultural interests and environmental groups began to work together to lobby for water releases in 2012, 2013, 2014, and 2015. Agricultural interests joined national environmental organizations, such as Ducks Unlimited, Sierra Club, and the National Wildlife Federation, to decry the LCRA's cutoff decisions. Rice farmers also formed alliances with local school districts, hunting and fishing guides, birding groups, and nature tourism businesses (Price 2014). Expressing his concern over the 2012 decisions, one biologist from Ducks Unlimited stated:

> Water is part of the foundation for the basin-wide regional economy, and the fact is there is not enough water at present for all uses and users. However, it is unconscionable to cut off water for food production – which in turn provides vital habitat for millions of migratory birds and supports a multi-million-dollar, natural-resource-based economy – while allowing non-essential uses such as lawn watering, car washing and filling swimming pools to continue. We are all in this together, and we must all conserve our limited resources and seek sensible compromises in water allocation. Without unprecedented winter rainfall, this decision will cut off water for rice farming within the LCRA irrigation districts for the third year in a row (Halvorson 2013b).

Finally, agricultural interests tried to revive social relationships with urban interests, appealing to a shared concern in the basin's water supply, and stressed the equitable distribution of the basin's water supplies within its historic precedent. One agricultural interest remarked:

> Since the beginning, the lower counties have advocated the entire basin sharing the suffering from the drought. But everyone below the dams in Austin is taking the brunt. No one else is sacrificing. But we are being forced to give up agriculture production, environmental concerns and our rural economy to accommodate their needs. Where is the shared sacrifice? It's just not there (Halvorson 2014).

Another concerned agricultural interest responded:

> The LCRA was established to provide flood control and water conservation primarily in response to the efforts by the lower basin counties to harness the river for everyone's benefit. What has evolved is a self-serving notion that water for others has become paramount. Thus the needs in the lower basin have been

> relegated to a position with no standing at all. This flies in the face of the right to the water by the rice farmers, historically, morally, regulatory and legislatively created (Halvorson 2013c).

The second access narrative evident in the public discourse used by agricultural interests revolved around market access. By limiting water supplies to agricultural interests, the LCRA was also limiting farmers' ability to make a living. In other words, without water, the LCRA denied agricultural water interests access to agricultural markets; they had no product to bring to the market. This limitation not only impaired farmers economically but also an entire community built primarily around rice production. Thus, in their efforts to maintain access to water, agricultural interests repeatedly brought up their concerns for the wider agricultural economy. One agricultural interest stated, "… the rice industry and the communities, businesses, church, charities and local governments that have already suffered through one year without water that plays such a big part in circulating dollars through their budget" (Halvorson 2013e). Another added:

> It will change the county. Irrigated cropland changes the tax base. You have to place a lower value on farmland if it is not producing an irrigated crop like rice, which is about the only irrigated crop grown here. And that's going to mean less tax revenue. We need to get some water from the LCRA or we're going to lose our agriculture infrastructure. We're already starting to lose some of the other businesses that are tied to rice farming (Halvorson 2013a).

As the above quotes suggest, the economic consequences of the ongoing water conflict weighed heavily on the minds of the rice farmers and the agricultural communities in general. Within their narratives of access, the important and vital role that water plays in sustaining the economies of agricultural counties becomes apparent.

Despite their best efforts, in some sense, the political tide had shifted for agricultural interests. Urban interests backed by influential politicians with ties to the

LCRA and TCEQ managed to argue successfully to constrain agricultural interests' access to water during the worst portion of the drought. Urban interests complained about paying more for water than their agricultural counterparts, argued that flood irrigation of rice fields was wasteful, and accused the LCRA of mismanaging water stored in the Highland Lakes. In doing so, the LCRA raised rates for interruptible water supply customers, and the water management plan of 2015 moved to a more stringent allocation system to meet interruptible water supply contracts while preserving more water in the Highland Lakes to meet firm water contracts. Observing the water allocation decisions made during the drought, a local water resources expert commented:

> We're moving toward an allocation system, which I call 'Big dogs eat first.' We haven't given any water downstream on the Colorado over the last three years. The feeling is 'We're bigger than you, so we're going to take the water' (Price 2014).

Agricultural interests felt the tide shifting as well. One agricultural water representative noted, "Matagorda County farmers have contended with forces of nature for more than 100 years and have prevailed, only to be assaulted by human fiat, a stroke of the pen that may destroy what nature's worst could not do" (Halvorson 2013c). Figure 31 illustrates the access mechanisms and conditions characteristic of period 3.

