FACILITATING SUSTAINABLE USE OF THE RIO GRANDE:

A SOCIAL-ECOLOGICAL ANALYSIS

DISSERTATION

Presented to the Graduate Council of
Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for the Degree

Doctor of Philosophy

by

Kathy Ann Alexander, B.A., M.A.G.

San Marcos, Texas
August 2012

FACILITATING SUSTAINABLE USE OF THE RIO GRANDE:

A SOCIAL-ECOLOGICAL ANALYSIS

Committee Members Approved:

____
Walter Rast, Chair

____
Vicente Lopes, Co-Chair

____
Timothy Bonner

____
Walter Wright

____
Todd Votteler

Approved:

____
J. Michael Willoughby
Dean of the Graduate College

ACKNOWLEDGEMENTS

I would like to express my deep appreciation to my parents, Baird and Betty Martin, for their unwavering support throughout the long process of completing this degree. I would also like to thanks my daughters, Rosemary and Rachel Bickerstaff, and my partner David Harkins for their understanding and help in making things run smoothly during the past few years. I could not have done this without you! I would also like to thank my bosses from the Texas Commission on Environmental Quality (TCEQ), particularly Lann Bookout, Todd Chenoweth, and Kellye Rila, for their support, encouragement and even for the occasional not so gentle reminders to get the dissertation done. Regarding the TCEQ, it goes without saying that this dissertation is wholly my own work and does not reflect the policies or practices of the TCEQ.

Connie Napolitano and Danna Peck were always there when I needed them and Kirsten Dodge was a huge support in the latter stages of this effort. I also want to remember my late friend and mentor, Professor Joe G. Moore, Jr. Joe fostered my interest in water issues and was always available to listen and provide guidance. Also, to my late friend Jeanne Jamail, I wish you were here to see this.

Of course, it goes without saying that I am so grateful for the support and guidance from the members of my committee. Tim Bonner provided invaluable assistance and direction, especially with Chapter 1, and I appreciate his patience. Walter Wright opened my eyes to the importance of dispute resolution in water resources. His unique perspective from the social sciences fostered the interdisciplinary aspect of this project, which is so important in water resources research. Todd Votteler not only stepped up to the plate to serve on my committee, but also provided a practical perspective that guided my research efforts. In addition, Todd is also a great friend and fellow editor of the Texas Water Journal.

Without my co-chairs, Vince Lopes and Walter Rast, this dissertation would not have been possible. Vince introduced me to ideas of social-ecological resiloience and complex adaptive systems and was not only extremely supportive but, more importantly, helped me refine my thoughts on this important perspective for natural resource issues. Finally Walter was a pleasure to work with throughout my graduate studies. He was the first person I met in the program, remained calm throughout, helped me see things from an international perspective, and also helped me sort through the frustrations that are part and parcel of working full time and pursuing an advanced degree.

This manuscript was submitted on May 2, 2012.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

ABSTRACT

FACILITATING SUSTAINABLE USE OF THE RIO GRANDE:

A SOCIAL-ECOLOGICAL PERSPECTIVE

by

KATHY ANN ALEXANDER, B.A., M.A.G.

Texas State University-San Marcos

August 2012

SUPERVISING PROFESSORS: WALTER RAST AND VICENTE LOPES

The institutional structure underlying the management framework of the transboundary Rio Grande basin was examined to provide insight into the status and efficacy of the institutional controls that underlie management of the river. This analysis was undertaken in several steps. Changes in ecologically-important aspects of streamflow and changes in fish assemblages for four reaches of the river, governed by different water management policies and practices, were identified and evaluated. A historical profile of the basin was constructed to examine the structure and function of institutions governing water management, utilizing a complex adaptive systems perspective that considered the interplay of social processes and resulting ecosystem

responses. The results included theoretical insights into how spatial and temporal scales can best be considered in a transboundary river system. The issues of conflict management and public participation were evaluated from an outcome-based perspective to identify opportunities to incorporate environmental needs into basin water management . A conceptual framework, based on dialog and deliberation, that considers cultural factors and which allows for multiple stages, multiple forums, and stakeholder control over decisions, is proposed. Institutional diagnostics also were used to perform a comparative analysis of management attributes for ten transboundary rivers around the world to identify management options that might be transferable to the Rio Grande basin. The insights from this research suggest three feasible options for more effective management of the transboundary Rio Grande basin for sustainable use, including (i) no modification to the current institutional structure, (ii) a modified institutional structure using the Minute system under the 1944 Treaty, and (iii) complete reconfiguration of the transboundary water management regime.

CHAPTER I

INTRODUCTION

The Rio Grande/Rio Bravo Basin drains two countries, the United States and Mexico, and eight states within the two countries: Texas, New Mexico, Colorado, Chihuahua, Coahuila, Durango, Nuevo Leon and Tamaulipas. In addition to being a major boundary between the two countries, it is the fifth longest river in North America, flowing over 1,885 miles from its headwaters in Colorado to its outlet at the Gulf of Mexico. The drainage area of the basin is approximately 355,000 square miles, with a contributing area of 176,000 square miles. The climate is arid to semi-arid, with precipitation ranging from less than 8 inches per year in the San Luis Valley of Colorado, to 10 inches per year near Ciudad Juarez/El Paso, to approximately 24 inches per year at Brownsville/Matamoros.

Historically, attaining adequate water supplies for agricultural use and the water needs of rapidly-growing human populations has been the predominant management focus, generating varying degrees of conflict at the local, state, and international level. These conflicts generally involved allocation of water between the two countries and between users within the two countries. They were often rooted in a fundamental belief that the river exists solely for the use of humans, with ecosystem needs not usually being considered. As an example, current water supply management paradigms identify water needs for human consumptive uses, but typically do not identify flows to sustain riverine ecosystems. Unfortunately, the institutional structure in the basin does not include or foster mechanisms to resolve conflicts in ways that result in sustainable use of the river. Early conflict resolution efforts resolved water allocation issues on the basis of conditions existing at the time these agreements were reached. However, the world is constantly changing. Extraordinary drought, growing populations, and deterioration of riverine ecosystems have strained the existing agreements, and they have thus far proven ineffective for resolving the more complex issues associated with achieving the sustainable use of the river and its resources.

Current efforts to balance irrigation needs with increasing municipal demands in the Rio Grande/Rio Bravo basin fail to address the instream needs of the riverine ecosystem. This is not surprising, however, given that the underlying water allocations did not recognize these needs, and because the institutions designed to manage the allocations do not have mandates that allow consideration of this issue in their activities. A growing movement towards recognition of instream water rights for meeting ecosystem needs, both for aquatic organisms and for the river itself, will likely exacerbate existing disputes over water allocations. Failing to deal with these problems may further strain an institutional structure essentially lacking the ability to deal with such issues.

In addition to water allocation issues for both humans and the environment, relevant basin problems include: (i) habitat loss; (ii) lack of a unified cross-sectoral, cross-jurisdictional forum to address ecosystem management; (iii) reliance on litigation pursuant to the Endangered Species Act to protect the growing numbers of species at risk in reaches of the river subject to the jurisdiction of the United States; (iv) legal and financial issues related to listing and evaluation of risk to listed species in Mexico; (v) population growth and associated social and economic issues; and (vi) water quality concerns. Although there are numerous individual programs addressing these issues, fragmented authority at all governmental levels and a reluctance to address water allocation frameworks codified in existing treaties and interstate compacts make sustainable management of water resources within this basin a daunting challenge.