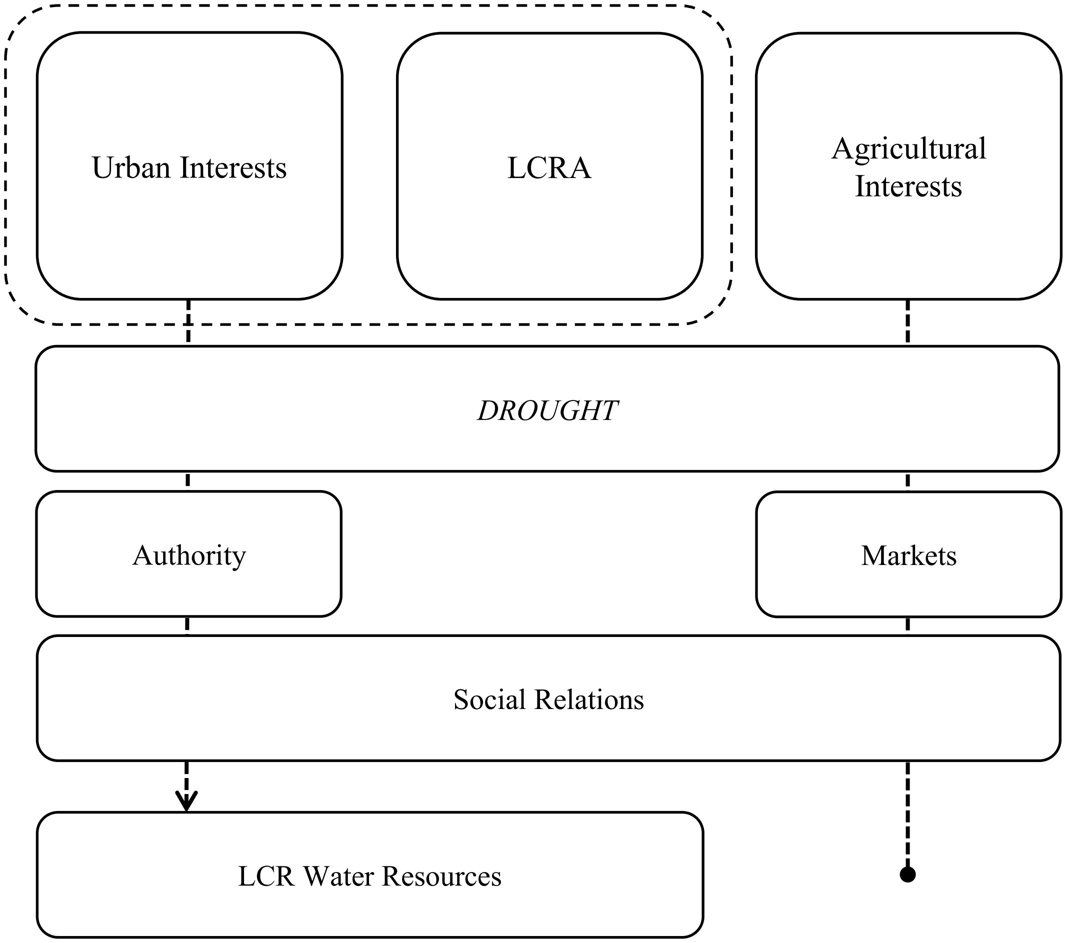

Figure 31. Period 3, urban ascendance access mechanisms and intervening conditions on the path to the water resources of the lower Colorado River.

5.3 Discussion and conclusions of qualitative findings

I used qualitative content analysis to locate and describe access narratives that developed around water issues within three distinct periods of social and political-ecological conditions. The narratives of access identified and discussed within each period of change provide a representation of who is speaking on whose behalf and how – through discourses – access to the benefits of the basin's water resources is controlled, maintained, or acquired. A number of access mechanisms were identified in the narratives presented in each period; however, all access mechanisms were not successful and both urban interests and agricultural interests deployed different access mechanisms depending on the period of change. Moreover, changing social, political, and environmental conditions influenced access and access mechanisms. Thus, the documentation of the various access mechanisms in each period provided an overall characterization of the changing relationship between urban and agricultural water interests vis-à-vis changing social and political-ecological conditions.

In the first period of change, basin interests aligned to constrain access to the valley's water resources from outside interests. Their narratives of access reflected authority and knowledge access mechanisms. Narratives of access included appeals from authority figures and questioning state studies and recommendations and countering these studies with their own analyses. Period of change 2 was characterized by the LCRA's territorial expansion of water resources and strategic water alliances with Austin. Through its ability to access capital and form social relations, the LCRA accumulated a number of significant water rights and entered into many contracts to deliver water to urban developments and municipalities in the central Texas area, increasing its control over the basin's water resources. Agricultural interests were busy defending their water supply by questioning the LCRA's claims on FIN. As the basin entered the 2008-2015 drought and water resources became increasingly scarce, narratives of access shifted as both urban interests and agricultural interests sought to maintain their water supplies. Urban interests relied on authority to constrain agricultural interests, while agricultural interests relied on social relations and market arguments to (ineffectively) maintain their water access.

Social relations as an access mechanism appeared in the narratives of each period of change. Yet, social relations manifest in different ways across the periods of change. In period 1, social relations were informed by a collective connection among all basin interests and the waters of the lower Colorado River valley. This connection is most obvious when authoritative figures' comments reflect the many water interests that use water in the basin, including urban, industrial, agricultural, environmental, and recreational interests. The social relations referenced and used here work in a relational fashion, where access to the basin's water is constrained from outside interests by connecting all water users in the basin. In period 2, social relations are solidified more concretely to enable water access. They are manifest in the alliances formed by the LCRA and the basin's growing urban areas. Here, social relations provide legal access to a share of the basin's water. In period 2, social relations again pivot to a relational tool. Agricultural interests develop relationships with local and outside organizations in an effort to maintain water access. Thus, while social relations are present in each period of change, urban and agricultural water interests use social relations in different ways to enable or constrain water access.

Finally, my interpretation of the narratives of access within public discourse produces an account of the significant events (i.e., those events encapsulated in each period of change) that led to the prioritization of urban water interests over agricultural water interests in the valley. The trajectory of water access in the basin moved from water interests working together collectively to urban and agricultural water users focusing on their own individual interests at the expense of others. The findings also point to the importance of the positionality of water interests in determining which narratives of access they deploy during the periods of change. In period 1, when urban and agricultural interests are more or less on equal ground, narratives of access coalesce around defending the basin's water resources. This is largely achieved through constant pushback by local political authorities. In period 2, as the rupture between urban and agricultural interest begin to form, urban interests start to increase position within the water structure hierarchy in tandem with the LCRA. Urban interests use capital and social relations to improve their access to the valley's water supplies. Agricultural interest during this period must work to maintain water access by questioning the LCRA. In period 3, urban interests have moved to the top of the lower Colorado River water hierarchy. Narratives of access leveraged by urban interests relied on state-level, political authorities to maintain urban water access. Agricultural interests looked outside of the basin, forming alliances with national organizations, in attempt to maintain their water access. Thus, urban water interests maintained water access through direct contact with elected officials, whereas agricultural interests attempted to maintain water access using public pressure exerted through social contacts with various interest groups. Urban interests essentially played an inside game, and agricultural interests relied on an outside game to maintain water access. Yet, based on their rising position, urban interests succeeded in maintaining water access.