This research focuses on the institutional structure of the basin at the international level. The general objective of this research is to evaluate the institutional structure of the Rio Grande using a social-ecological systems perspective. This involves examining the structure and function of institutions governing water supply from a historical perspective that considers both social processes and resulting ecosystem responses. This general objective led to five specific objectives.

The first objective was to examine river flow modifications and changes in fish assemblages. In support of this objective, changes in ecologically important aspects of streamflow and fish communities were evaluated for four reaches of the river representing different water management regimes. The second objective was to outline and review the legal constraints applicable to river management. Because the Rio Grande is a transboundary river basin, the evolution of existing water allocation paradigms in both the United States and Mexico are reviewed with specific focus on the 1944 water allocation treaty between the United States and Mexico.

The third objective was to examine the historical evolution of institutions using a complex adaptive model for social-ecological systems. A historical profile of the basin, focusing on cross-scale dynamics in the institutional setting, is constructed to assess the interplay of physical and social factors that can lead to the loss of resilience in its socio-ecological system. The fourth objective was to examine conflict management and public participation to identify opportunities to integrate environmental needs into basin water management efforts. Conflict management and public participation are evaluated from an outcome based perspective to support development of more inclusive dispute resolution practices. Finally, the fifth objective was to compare the management regime in the Rio Grande to ten transboundary water management regimes from around the world. The purpose of this comparative analysis was to identify areas where the existing international institutional system in the Rio Grande basin could be considered ineffective and to identify transferrable institutional structures.

The insights gained from this research suggest opportunities for transformative changes that could improve the ability of basin institutions to include consideration of ecosystem needs and more sustainably manage the water resources of the Rio Grande/Rio Bravo Basin. To this end, the primary research question being addressed in this study is: ***What are the pathways and processes necessary for adaptive institutional solutions that enhance social-ecological resilience in the Rio Grande/Rio Bravo Basin?***

CHAPTER II

EFFECTS OF THE BINATIONAL INSTITUTIONAL REGIME ON STREAMFLOWS AND FISH ASSEMBLAGES IN THE RIO GRANDE

Introduction

Variability, i.e., drought and flood cycles, is characteristic of the hydrology of arid land systems, such as the Rio Grande. Walker and Salt (2006) suggest that modification of key ecological processes to satisfy societal goals can lead to a loss of resilience in a given system. Management practices can exacerbate naturally-occurring conditions, particularly drought, placing stress on aquatic ecosystems (Cowley et al. 2007, Bond et al. 2008). These effects are more severe in arid and semi-arid systems (Cowley 2006, Dudgeon et al. 2006, Rinne and Miller 2006). Change in freshwater biodiversity also alters ecosystem goods and services, with these changes being difficult to reverse (Hooper et al. 2005). Dudgeon et al. (2006) identify five categories of threats to freshwater biodiversity: overexploitation; pollution; flow alteration; habitat modification; and introduction of exotic species. As noted by these authors, the five categories are not distinct from one another, but interact in complex and interrelated ways.

For example, modification of the landscape to support agriculture leads to habitat modification of the terrestrial landscape, including riparian areas and geomorphic changes in the stream due to alteration of sediment fluxes (Schmidt et al. 2003). Due to low rainfall in arid land systems, agriculture is usually based on irrigation, which can lead to overexploitation of the river during dry times. In order to supply agricultural water demands, reservoirs are constructed to provide certainty in water supply which, in turn, can lead to significant river flow alterations. The Rio Grande system typifies this cycle.

The magnitude, timing and duration of water flows are important determinants for the life cycles of riverine fish. Native species, and the geomorphology of the river systems they inhabit, evolved based on natural flow variability. Flow, habitat variability, and species life cycles, are interrelated. Flow variability determines the diversity of habitats at various scales, and this habitat diversity is important to the life history requirements of individual species. The degree of change in fish assemblages is related to life history traits, such as reproduction, with obligate riverine species typically being the first affected by changes in flow regimes (Williams and Bonner 2007). One confounding factor closely related to flow variability is river fragmentation (Dudley and Platania (2007).

Species declines are of concern throughout the Rio Grande drainage (Williams et al. 1985, Williams et al. 1989, Anderson et al. 1995, Stotz 2000, Hoagstrom and Brooks 2005, Calamusso et al. 2005, Contreras-Balderas et al. 2008, Hubbs et al. 2008, Jelks et al. 2008). One of the native pelagic-spawning minnows, Rio Grande silvery minnow (*Hybognathus amarus)*, is a federally-listed endangered species. The historic range of this species once extended the length of the Rio Grande; however, it has been extirpated from all but a 240 km reach in New Mexico. Currently, reintroduction efforts in the Big Bend reach of the river are in progress (USFWS 2009). The final rule listing the Rio

Grande silvery minnow states that in the remaining reach where this species exists naturally, water management was directly responsible for species decline (59 Fed. Reg. 36988).

But what is the natural flow regime in the Rio Grande? Water withdrawals began to increase dramatically with the arrival of large numbers of European settlers after 1850 (Hundley 1966). Additionally, conflicts among water users in the basin, the resolution of which was the basis for many of the current management institutions at the regional scale, began in the 1870s (Utton 1999). Thus, changes in water management and allocation regimes and resultant flow alterations and impacts on fish assemblages likely began over one hundred years ago.

Water management institutions have evolved through time. The United States and Mexico signed a water allocation Treaty for Rio Grande flows in 1944 (1944 Treaty). Environmental considerations began to be a formal part of the binational legal and institutional framework in 1983 when the two countries signed the La Paz Agreement (La Paz Agreement 1983). In this agreement, the two countries recognized that a healthy environment was important for economic and social well being and agreed to cooperate on environmental protection. Unfortunately, the La Paz Agreement, and its annexes, clearly delineated the institutional boundaries between the 1944 Treaty and the La Paz Agreement by separating water quality from water quantity. In other words, if a sustainable resolution of a water quality problem meant modifications to the allocative framework or its implementation, a non-sustainable alternative would likely be the only option (Alexander et al, 2012). This study examines river flow modifications and changes in fish assemblages for time periods before (Pre - 1946-1983) and after (Post-

1984-2010) the La Paz Agreement formalized incorporation of environmental concerns at the binational level. It presents an assessment of whether the shift to consideration of environmental concerns resulted in positive changes to the riverine environment, in terms of both water flows and the species that depend upon them. This is accomplished by evaluating changes in specific attributes of the flow regime and in the fish assemblages. A metric for illustrating these changes is constructed and applied to four reaches of the binational Rio Grande.

Study Area

The river drains two countries, the United States and Mexico, and eight states within these countries: Texas, New Mexico, Colorado, Chihuahua, Coahuila, Durango, Nuevo Leon, and Tamaulipas. The Rio Grande is the fifth-longest river in North America, with a drainage area of approximately 355,000 square miles (Figure 2.1). Management of river flows under the various legal instruments is different depending on location in the watershed (See Alexander Martin 2010 for a complete description of the legal instruments governing Rio Grande river flows).

Streamflow from Fort Quitman down to the confluence with the Rio Conchos is highly influenced by a 1906 Convention between the United States and Mexico (1906 Convention), which determines the amount of water released for Mexico’s use in the El Paso area. The 1938 Rio Grande Compact between Colorado, New Mexico, and Texas further influences total flow in this reach by specifying how much water must be passed downstream to Texas (1938 Compact). Streamflows in this reach are controlled by Elephant Butte Reservoir in New Mexico, which impounds 2.2 million acre-feet of water, Caballo Dam which impounds 334,990 acre-feet of water and five diversion dams which deliver water to various canal systems (USBR 2012).

From Fort Quitman, Texas, downstream to the Gulf of Mexico, the waters of the Rio Grande are subject to the 1944 Treaty. The Rio Conchos in Mexico is the major contributing tributary, entering the Rio Grande in the Big Bend reach. The Rio Conchos has a drainage area of about 26,400 square miles and provides much of the flow to downstream users on both sides of the border. Like most of the Rio Grande, the Rio Conchos is not a free flowing river, with the river and its tributaries being impounded by seven major reservoirs impounding a total of 3.3 million acre-feet of water (Texas Center or Policy Studies 2001). The Rio Grande is relatively free-flowing through this reach until it reaches the headwaters of Amistad Reservoir.

In the Laredo reach, flows are influenced by impoundment at binational Amistad Reservoir, impounding 5.25 million acre-feet, as well as releases from this reservoir for hydropower generation, uses between Amistad and Falcon reservoirs and releases to Falcon Reservoir for impoundment and use (IBWC 2005). In the Brownsville reach, streamflows are influenced by Falcon reservoir, impounding 2.65 million acre-feet, and releases for use on both sides of the border (IBWC 2005). There are also two diversion dams that facilitate diversions for human use as well as diversion of higher flow events into floodways (IBWC 2005). Major Mexican tributaries enter the Rio Grande in this reach, but their contributions are reduced by impoundments in Mexico.

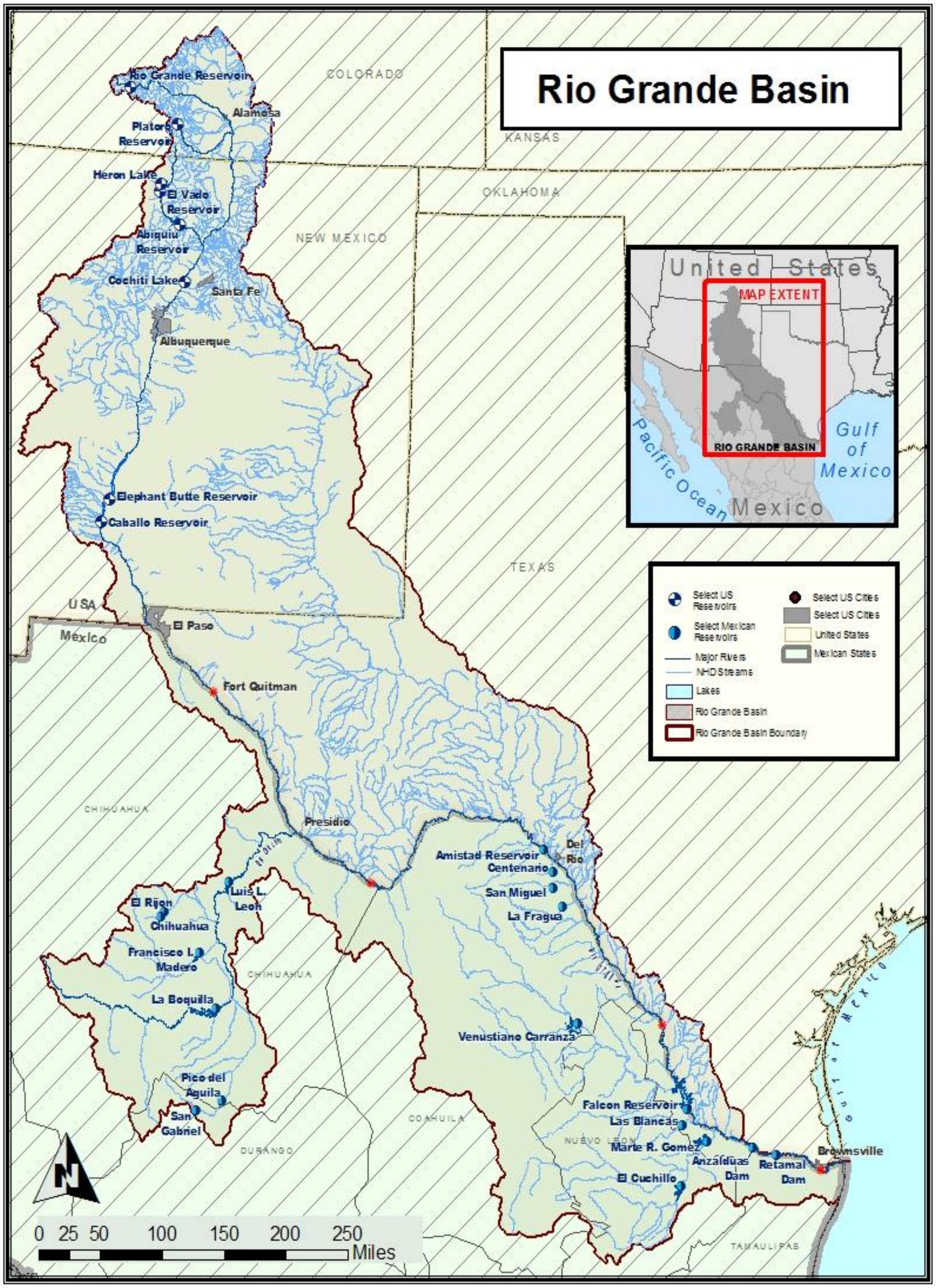

Figure 2.1 Extent of the Rio Grande Basin with Reservoirs Indicated.

Based on the differences in water management described above, four reaches were selected for analysis for this study being Reach 1 (Fort Quitman) extending from Fort Quitman to above the Rio Conchos, Reach 2 (Big Bend) extending from downstream of the Rio Conchos to Amistad reservoir, Reach 3 (Laredo) extending from Amistad reservoir to Falcon reservoir, and Reach 4 (Brownsville) extending downstream of Falcon reservoir to a point near Brownsville where fish communities begin to be comprised of mostly marine species. In addition to legal and management considerations, the reach division takes into account the spatial distribution of gaging stations with a sufficient period of record to perform the analysis and the spatial distribution of fish collections. The reaches are next described in more detail.

Reach 1 (Fort Quitman)

At a point approximately 23 miles north of El Paso, the Rio Grande enters Texas and becomes the boundary between the United States and Mexico. The river at this point is severely degraded and frequently dries up during the winter months. Intensive agricultural diversions by irrigation districts on both sides of the border have resulted in severe alteration of the natural water flow regime of the river. For example, the average annual water flow at Fort Quitman was reduced 96% between 1884 and 1964 (Schmandt 1993). The river then flows through a reach known as the "Forgotten River" from below Fort Quitman to the confluence of the Rio Grande and Mexico's Rio Conchos. Because of upstream diversions and the construction of Elephant Butte Reservoir, the river's flow is often reduced to zero at times when its flow would have occurred historically.

Reach 2 (Big Bend)

When the Rio Grande reaches Presidio and Ojinaga, flow from the Rio Conchos in Mexico replenishes the mainstem of the river. Historically, the Rio Conchos contributed approximately two-thirds of the flow of the Rio Grande below its confluence. However, water flow from the Rio Conchos is influenced by reservoirs in Chihuahua (Region M Regional Water Planning Group 2011). This water contribution significantly declined in recent years, leading to water disputes between the United States and Mexico (Alexander Martin 2010). There are no significant inflows or diversions in the Big Bend reach of the Rio Grande, although there are some smaller tributaries.