The findings also show that environmental events (i.e., drought in this case) influence social, political, and economic systems, and ultimately, affect access mechanisms. During period 3, basin interests faced a real water scarcity problem, which was completely different from the more nominal water problems experienced in earlier periods of change. The environmental situation resulted in a struggle for water access between urban interests and agricultural interest as basin water supplies dwindled. In this way, access mechanisms were tightly connected to both the changing positionality of water interests, the underlying social, political, and economic circumstances, and the environmental conditions present in the basin.

6 SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

The waters of the lower Colorado River of Texas have sustained both urban populations and agricultural operations for over a century. Recent rapid urban growth and a changing climate, however, have ruptured an otherwise equitable relationship between urban and agricultural water interests in the valley. Through a mixed-methods research design, this dissertation study identified changes in the consumption and control of the basin's water resources among urban and agricultural interests from 1970 to 2015. By analyzing a variety of variables on or related to water use, I described spatial patterns and temporal trends of water use among urban and agricultural water interest in the valley. I located annual change points for a number of the variables under consideration, using a novel approach to define significant shifts in water use and associated variables. Finally, I defined distinctive periods where water use and access changed and documented the mechanisms that urban and agricultural water interests used to constrain or enable access to the basin's water resources. By leveraging contemporary theory on resource allocation and control, I gave particular attention to how political, social, economic, and environmental conditions influenced human responses relative to the distribution of water resources. In doing so, I offered an interpretation of a socio-natural system where water access plays an integral role in determining social and economic outcomes of urban and agricultural counties of my study area.

6.1 Changing patterns of water, access, and public discourse

This mixed-methods research exposed variation in how much water urban and agricultural interests used during the study period and documented water access through public discourse. Specifically, the quantitative portion noted a number of changes in water-related variables – both urban and agricultural – in the valley. Additionally, annual change points for a number of the variables under consideration signaled significant shifts in water use among urban and agricultural interests. In this way, the quantitative methods of my research provided a replicable mechanism to verify changes in water use. I used these results to inform my qualitative analyses, which identified the mechanisms urban and agricultural water interests used to access the waters of the lower Colorado River. Together, my quantitative results and qualitative findings provide an interpretation of the changing patterns of water, access, and public discourse in the lower Colorado River valley. In the following section, I recap these patterns before offering my final thoughts on the implications and recommendations of this research.

Over the past 40 years, the lower Colorado River valley has experienced increasing summer temperatures and periods of floods and droughts. Summer temperatures were cooler during wet years and warmer during dry years, but temperatures increased overall during the study period. A significant shift in temperatures occurred in 1997, and an extended dry period began in 2008. This dry period corresponds to the drought that overwhelmed the watershed from 2008 to 2015.

During the study period, water use (from both surface water and groundwater sources) in the lower Colorado River valley has trended downward with a few exceptions. High water usage occurred in 1988, 1996, and 2011, and in 2007 and 2014, water use was lower than other years in the study period (Figure 14). High water usage in 1996 and 2011 occurred during dry periods. Low water usage in 2007 coincided with a wet period, and low annual water usages after 2012 were the result of management decisions to withhold water to agricultural interests.

In addition, during the study period, urban water use in the lower Colorado River valley increased (Figure 15) while agricultural water use declined (Figure 16). A significant shift in the proportion of water used by urban interests occurred in 1996. As of 2014, urban interests' share of the water used in the valley was approximately 35 percent (Figure 15 E). Around the same time, urban surface water and groundwater use increased significantly (Figure 15 B and C, respectively). At the other end of the watershed, agricultural surface water and groundwater use declined beginning in 2001 and 1999, respectively (Figure 16 B and C). Agricultural production also declined significantly from 1995 to 2002 (Figure 21).

Area lake levels and river discharge fluctuated from 1970 to 2015. Low lake levels corresponded mostly to dry periods, whereas high levels corresponded to wet periods. Significant declines existed beginning in 2005 and extending into 2007 (Figure 18), with a precipitous decline in lake levels occurring after 2011 – the worst year of the drought. River discharge typically increased during the rice-planting season, but a significant change occurred in 2007 when discharge dropped rapidly in the years afterward. Low flows from after 2011 were the result of orders to cut off water to downstream agricultural interests, holding interruptible water contracts.

In the qualitative portion of my study, I documented a number of governance actions and transactions that took place during the study period. State-level, regional, and local water governance organization took actions that influenced water consumption and control in the basin. In the late 1980s and early 1990s, the LCRA developed multiple water management plans, entered into a water contract with the City of Austin, and purchased the remaining water rights in the Lakeside Irrigation District. A decade later, another series of influential water governance actions took shape. During this period, the state of Texas passed Senate Bill 1, changing the way water would be managed in the state, the LCRA made multiple, large water rights purchases, accumulating a majority of the basin's water supply, and the City of Austin entered into a multimillion-dollar water contract and later formed a water partnership with the LCRA, securing its water supplies for the foreseeable future. The LCRA also developed water management plans in 2010 and 2015. The 2015 plan significantly altered the structure of the curtailment procedures for interruptible water supplies in drought periods.

Additionally, I used Ribot and Peluso's "theory of access" (2003) as a basis to code newspaper articles on water resources in the lower Colorado River valley. These efforts produced a description of access mechanisms located in particular public discursive moments related to the distribution and competition for water among urban and agricultural interests. I found that urban and agricultural water interests in the lower Colorado River basin rely on a number of access mechanisms and that they use these mechanisms in an effort to control or maintain access to their share of basin's water resources. Access mechanisms change over time depending on the social and political-ecological circumstances.