Reach 3 (Laredo)

The river then enters a reach extending from Amistad Reservoir to Falcon Reservoir. The Pecos and Devil's Rivers, both tributaries on the Texas side, enter the mainstem of the Rio Grande at Amistad Reservoir. The river is heavily regulated in this segment, with water quality being an issue. Pressures on the river system are primarily a function of explosive population growth on both sides of the border. Withdrawals of river water for irrigation and municipal uses, as well as construction of international Amistad Reservoir, have substantially modified the natural flow regime in this section of the river. Flows in this reach are also quite variable on a daily because of large diversions by users in both the United States and Mexico and power generation from Amistad Reservoir.

Reach 4 (Brownsville)

In the Lower Rio Grande Valley, as described for Reach 3, population growth on both sides of the border is a driver for increased water withdrawals from the river. For example, the population of the Lower Rio Grande Valley grew 216% between 1950 and 1995 (Schmandt et al. 2003). Current 2010 population is approximately 7.6 million people, with populations on the United States side of the border expected to more than double by 2060 (Region M Regional Water Planning Group 2011). In addition to high population growth rates, the region is also one of the poorest regions in the United States; border counties on the Texas side have the lowest per capita income in the country. Most river water in the Lower Rio Grande is used for irrigation purposes, although the area of irrigated land is steadily declining (Region M Regional Water Planning Group 2011). In addition to diversions for irrigation and municipal purposes, periodic flood flows are diverted through floodways on both sides of the border (IBWC 2005).

Methods

Daily discharge data was obtained for 4 International Boundary and Water Commission (IBWC) gages that measure flows in the study reaches (Table 2.1 and Figure 2.2). The selected gages have long periods of record and are representative of flows resulting from different management regimes in the river. Daily discharge data was also collected from an additional gage to evaluate flow changes for the Rio Conchos.

Table 2.1 Rio Grande Gages Used in the Analysis

Gage ID	Gage Name	Reach
08-3705.00	Rio Grande at Fort Quitman, Texas near Colonia Luis Leon, Chihuahua	1
08-3730.00	Rio Conchos at Ojinaga, Chihuahua	
08-3750.00	Rio Grande at Johnson Ranch near Castolon, TX and Santa Elena, Chihuahua	2
08-4590.00	Rio Grande at Laredo, TX and Nuevo Laredo, Tamaulipas	3
08-4750.00	Rio Grande near Brownsville, TX and Matamoros, Tamaulipas	4

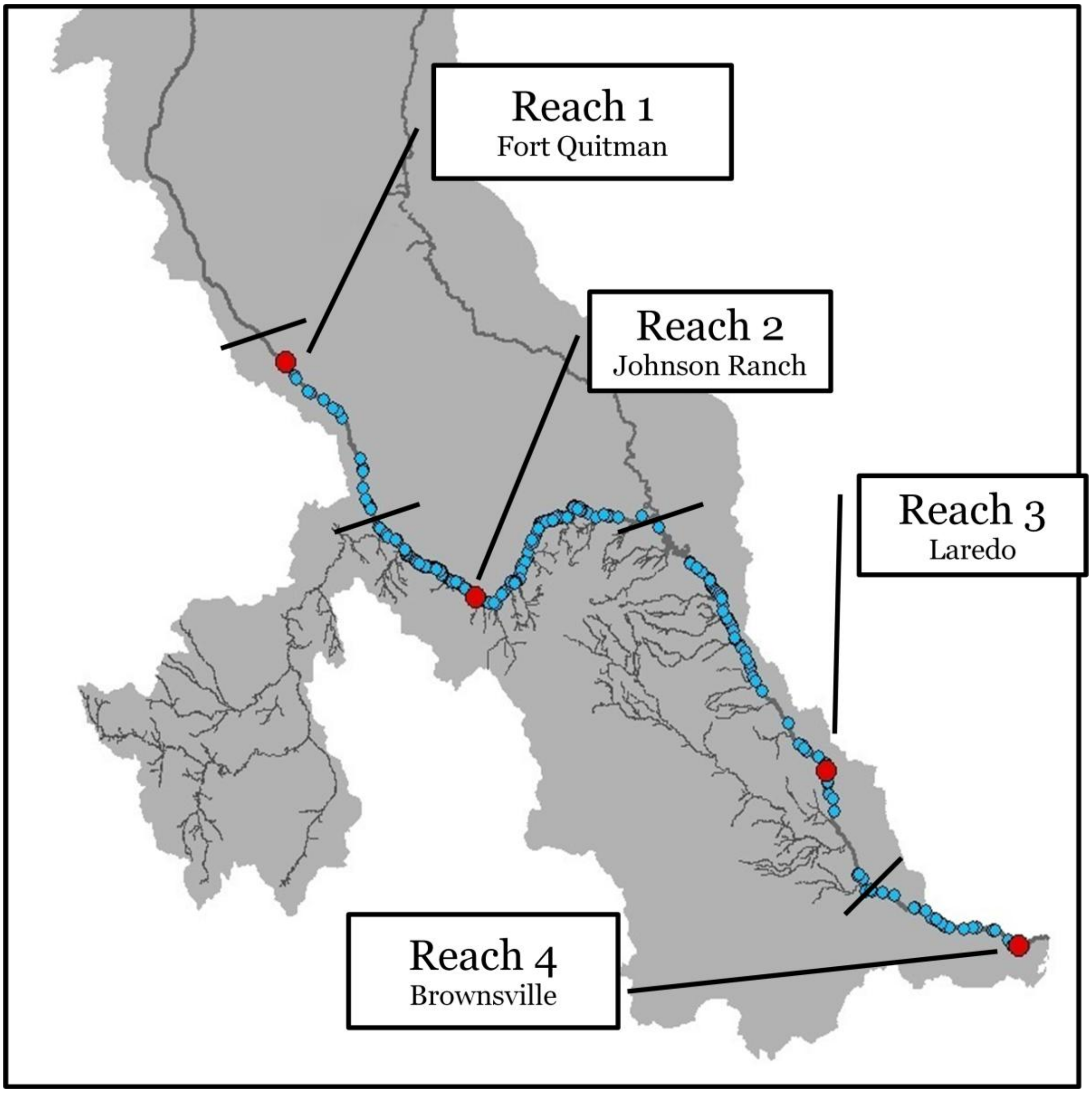

Figure 2.2 Gage Locations and Collection Locations. Collection locations are shown as blue dots, gage locations are shown as red dots and reaches are delineated by black lines perpendicular to the river.

For each gage, the discharge data was separated into a pre-impact (1946-1982) and a post-impact (1983-2010) period. The daily data sets for both time periods were examined to ensure that both periods included a severe drought period and large flooding events. This ensures that the statistical attributes of flow variation are not unduly influenced by sequences of very high or very low flows in either period. To perform this analysis, a composite climatological index was created using data from the National Climatic Data Center (NOAA 2012). The index accounts for monthly departures of precipitation from the long term (Moisture Anomaly Index or Palmer Z Index), the probability of observing a specific quantity of precipitation for a two year time period (Standardized Precipitation Index), a meteorological index including precipitation, temperature, and soil moisture (Palmer Drought Severity Index), and long term moisture supply (Palmer Hydrological Drought Index). The composite index accounts for short-term and long-term climatic trends, and considers temperature, terrestrial conditions, and lag effects. Values of the composite index were calculated for each month and year for the pre-impact, post-impact and total period. Results indicate that the two periods at each site were similar to one another and each was indicative of long term climatic conditions, although the post-impact period tended to be slightly wetter than the pre-impact period. Based on the climate analysis, the flow data sets were determined to be sufficiently similar and therefore adequate for the analysis in this study.

Streamflows between the two periods were analyzed using the Indicators of Hydrologic Alteration, v. 7.1 (IHA) and non-parametric statistics (median/percentile). IHA characterizes intra-annual variations in the flow regime, and then uses inter-annual characteristics to calculate changes in natural water flow patterns. Streamflows in this system are highly skewed. Therefore, median statistics, which are more representative of the central tendency of the data, are more appropriate because outliers such as extremely high floods do not overly influence monthly flow values. Extended periods of extremely low flows can impact the IHA hydrographic separation. Therefore, flow duration curves were constructed and visually inspected. Based on an estimated breakpoint in the flow data for low flows, the extreme low flow threshold in these analyses was set to the 30th percentile.

The IHA categorizes statistical attributes of the flow regime using 33 parameters, categorized into five parameter groups. The parameter groups characterize: i) magnitude of monthly conditions (12 parameters), ii) magnitude and duration of annual extremes (12 parameters, iii) timing of annual extremes (2 parameters), iv) frequency and duration of high and low pulses (4 parameters), and v) rate and frequency of change (3 parameters). Each of these groups of flow statistics are presumed to be biologically relevant (Richter et al.1996). IHA calculates a deviation factor for each parameter. The deviation factor is an indicator of changes between the pre- and post-impact period and is calculated as:

$$\frac{\left|(Post - impact\ value) - (Pre - impact\ value)\right|}{Pre - impact\ value}$$

IHA also calculates a significance count (S) for the deviation factor. The significance count is based on 1,000 random trials with the significance count indicating the fraction of trials where the deviations were greater than the actual deviations (Nature Conservancy 2009). Thus, the lower the value of the significance count, the more likely the deviation is significant. The significance count (S) is used to create a weighting factor. A value of (1-S) is multiplied by the deviation factor for each parameter so that more significant deviations are weighted more highly.

In addition, alteration of aspects of the flow regime may have biological consequences. Reduction of base flows during the spawning season, changes in the length of dry and wet sequences, and changes in pulse flow characteristics may lead to changes in fish community composition (Richter et al. 1997, Bunn and Arthington 2002). Therefore, weighted deviations for spawning season flows (March through May), magnitudes and durations of annual extremes, and pulse flow characteristics were multiplied by 2 to reflect the importance of these flow regime components. The average of the weighted and adjusted deviation factors for all parameters is the Flow Impact Index. The Flow Impact Index does not determine causality for flow alterations, but rather determines identifiable trends in the flow data sets to facilitate comparisons between reaches and within time periods for each reach.

Historical fish collections were created for each reach using published museum collections, agency reports, and published documents. Museum collections included Texas Natural History Museum (University of Texas), Tulane Museum of Natural History (Tulane University), Oklahoma Museum of Natural History (University of Oklahoma), and the University of Michigan Museum of Zoology). Agency reports include International Boundary and Water Commission (1994 and 1997) and the United States Department of the Interior (2002, 2006, and 2007, and Moring 2005). Published documents include Edwards et al. (1991), Hubbs et al. (1977), Edwards et al. (2002), and Contreras-Balderas et al. (2002). Species occurrence and abundance, year of collection, and source of the data are included in Appendices I-IV.

Perkin and Bonner (2009) point out uncertainties associated with data compatibility when assembling historical fish collection data sets for the purpose of analyzing temporal changes. Museum collection data sets were generally adjusted as suggested by these authors. In addition, collection data were reviewed using ArcGIS Explorer with Bing Imagery, and Google Earth, to validate location information provided in the museum collection data sets. Based on this assessment a small number of questionable data points were removed. Fifty collections were included in the analysis with 66% from museum collections, 14% from published literature, and 20% from agency reports. The number of collections by reach were 7 (Reach 1), 22 (Reach 2), 11 (Reach 3), and 10 (Reach 4). There are temporal gaps in the datasets for some river reaches. However, there was at least one collection or series of collections in the pre- and post impact periods for each reach.

Collection methods also varied between the different collections; however, temporal changes in assemblage composition can still be evaluated (Perkin and Bonner 2009). Seasonality of the collections was reviewed for each reach. For Reach 1, the pre-impact collections occurred during late winter and early spring. The post-impact collections occurred during fall and winter. For Reach 2, the pre-impact collections occurred during spring and summer. The post-impact collections occurred across all seasons. For Reach 3, the pre-impact collections occurred in all seasons except fall. The post-impact collections occurred across all seasons. For Reach 4, both the pre-and post-impact collections occurred across all seasons. The lack of complete seasonal coverage for all reaches is likely the result of the small number of historical collections. Overall, the seasonal coverage appears to be adequate for this analysis.

In addition to seasonality, the collections were reviewed to determine whether they were representative of a range of climate conditions. The composite climate condition for the year of each collection was calculated for the pre-and post-impact collections. More collections tended to occur during wetter times in the post-impact period, particularly for Reaches 1 and 3. However, there were collections during both relatively wet and relatively dry times in both the pre- and post-impact data sets so the collections should adequately reflect assemblage composition along a climatic gradient.

The fish collections were aggregated into pre- (1946-1982) and post- (1983-2010) impact data sets for each reach, and relative abundance for both periods was calculated. For each reach, taxa richness and Simpson's Index of Diversity (1-D) were calculated for both periods. Species classified as endangered, threatened, or special concern (Table 2.2 based on Hubbs, et al. 2008) were aggregated and the relative abundance of this group (ETS species) in the post-impact collections was calculated. In addition, the Renkonen Index of Similarity (Krebs 1989) was calculated and used to compare the pre-and post-impact fish assemblages. The Renkonen Index was used because it is not overly influenced by sample size and species numbers, and it accounts for species relative abundance (Balmer 2002 and Wolda 1981).

Table 2.2 Species Classified as Extinct (EX), Endangered (E), Threatened (T), or of Special Concern (SC) (Hubbs, et al. 2008).

Species	Status
Cyprinella proserpina	T
Dionda episcopa	SC
Hybognathus Amarus	E
Macrhybopsis aestivalis	SC
Notropis braytoni	SC
Notropis chihuahua	SC
Notropis jemezanus	SC
Notropis orca	EX
Rhinichthys cataractae	SC
Cycleptus sp.	SC
Moxostoma austrinum	SC
Ictalurus lupus	SC
Etheostoma grahami	T

An Assemblage Characterization Index was calculated using the Renkonen Index and the relative abundance of the ETS group in the post-impact period. This index accounts for changes in relative abundance between period and gives a greater weight to the relative abundance of ETS species in the post-impact period.

Results

Flow Alteration

Overall, the study reaches exhibit increasing flow alteration in a downstream direction. The exception to this trend occurs at the Fort Quitman gage (Reach 1). Base flows in the post-impact period exhibit a marked increase and the flow regime is generally more variable (Figure 2.3). The weighted parameters (spring flows, annual extremes, and pulses) increased by over 100%. The Flow Impact Index for this reach was set at 1, the maximum value.

The flows at Johnson Ranch (Reach 2) exhibited the least alteration; however, median flows during December and January exhibited significant downward trends. The Flow Impact Index for reach 2 is 0.34. The overall flows at Laredo (Reach 3) exhibited a relatively small alteration. The most significant alterations occurred in variability (rise and fall rates and reversals) with smaller rise and fall rates between consecutive days in the post-impact period. There were also significant increases in median base flows in April and May and 7-day minimum flows in the post-impact period. The Flow Impact Index for Reach 3 is 0.39. The flows at Brownsville (Reach 4) exhibited a high degree of alteration. The most significant alterations were an increase in the base flow index (7 day minimum for the year), reduction in peak flows, and a shift from higher to lower pulses in the post-impact period. The Flow Impact Index for Reach 4 is 0.57.