The quantitative stage and the qualitative stage of my research assisted in the identification of three periods of change in the relationship between urban and agricultural water interests in the lower Colorado River valley (Figure 32). Within these periods, my interpretation suggests that in addition to the two primary water interests –

urban and agricultural – one quasigovernmental entity (i.e., the LCRA) plays a prevalent role in water matters. The periods of change also suggest that a mix of social, political, economic, and environmental events have shaped water resource management and development, including access to and control over water resources in the valley.

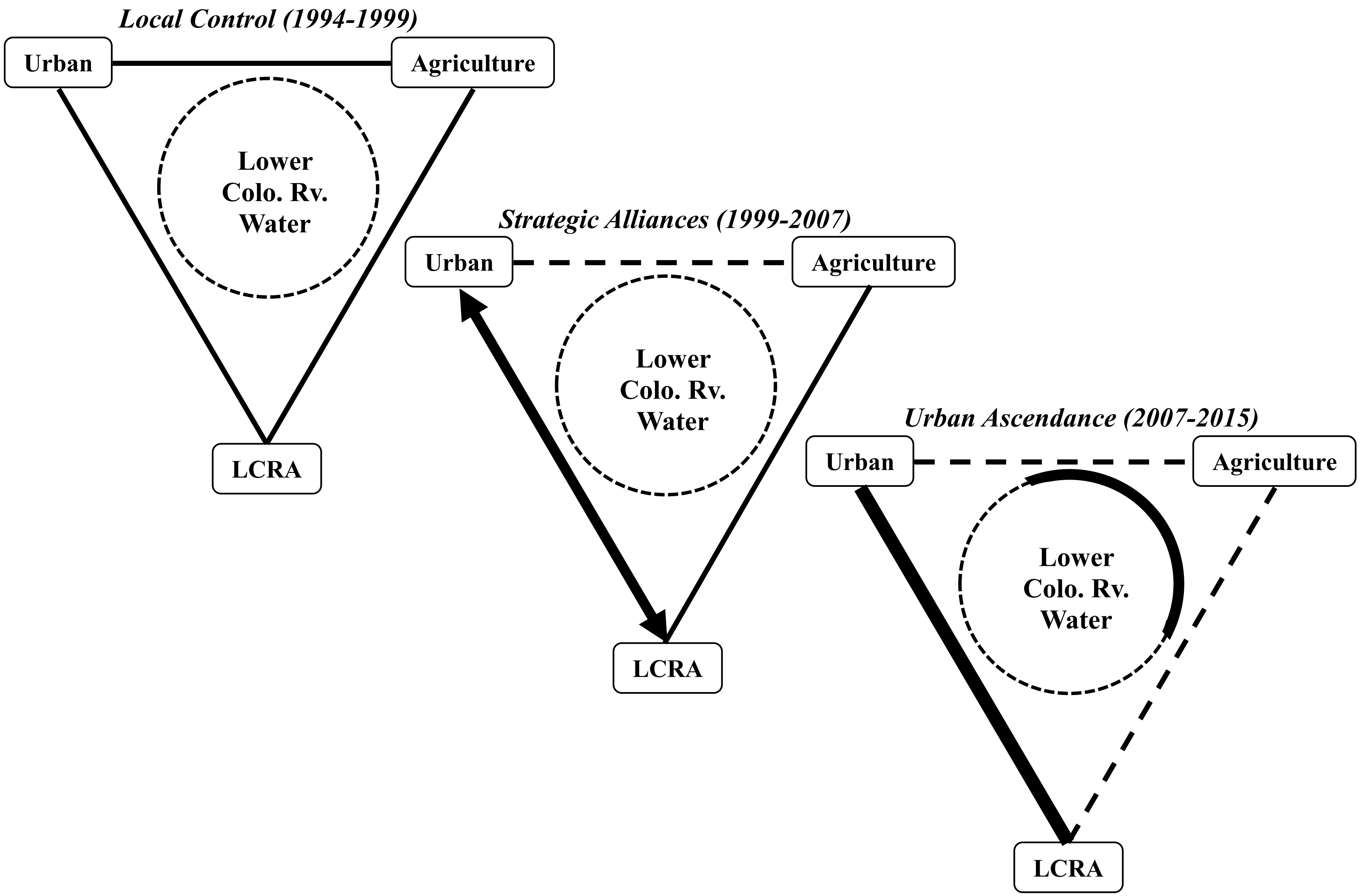

Figure 32. Conceptual model of periods of change in water use and access in the lower Colorado River valley from 1970 to 2015.

The first period of change (1994 to 1999) coincides mostly with the first quantitative period identified though the CPM analysis. A concerted effort from basin interests – urban and agricultural – to constrain external actors from acquiring the basin's water resources framed this qualitative period of change. Urban and agricultural interests worked together along with the LCRA to defend the basin's water supply from outside interests. The second period of change (1999 to 2007) merges both quantitative periods of change 1 and 2 identified in the CPM analysis. Water rights purchases and water deals and contracts within the basin characterized qualitative period of change 2. During this period, the LCRA made a number of significant water rights purchases, which considerably expanded its control over the basin's water resources, and entered into two major water contracts with the City of Austin. The contracts between Austin and the LCRA solidified their relationship and led to their control over much of the basin's water supply. The third and final period of change begins in 2007 after the last CPM signaled, and it ends in 2015 with the updated LCRA water management plan. The beginning of an extended drought, resulting in a period of conflict between urban and agricultural interests as both competed for a dwindling water supply, marked this qualitative period of change. It is also informed by the increasing influence of Austin in the valley's water matters and signals the decline of agricultural interests and the rise of urban interests in the basin as water for agriculture production became restricted but continued to flow to central Texas municipalities.

The narratives of access that emerged in each period of change provide insight into the (trans)formation of environmental discourses and counter-discourses as urban and agricultural water interests attempt to control, maintain, or acquire access to the basin's water resources. Access mechanisms are dynamic and water interests change mechanisms in response to social, political, economic, and environmental conditions. Thus, as these conditions change so does the relationship between urban and agricultural interests. Furthermore, pressure on the basin's water resources has come from interests inside and outside the watershed, and access mechanisms differed depending on the source of pressure and the perceived versus real threat of water scarcity. Additionally, over the course of the past 30 years, urban interests have become more powerful and gained an increasing amount of control over the basin's water resources, whereas agricultural interests have had to continually defend their access to water. This shift was brought about through the arrangement of specific access mechanisms and led to the formation of new access mechanisms in both urban and agricultural areas of the lower Colorado River valley.

Additionally and importantly, the spatial arrangement of activities along the lower Colorado River played an integral role in the outcomes found in the quantitative and qualitative portions of this research and provided the setting to explore the changing relationship between urban and agricultural water interests. Both the physical geography and human geography represented in the urban-to-agricultural gradient of the lower Colorado River valley fundamentally shaped the relationship between urban and agricultural water interests. Historically, the dams forming the Highland Lakes system provided urban residents relief from the devastating floods frequent to the Colorado River valley. Flood prevention along with a stable water supply and hydroelectric generation, contributed to the Austin area's growth. Currently, over one million people in the greater Austin area depend on waters derived from the Highland Lakes as their primary municipal water source. Agricultural interests located further down the river valley took advantage of the sandy soils and abundant water of the lower Colorado River valley to develop successful agricultural operations at the turn of the 20th century. The dams of the Highland Lakes provided agricultural interests with regular, reliable flows of water to the many irrigation districts operating in Colorado, Wharton, and Matagorda counties. While the demands of urban interests have grown considerably, downstream agricultural operations still rely on releases from the Highland Lakes to irrigate their crops, creating competition for a dwindling water supply.

Under a backdrop of competition and conflict, urban water interests, located near the primary sources of water for the entire lower Colorado River valley and home to Texas' seat of government, have exploited their position in the watershed to increase control over issues related water use and access. At the same time, agricultural interests have failed to sustain their historical political influence in water issues and struggled to overcome the friction of distance between their location and the people and institutions driving water management decisions in the basin. This friction was evident at a 2012 meeting of the LCRA board of directors held in the upper portion of the lower Colorado River valley that discussed future water curtailments. At this meeting "[o]nly about a dozen or so (attended) from our lower counties [including Colorado, Wharton, and Matagorda counties] … about 25 (speaking against ag [agricultural] interests) to one (representing the ag [agricultural] interests)," and "[f]rom the statements made, if the LCRA (board of directors) had responded on the basis of numbers, there would not be any irrigation water for 2013, or indeed ever!" (Staff Reports 2012). These statements also reflect the erosion of an historical urban-agricultural (city-hinterland) relationship in the basin. No longer is the Austin urban area linked socially, economically, or culturally to agricultural interests downstream. In short, geography matters in the lower Colorado River valley. Without strong ties to the urban core, the rice belt formed over a century ago is left to fade into history or reinvent itself on its own terms.

6.2 Implications and recommendations

Little research has been conducted on the transfer of water from agricultural uses to urban uses and the spatiotemporal patterns associated with this shift. Those that have explored water appropriation from agricultural uses to urban uses have done so in developing regions of the world (Celio and Giordano 2007; Molle, Hoogesteger, and Mamanpoush 2008; Celio, Scott, and Giordano 2010; Birkenholtz 2016) and the American West (Howe, Lazo, and Weber 1990; Moore, Mulville, and Weinberg 1996; Villarejo 1996). The results of this dissertation research highlighted the geographic patterns and processes related to social, discursive constructions of water resource allocation at particular influential moments while illuminating a larger environmental geography of water access and control in the lower Colorado River basin of Texas.

Additionally, during the exposition of this study, I suggested that the relationship between the lower Colorado River and those that use and benefit from its waters make up a hybrid, socio-natural system. In the following paragraphs, I situate my research within the broader literature that considers water and society to be tightly intertwined in a socio-natural system, where water changes society and society, in turn, changes water. In particular, I locate my findings within the theoretical research related to water resources development, access, and control and offer recommendations for practitioners responsible for water resource allocation in urbanizing regions.

My research expands our understanding of water consumption and access and provides an example of how water has been reallocated from agricultural uses to urban uses in a semi-arid, rapidly urbanizing watershed subject to recurring droughts. Moreover, I employ a mixed-methods approach that is unique to studies related to resource access and control. First, I used the change point model to discern significant shifts in urban and agricultural water usage and other associated characteristics. This method allowed me to identify important periods of change in the way water was used in the basin. The identification of changes in water use is critical to both practitioners and researchers. Without knowing when water use and other characteristics related to water use change, we do not have an opportunity to intervene and analyze why a shift occurred and offer prescriptive measures to correct the shift. In other words, the change point analysis offers a robust technique in which to monitor trends in water usage across a number of variables in an effort to stabilize changes that may harm one or more water interests. I also used newspaper articles to locate and trace narratives of access. This method is also relatively unused in natural resource management research but provides a geographical perspective and longitudinal representation of environmental change and associated events. Specifically, by examining access narratives documented in news articles from two geographically distinct locations, I illustrate how site-specific responses to increasing water scarcity (both nominal and real) inform changes in the relationship between urban and agricultural water interests over time. Moreover, the documentation of public discourses through news articles highlight synergies and tensions as well as spatial and temporal differences between the mechanisms urban and agricultural water interests used to enable or constrain water access. In exploiting this source of information, I further defined periods of change in the relationship between urban and agricultural water interests. Using both of quantitative and qualitative methods, my research offered a more nuanced view of how water use has changed in the lower Colorado River valley and how urban and agricultural interests attempted to control, acquire, or maintain access to its waters.