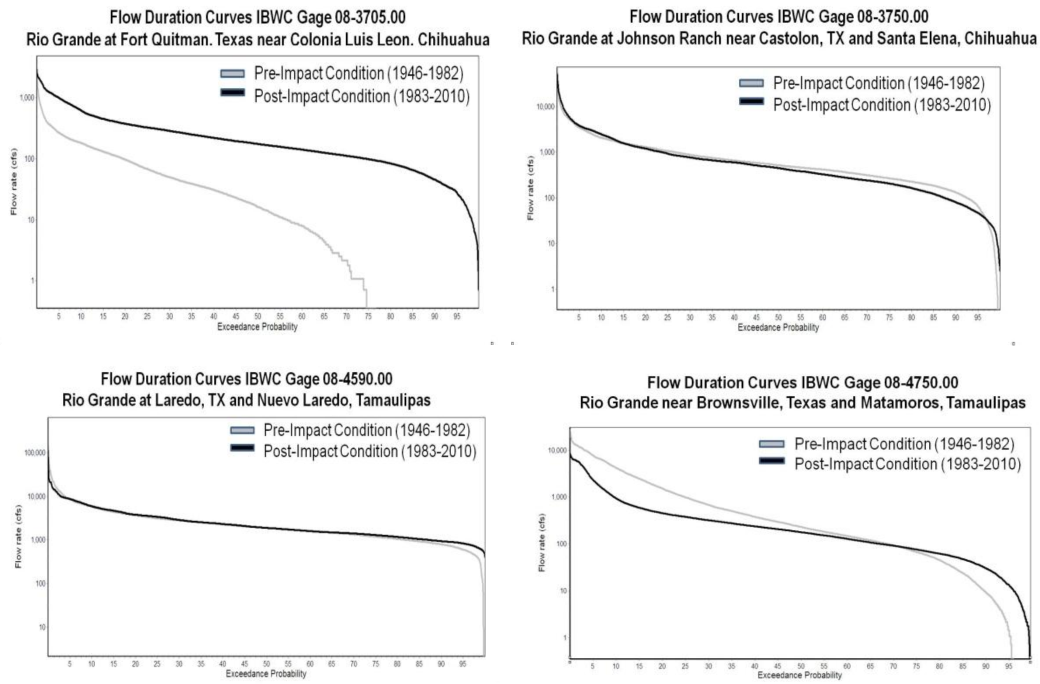

Figure 2.3 Flow Duration Curves for Pre- and Post-Impact Periods for the Rio Grande at Fort Quitman, Johnson Ranch, Laredo, and Brownsville (Generated by IHA).

Flow alteration for contributions of the Rio Conchos to Rio Grande flows was also reviewed. The Rio Conchos exhibited a very high degree of flow alteration. The Flow Impact Index for the Rio Conchos is 0.64. This is the result of reductions in median monthly flows in November through March and July through August, reduced variability, reduced high pulses, and reductions in the 30 and 90 day minimum flows and in the 90 day maximum flows in the post-impact period.

Fish Assemblage Changes

A total of 57 species and 88,650 individuals were reported in the collections retained for analysis. Cyprinidae were most abundant (51% relative abundance), followed by Catostomidae (5%), and Poeciliidae (4%). The remaining families each comprised less than 4% of the individuals.

Reach 1 (Fort Quitman)

Within Reach 1, a total of seven collections comprising18 species and 2,684 individuals were analyzed. Cyprinidae were the most common (52% relative abundance), followed by Centrarchidae (16%), Poeciliidae (12%), and Clupeidae (11%). The remaining families each comprised less than 4% of the individuals. Taxa richness decreased between the pre- and post-impact periods (S = 17 to S = 14) and diversity also decreased (D = .80 to D = .71). Assemblage similarity was 58%. Relative abundance of ETS species decreased from 5% to 2% between the pre- and post-impact periods. Relative abundance of *Cyprinella lutrensis* and *Gambusia affinus* significantly increased through time while relative abundance of *Cyprinus carpio* and *Lepomis sp.* significantly decreased through time.

Reach 2 (Big Bend)

Within Reach 2, a total of 22 collections comprising 31 species and 42,123 individuals were analyzed. Cyprinidae were the most common (77% relative abundance), followed by Catostomidae (10%), and Poeciliidae (7%). The remaining families each comprised less than 4% of the individuals. Taxa richness increased between the pre- and post-impact periods (S = 25 to S = 30) and diversity was relatively unchanged (D = .71 to D = .73). Assemblage similarity was 43%. Relative abundance of ETS species decreased from 65% to 31% between the pre- and post-impact periods. Relative abundance of *Cyprinella lutrensis* and *Notropis chihuahua* significantly increased through time while relative abundance of *Rhinichthys cataractae* significantly decreased through time.

Reach 3 (Laredo)

Within Reach 3, a total of 11 collections comprising 33 species and 12, 430 individuals were analyzed. Cyprinidae were the most common (78% relative abundance), followed by Fundulidae (7%). The remaining families each comprised less than 4% of the individuals. Taxa richness increased between the pre- and post-impact periods (S = 26 to S = 33) and diversity was relatively unchanged (D = .84 to D = .83). Assemblage similarity was 41%. Relative abundance of ETS species decreased from 49% to3% between the pre- and post-impact periods. Relative abundance of *Cyprinella lutrensis* and *Cyprinella venusta* significantly increased through time while relative abundance of *Notropis braytoni*, and *Notropis jemezanus* significantly decreased through time.

Reach 4 (Brownsville)

Within Reach 4 a total of 10 collections comprising 38 species and 8,147 individuals were analyzed. Cyprinidae were the most common (24% relative abundance), followed by Clupeidae (21%), Atherinopsidae (17%), Characidae (11%), and Poeciliidae (8%). The remaining families each comprised less than 4% of the individuals. Taxa richness decreased between the pre- and post-impact periods (S = 38 to S = 30) and diversity decreased slightly (D = .92 to D = .88). Assemblage similarity was 59%. Relative abundance of ETS species decreased from 20% to 2% from the pre- to the post-impact period. Relative abundance of one species, *Menidia beryllina*, significantly increased through time while relative abundance of no individual species significantly decreased through time. The Fish Impact Statistic for this reach is .35.

The results of this analysis indicate that incorporation of environmental concerns into the national and binational institutional structure did not translate into management actions that would result in a more natural flow regime in the binational Rio Grande. This analysis identifies impacts in all reaches of the binational river, although the nature of the impacts varies. The relationship of the Flow Impact Index and the Assemblage Characterization Index is depicted in Figure 2.4.