Equitable access to water is an important component of managing large water systems with competing demands. Through the layered understanding presented here, water practitioners should be more aware of how broader social, political, economic, and ecological events affect water use among various interests. With that knowledge, water managers and controlling interests should be able to better tailor their management decisions and plans to meet the demands of all water users.

My research also adds to the literature on water resources development and has the potential to extend models of river basin development. Specifically, it provides an example of a basin undergoing economic restructuring characterized in late stage river basin development. My study chronicles responses to water scarcity (both nominal and real). Yet, it suggests that not only are responses to water scarcity dependent on physical and social systems (Molle 2003) but the mechanisms used to maintain access are also dependent on these same systems. Thus, the access mechanisms water interests use are mediated by political, social, economic, and environmental conditions occurring in the basin.

My study also advances our understanding of how interests gain control over water and constrain or enable water access. Strategic partnerships, new water contracts, and significant water rights purchases allowed the LCRA exercise a more authoritative control over the valley's water resources. This accumulation of real and virtual water supplies was critical to the expansion of the LCRA's control over the valley's water resources. By holding virtually all of the major and significant water rights, the LCRA positioned itself to dictate water supply terms. Additionally, its multiple alliances with the City of Austin most likely led to the most dramatic example of the shift from agricultural control to urban control, namely the water curtailments for interruptible customers during the height of the 2008 to 2015 drought. In this way, my study details the expansion of Austin's urban hydraulic reach in the lower Colorado River valley as its waters have been gradually brought into the service of urban uses.

This expansion and control has led to changes in both urban counties and agricultural counties social, physical, and economic landscapes. Important questions arise that warrant further research: how have agricultural counties coped with losing a large staple of their economies, how have farmers coped with water shortages, and what obstacles have they encountered since the water cutoffs? On the other end of the spectrum, urban centric questions also surface. How have urban interests adjusted to the new waterscape, who has benefited the most from the shift in water resources, how has this fueled further urban expansion and economic growth. Each water interest is tied together via a common resource that has become a commodity and one that can be withheld at will.

Additionally, my study emphasizes the importance of water acquisition in a rapidly-urbanizing watershed subject to recurring drought. The acquisition of water is not just about water... it is "buying control over our destiny" (Lindell 1999). In this way, strategic partnerships, new water contracts, significant water rights purchases, and water curtailment function as tools to control the water resources of the lower Colorado River valley. Control over water has required others to defend their own interests through a variety of mechanisms in an effort to maintain access to water. From this, a new waterscape has emerged in the lower Colorado River valley. The new waterscape reflects the rise of urban interests and the decline of agricultural interests, inverting the historical hierarchy of water distribution and access in the valley. This shift – from agricultural to urban – has magnified the standing of water in the watershed and its importance to the many water interests from the Highland Lakes to Matagorda Bay. Therefore, "if water is the new oil, [and the] LCRA [the entity that controls it] is [now] chief of the emirates," (Price 2007) efforts must be made to balance the interests of all water users in the valley to prevent "a self-serving notion that water for others has become paramount" (Halvorson 2013c). In order to move past a system "where big dogs eat first" (Price 2014), new tools must be developed to ensure that equitable water access is achieved. Thus, detailed analyses of historical access mechanisms and their narratives, much like the one presented here, are key to planning for our future. The findings aid and contribute to our further understanding of the dynamic challenges involved in the management and distribution of water at the basin scale.

Finally, my study synthesizes the processes – political, social, economic, and environmental – that make up a multidimensional environmental issue. In this way, my findings implicitly enhance our knowledge of a complex socio-natural process. In particular, it answers where, when, and why water relations are formed and others ruptured. Additionally, by documenting the changing relationship between urban and agricultural water interests in the lower Colorado River valley, my study provides an example of how water and society make and remake each other in new ways. The current waterscape operating in the lower Colorado River valley favors urban uses over agricultural uses. Yet, moving forward, the waterscape offers many different outcomes. Under these new conditions, the economies of agricultural counties will need to reinvent themselves. There is evidence that agricultural counties are turning to the tourism industry to help bolster their economies. Farmers are planting and testing new crops, such as sorghum, corn, and soybeans. Many agricultural interests, however, look forward to the development of a new reservoir in Wharton County to bolster water supplies. It remains to be seen whether these steps will mitigate the increasing presence of urban interests in water matters in the valley or simply provide more resources to be assumed under regional access mechanisms favoring development of urban landscapes over the economic resilience of agriculture.

APPENDIX SECTION

Codebook for qualitative content analysis of newspaper articles

Introduction

This codebook guides the second stage of my dissertation research project. This portion of my research uses public discourse found in news media to document the various mechanisms water interests use to access water resources in the lower Colorado River valley and the extent to which social, political, economic, and environmental events influence access mechanisms. Here, access is defined as "the ability to derive benefits from [the valley's water resources]" (Ribot and Peluso 2003). Access is seen as a dynamic process, changing over time, and changes in access strategies are documented in this analysis. I employ a qualitative content analytic approach to code text from newspaper articles from 1994 to 2015 in order to document the mechanisms – and changing strategies – by which water interests control, maintain, or acquire access to the valley's water resources. The time frame corresponds to periods of change identified in stage one of my dissertation project.

Qualitative content analysis outlines "an approach of empirical, methodological controlled analysis of texts within their context of communication, following content analytical rules and step by step models, without rash quantification" (Mayring 2000, 2). This codebook details the step by step process used to analyze media discourse relative to water resource access. More specifically, this codebook provides the coding structure for analyzing newspaper articles on water resources in the valley. The contents of this codebook and coding structure are guided by Ribot and Peluso's (2003) theory of access and other factors affecting water allocation (OECD 2012). Together, these theoretical and conceptual frameworks provide the thematic organization for coding media discourse relative to water resources and access mechanisms. Accordingly, this codebook directs the coding of newspaper articles under analysis to pinpoint and return information relevant to answering dissertation research question 3 (see below). Because this study employs a qualitative content analysis and not a quantitative content analysis, the objective of this study is not to quantify the contents of the news articles; rather, the goal of this codebook is to provide an overall framework for coding articles in order to keep the researcher focused and provide a guide for interpreting key components of access, namely who is participating, how are water resources accessed, and what does this disclose about the changing landscape of water allocation in the basin.

Research purpose

The purpose of this dissertation research is to provide an environmental geography of water resource use and access in the lower Colorado River valley, to identify periods of change that led to the prioritization of urban water uses over agricultural water uses, and to analyze discursive systems used to enable or constrain water access during periods of change. Throughout the dissertation, my analyses examine the complex relationship between a major urban area and its wider influence on the basin's water allocation system and how this relationship affects spatial and temporal outcomes of water use and access in both urban and agricultural portions of the watershed. In doing so, I give particular attention to how "natural processes that are larger than an urban system instigate varied human responses" in water management (Colten 2012, 203). As such, this research answers the following questions:

1. What temporal trends and spatial patterns occur in water use and access among urban and agricultural interests in the lower Colorado River valley of Texas from 1970 to 2015?
2. In what years do significant changes occur in water use and access among urban and agricultural interests, and what do these changes reveal about water use and access between urban and agricultural interests?
3. What distinctive periods of water use and access develop in public discourses, and through public discourses, how do urban and agricultural interests enable or constrain access to the water resources of the lower Colorado River given the underlying, changing social, political, economic, and environmental conditions?

Data

Data for this portion of the study is derived from newspaper articles related to water resources in the lower Colorado River valley. In order to capture spatial differences between urban and agricultural portions of the study area and to key in on important differences access mechanisms deployed by the two groups of water interests, news articles were drawn from an urban-centric, regional newspaper located in Austin, Texas – *The Austin American-Statesman* – and a local, bi-weekly newspaper – *The Bay City Tribune* – situated in the heart of the study area's agricultural producing region.

Articles from *The Austin American-Statesman* were collected from LexisNexis Academic via a series of targeted searches. LexisNexis Academic maintains complete, searchable archives of *The Austin American-Statesman* from 1989 to present. Articles from *The Bay City Tribune* were gathered from NewsBank via similar search criteria. NewsBank houses archives of *The Bay City Tribune* from 2001 to present. News articles from 1994 to 2000, where acquired from the Bay City Public Library in Bay City, Texas. The library holds historical archives of *The Bay City Tribune* on microfilm. These article were gathered by scanning each edition from 1994 to 2000.

Units of analysis

The main purpose of this portion of my dissertation research is to describe mechanisms of access deployed by both urban and agricultural water interests over time as revealed in media discourse. In order to do so, I locate and code five themes: 1) the primary theme of each article and associated cause(s), 2) water interests present in each article, 3) mechanisms of access described in each article, 4) climate-related factors mentioned in each article, and 5) the source(s) attached to these claims. The coding of article text advances in two stages. The first unit of analysis is the entire newspaper article. The entire article was read in order to identify the overall theme of the article and any associated cause(s) of water issues presented, as well as what water interests are included. The second stage of this analysis provides more detail and takes the paragraph as the unit of analysis. Paragraphs were coded in order to identify mechanisms of access, climate-related factors, and their sources.

Coding

Article theme: Competition for limited water resources is increasing among water users. Strategies exist to both increase and limit water use. For example, new reservoirs may be built to increase water supply or policies and water use decisions may effectively redistribute water resources across water users in an effort to extend water resources. These strategies may elicit cooperation among water users or may provoke conflict or competition for the valley's water resources. The following article themes will be coded related to competition and cooperation.

1. Competition refers to a struggle or conflict between water interests vying for the valley's limited water resources. Articles that mention a conflict or competition between water interests will be coded as such.
2. Cooperation denotes approaches to solving water problems (or increased efficiency of water use) between water interests and authorities.
3. Both refers to an article that includes references to both competition and cooperation between water interests.

If an overall theme cannot be discerned, it will be marked as no identifiable theme. If another theme is present, it will be coded as other and identified.

Overall cause: The literature has suggested that increasing competition to access limited water resources is the result of three primary causes: 1) population growth, 2) sustained economic development, and 3) a changing climate. Population growth puts a strain on local and regional water resources as demand for municipal water increases. Population growth also leads to the redistribution of water resources both locally and regionally and spurs development of reservoirs to augment supply. Economic development refers to increases in financial or business-related growth, including increasing or retaining employment opportunities and supporting local incomes. Economic development along these lines may initiate a redistribution of water resources in the valley or may play a role in the area's dwindling water resources. Economic development may also indicate broader economic restructuring in the valley that affects the redistribution of regional water resources. Climate-related phenomena refer to variables, such as drought, floods, precipitation, and temperature. Changes in climate-related variables often impact the availability of water resources, leading to policy changes and shifts in management strategies.

As such, each cause will be coded. If multiple causes appear in an article, each mention will be in coded in combination and identified. This theme also has a coding options for other and no mention.

Water interests (or demands): People derive a number of benefits from the valley's water resources. As such, multiple categories of water use exist. These categories are characterized according to their primary objectives. This research codes the following water interests (or demands).

1. *Municipal* water interests are primarily concerned with domestic, public, commercial, and small industrial uses. The objectives of these uses, respectively, include drinking, cooking, washing, watering, and air conditioning; public facilities and firefighting; shopping centers, hotels, and laundries; and small scale manufacturing processes.
2. *Industrial* water interests typically include large scale, self-supplied water for the manufacture and production of industrial products.