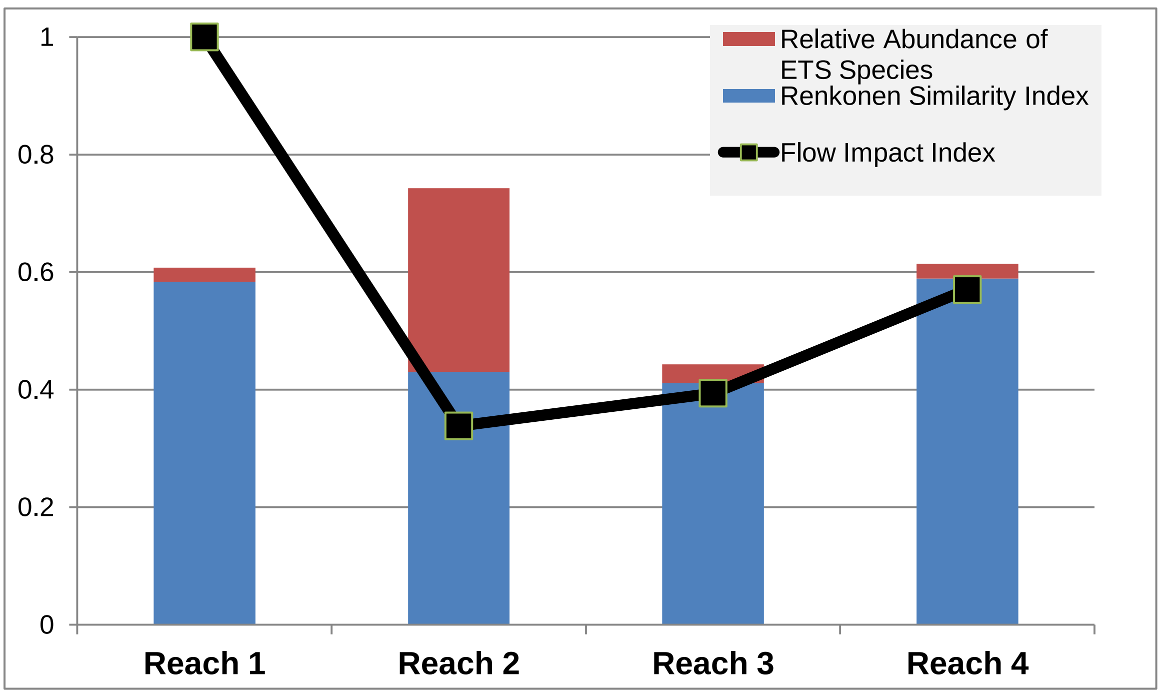

Figure 2.4 Flow Impact Index and Assemblage Characterization Index for 4 Reaches of the Rio Grande.

Substantial water flow alterations in Reach 1 likely predate the analysis period, as most of the river flow is diverted upstream of El Paso. Elephant Butte reservoir was designed to impound all of the spring runoff from the mountains of Colorado and New Mexico. This has led to use of virtually all of the water in the river upstream of Fort

Quitman. In recent years, flow in the reach has increased, partially due to municipal and irrigation effluent discharges to the river. However, this contribution to river flow is likely to decrease in the future as entities in the El Paso area begin to recycle and reuse more of their water (Far West Regional Water Planning Group 2011).

Recent actions by the IBWC, if continued in the future, may also negatively impact river flows in the Fort Quitman Reach. Extreme drought conditions led groups in the United States to modify how agricultural water would be delivered from Elephant Butte reservoir in 2012 to avoid high losses and waste of water. The IBWC ordered early releases of water for Mexico in March of 2012, which would increase the amount of water lost to evaporation and conveyance. The IBWC made this decision without considering either the needs of the river or the needs of water users (Staples and Rubinstein 2012 and Drusina 2012).

Reductions in river flow upstream of Fort Quitman can also exacerbate changes in the river channel below Fort Quitman. The river channel in this reach is estimated to be 90% smaller than the channel of 100 years ago although it is considered to contain many essential elements of the natural ecosystem and sustains higher water flows today than prior to 1940 (Schmidt et al. 2003). Although the river channel downstream of Fort Quitman may have recovered to a certain extent after Elephant Butte spilled, drought conditions in the upper basin are significantly reducing downstream flows. Despite indications of channel recovery, dewatering of the river by upstream water users also likely impacted fish assemblages. The very low relative abundance of ETS species in both the pre- and post-impact periods suggests that the historical assemblage in this reach was already fundamentally altered prior to the study period. The need for water for human populations and management practices of the IBWC could lead to extended periods of zero flow conditions, changes in stream channel morphology, negative changes in available habitat and negative impacts to the fish assemblage in this reach.

Reach 2 (Big Bend) may be the least impacted stretch of the binational Rio Grande, although both the flow analysis and species review indicate cause for concern. The flow analysis indicates a trend towards lower low flows in the post-impact period during the winter months. However, the main concern related to flow impacts in this reach is Mexico’s delivery of water from the Rio Conchos. Analysis of flow data from the Conchos shows alarming negative trends across all parameters considered in the analysis. Flows from the Rio Conchos are governed by the 1944 Treaty, and Mexico has consistently had deficits in Rio Conchos deliveries in recent years. Under the Treaty Mexico is required to deliver an average of 350,000 acre-feet per year over a five year period. Through March 31, 2012, almost eighteen months into the five year cycle, Mexico has delivered 310,000 acre-feet (For a detailed discussion of Mexico’s water deliveries and deficits see Alexander Martin 2010). The analysis of impacts on fish communities conducted for the study herein found that relative abundance of ETS species was reduced by 50% and that the relative abundance of *Cyprinella lutrensis* increased by 25%. This resulted in low similarity (43%) between the pre- and post-impact periods and suggests a possible trend towards replacement of fluvial specialists with generalist species, especially in light of the potential for more severe flow alterations in this reach. Continuing delivery deficits from the Rio Conchos have the potential to negatively affect the relatively intact fish assemblage in this Reach.

Flow alteration in the Laredo Reach likely began prior to the analysis period in this study. The flow analysis clearly indicates changes due to the influence of upstream Amistad Reservoir. In the post-impact period, water flows tend to be higher in the spring and early summer. This is because of reservoir releases for irrigation during these months. The influence of the water release regime, including hydropower generation and water withdrawals through large pump stations, is indicated by significant changes in the number of flow reversals, which is a measure of positive or negative rate of change in daily flows. These frequent changes in water level elevations cause stresses to both fish and macroinvertebrate communities. The Assemblage Characterization Index shows low similarities between the pre- and post-impact periods and reflects a dramatic change in relative abundance of ETS species from 48% to only 3% in the post-impact period.

Flow data for Reach 4 suggests alterations consistent with those for the Reach 3. At this location, water flows are generally lower throughout the year. In particular, as shown in the flow duration curve (Figure 2.3), flows at the average to higher end of the flow distribution exhibit more striking reductions. This is likely the result of a number of complexly-associated river management practices that include impoundment and operation of Falcon Reservoir for downstream releases, and flood control management in this reach of the river.

Discussion

Drought management in this basin is likely to continue the negative trajectory of flow impacts and impacts to fish communities shown in this study. Drought effects on ecosystems at river basin scales are largely unknown, and there is less information about the effects of long-term droughts on fish communities (Matthews and Marsh-Matthews

2003, Lake 2003). In arid and semi-arid systems, synergistic interactions between hydro-climatological drought and human alteration of watersheds reduce drought recovery for aquatic species and, therefore, the resilience of the system to these types of perturbations. In the case of the Rio Grande, under natural conditions, refuge habitats likely persisted during historic droughts. Treviño-Robinson (1959) noted, for example, that the river at Laredo was completely dry during 1953, but that collections from the following year indicated there were no corresponding major species declines. However, increasing human demands on the rivers water will likely result in longer duration low flow events.