3. *Agricultural* water interests use water to irrigate field crops and to raise livestock.
4. *Electric-steam power* water interests use water for the purpose of producing electricity. Such facilities include hydropower production via turbines located in dams, coal-fired power plants, and nuclear power facilities.
5. *Recreational* water interests use water primarily for sport-related and leisure activities. These include such activities as boating, fishing, and swimming.
6. *Environmental* water interests primarily advocate for the ecological benefits of water. These may include the maintenance of environmental flows, wetland habitats for water fowl and other plant and animal life, and the overall preservation of ecosystems dependent on river flow.
7. *Other* water interests may also emerge in the course of coding. These will be documented and identified accordingly.

Source: Source refers to an identified person in an article. This is usually someone who comments on an issue related to water use in general, and water management strategies, water decisions (proposed or implemented), or water policies in particular. If a source appears in the news article, record the source's primary affiliation as identified in the article.

1. *Elected official* refers to someone with a capacity to speak on behalf of a water interest community or water policy. For example, an elected official may be a city council member, mayor, legislator, or governor.
2. *Water interest representative* is a person who represents a water interest (i.e., municipal, agricultural, etc.) either formally or informally. This may include, for example, the director of a non-profit environmental organization or the president of a homeowners' association.
3. *Water authority* is an individual employed by a local or regional water authority or governing body, such as the LCRA, whose primary task is water distribution or wholesale.
4. *Scientific authority* denotes an individual who possesses an academic background that allows him/her to comment on water resource issues based on his/her scientific knowledge (e.g., scholar, professor, researcher, etc.)
5. *Resident* refers to an individual who is identified as residing or having a dwelling in the study area.
6. *Other* (specify) refers to a source that is not defined according to the sources above.
7. *No attribution* can be discerned from the textual material.

Physical characteristics: The need for and availability of water resources is linked to the amount of water available stored (i.e., water reservoirs or groundwater sources) and regional weather patterns, such as precipitation, droughts, and floods. Thus, reporting on issues of water quantity may refer to weather phenomena and lake levels as an indication of current water stress. The following variables attempt to identify the extent to which newspapers articles and sources draw on physical characteristics when describing access mechanisms or further characterizing broad thematic issues in the news article.

Climate-related characteristics refers to mentions of regional weather patterns, such as precipitation, droughts, and floods. Specific climate-related characteristics in the coding structure include: drought, flooding, precipitation, heat, cold, and other characteristics.

Groundwater and surface water are interconnected, yet Texas law differentiates between the two. Identification of whether an article mentions surface water or groundwater will help characterize any differences that may arise between them. As such, categories for coding include surface water, groundwater, or both.

Lake levels refers to mentions of lake levels in reference to water availability, and often is an indication of water stress. Two lakes store house the majority of water used in the basin. If mentioned, lakes will be coded as either Lake Buchanan, Lake Travis, both, or other. The corresponding measure described for lake levels will also be coded as low, declining, rising, full, or other.

Governmental and management actions: The governance and management of water resources in the lower Colorado River basin ultimately determine who gets water, when, and where. Thus, mentions of policy implementation and decisions as well as significant water deals, contracts, and purchases will be coded and identified.

Mechanisms of access: Access mechanisms refer to the way(s) in which a water interest group or community controls, maintains, or gains access to the valley's water resources. These mechanisms are broadly categorized into two themes: 1) rights-based access mechanisms or 2) structural and relation access mechanisms. Mentions of access mechanisms will be coded along with their subthemes listed below.

Rights-based access:

1. *Legal access* refers to rights guaranteed via law, custom, or convention. For example, access to water may be granted via water rights, water lease, or water sale. Legal rights may also work to prevent access to water. For example, municipal water restrictions or water management decisions and policies may limit the amount of water an individual may use over a period of time.
2. *Illegal access* refers to access to water resources through either theft or violence.

Structural and relational access mechanisms:

1. *Technology:* Technological knowledge or specialized equipment may improve access to water. Agricultural interests, for example, may mitigate surface water shortages by digging wells to harvest groundwater resources.
2. *Capital:* Capital (or economic prosperity) may also be used to improve access to water. Such actions as purchasing water rights may be seen as a mechanism to acquire water resources or to control water use. Additionally, water leases, rents, or fees may be seen as a mechanism to maintain or acquire access to water.
3. *Markets:* Market access also drives the ability to benefit from water resource use. Market access includes the pricing of water resources, which may limit or increase access, as well as the ability to access markets for products produced with water resources, such as electricity and agricultural or industrial products.
4. *Labor:* Work or the ability to work (i.e., labor power) influences access to water resources. Specifically, in terms of water resource use, access to labor or labor power is linked to production processes that are dependent on water resources. For example, a farmer who holds no water rights or permits, may derive benefits from water by contracting with a water rights holder.

5. *Knowledge:* Knowledge and information also determines access to water. Knowledge, such as scientific information, may be used to control, maintain, or acquire water resources. Environmental reports, for example, based on objective scientific observations may be used to influence water management and policy decisions. Knowledge claims may also by countered.
6. *Authority:* The ability to make contact and build relationships with key individuals or institutions who make decisions (or possess authority in decision-making processes) on water use often leads to the control, maintenance, or acquisition of water resources.
7. *Social identity:* Social identity is a key component to determining access. Social identity refers to categories of individuals or groups of people based on age, gender, ethnicity, religious beliefs, livelihoods, cultural practices, etc. Identity may be used to control, maintain, or acquire access to water resources. Farmers in the valley, for example, may draw on their relatively long history of rice production to maintain access to water.
8. *Social relations:* Social relations and access stress the importance of relationships between groups or individuals and include negotiating and renegotiating connections via “friendship, trust, reciprocity, patronage, dependence, and obligation” (Ribot and Peluso 2003).

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