It is often difficult to separate the effects of drought from the impacts caused by water management regimes. Matthews and Marsh-Matthews (2003) described the difficulties of designing a research program specifically to determine the effects of drought on fish assemblages. Droughts are often unpredictable, and long-term droughts are often not identified until the drought is well underway. In addition, the effects of drought often lag behind the event itself, also being confounded by variations that would occur in specific populations under normal conditions. These authors also note that not only are there few studies on drought effects, there are also few studies that define base line normal conditions to which conditions during drought times could be compared, particularly at the river basin scale.

Drought is an ongoing concern from both the legal and institutional perspective in the binational Rio Grande. On the United States side of the border, current authorized uses exceed the United States share of the firm yield of the Amistad/Falcon System, with over two million acre-feet per year of authorized diversions. The shortage for municipal uses is projected to be over 300,000 acre-feet per year by 2060 (TRC/Brandes 2009).

This renders not only allocations, but also consideration of flows to sustain aquatic species, problematic under the best of flow conditions, being even less likely during supra-seasonal drought conditions.

Species flow needs are considered in the determination of water supply from the Rio Grande on the United States side of the border, albeit in a very limited fashion. Texas' Region M Water plan states that current planning paradigms do not allow consideration of environmental flows, and that water marketing is the best option to protect river flows (Rio Grande Regional Water Planning Group 2010). In the Trans Pecos Region below Fort Quitman, Texas' Far West Texas Regional Water Planning Group identifies a minimum flow of 250 cfs to support minimum species needs, although the origin and methodology used to produce this value is not specified (Far West Texas Regional Water Planning Group 2011). However, single level flow prescriptions, regardless of their derivation, are unlikely to be protective (Richter et al. 1997). This group also recommends that the binational reach within the boundaries of Big Bend National Park and the Black Gap Wildlife Management Area be identified as an ecologically-unique stream segment, although this designation does not guarantee flows in the river (Far West Texas Regional Water Planning Group 2011). In 2011, the United States Department of the Interior and the Secretariat of Environment and Resources of the United Mexican States signed a Memorandum of Understanding to develop a cooperative action plan with a goal of cooperating to develop an action plan to protect biological diversity and support conservation of the shared desert ecosystem in the Big Bend Reach of the Rio Grande (USDOI 2012).

Unfortunately, determination of the relationships between recurring drought conditions and species declines is presently a mostly speculative endeavor. Drought management in the Rio Grande suffers from the same types of knowledge gaps and reactive management as seen for other water systems subject to similar hydrologic variability (See Bond et al. 2008). There is no coordinated and funded research agenda for drought occurrences based on a complex social-ecological systems perspective, or on any other perspective for that matter. Of particular concern is the notion that initiatives to address drought might be undertaken from a water supply perspective or a human perspective, with little emphasis given to ecosystem effects.

Given repeated calls for certainty regarding the definition of extraordinary drought from water users on both sides of the border, it is not outside the realm of possibility that resolution of this issue could occur in the foreseeable future (Alexander Martin 2010). The drought issue has been recently discussed, for example, by the Water Worktable of the Border Governor's Conference (http://bordergovernors.org/en/worktables_water.html). Including fish species needs in these discussions may be difficult, however, given concerns expressed by water users about the potential for environmental allocations in a system that may not even supply sufficient water for human needs in the future (Rio Grande Regional Water Planning Group 2010).

One option would be to address this issue at the binational level through modification of the 1944 Treaty. The Treaty can be modified through minutes, which are agreed to by both countries (Alexander Martin 2010). There is some sentiment that ETS species issues could be addressed through an "Ecological" Minute that would bring the

IBWC’s water management more in line with current United States and international laws for endangered species protection (Umoff 2008). However, although the IBWC has approved Minutes touching on ecological issues for the Colorado River, the IBWC has generally been reluctant to address substantive issues through the Minute system (McCarthy 2011). In addition, the IBWC has not to date approved the use of any treaty waters for ecological purposes and current over-allocation of water and increasing demands makes this unlikely.

Richter et al. (2003) outline a framework for incorporating ecosystem needs into water management efforts in order to produce an ecologically-sustainable river environment. The first step is to estimate streamflow requirements. Specific flow requirements for Texas riverine fishes are largely unknown (Edwards 2001). Edwards noted several general impacts related to reductions in the lower range of water flows. Specific data and studies to support this type of analysis in the Rio Grande, however, are not readily available. In the future, at least for the Texas side of the border, Senate Bill 3 efforts may provide some estimates of the quantity of water necessary to support a sound ecological environment, which includes maintaining fish assemblages (See http://www.tceq.texas.gov/permitting/water_rights/eflows for complete information about this program). However, these efforts may encounter barriers to success in the Rio Grande because it is a binational river with a side-by-side geography. The Senate Bill 3 program is statutorily prohibited from recommending environmental flow standards that conflict with existing treaties and water management in the Rio Grande (Texas Water Code 11.02362(o)).

The second step is to determine and describe the effects of human alterations on the flow regime. This step alone is a challenge in the Rio Grande basin. Alterations of the flow regime began almost 100 years ago in some parts of the river. Another challenge is evaluating these impacts for a multi-jurisdictional system at a large spatial scale. The impacts may not be additive in a complex system. In other words, the extent of flow alteration derived from multiple water management strategies, themselves at different scales, may be impossible to disaggregate. In the absence of a more integrated institutional water management regime, such a disaggregation would be required because the basin is currently managed on the basis of national interests, rather than the interests of the river, including aquatic species needs.

The third step identifies “incompatibilities” between ecosystem and human water needs. In the case of drought management, this may be difficult since the ecosystem needs are largely unquantified, especially during drought conditions. The final steps involve collaboration, experimentation, and implementation of an adaptive management plan. Collaborative initiatives presuppose a process that fosters stakeholder participation, and a method for resolving the inevitable conflicts. However, stakeholder participation in binational water management is very limited (McCarthy 2011). In addition to problems related to quantifying how much water is needed to maintain some semblance of ecosystem form and function, the inclusion of stakeholders and mechanisms for dispute resolution in the Rio Grande basin may pose insurmountable problems in achieving integration of aquatic species concerns into water management regimes in the basin.

Appendix I. Collections for Reach 1 (Fort Quitman)

		Year of Collection and Data Source								
Scientific Name	**Common Name**	1977 (Hubbs et al., 1977)	1977 (UMMZ, TNHC)	1978 (TNHC)	1988 (TNHC)	1992 (IBWC, 1994)	1995 (TNHC)	2002 (TNHC)	PRE (1977-1978)	POST (1988-2002)
Lepisosteus osseus	longnose gar			3					3	
Dorosoma cepedianum	gizzard shad	259	3		4		16		262	20
Cyprinella lutrensis	red shiner	610	6	8	59	270		4	624	333
Cyprinus carpio	common carp	377	2		14	1	13		379	28
Macrhybopsis aestivalis	speckled chub			7		6			7	6
Notropis braytoni	tamaulipas shiner			4		1		1	4	2
Notropis chihuahua	Chihuahua shiner		1	4					5	
Notropis jemezanus	Rio Grande shiner			7					7	
Carpiodes carpio	river carpsucker	79	1	5		2	1		85	3
Cycleptus sp.	blue sucker						5			5
Astyanax mexicanus	mexican tetra			1	1	3	1		1	5
Ictalurus furcatus	blue catfish		1	6		4		1	7	5
Ictalurus punctatus	channel catfish	8	1	7		47			16	47
Pylodictus olivaris	flathead catfish		1	5	4				6	4
Gambusia affinis	western mosquitofish	192	1	7	25	90		1	200	116
Menidia beryllina	inland silverside	6	1	6	56				13	56
Morone chrysops	white bass	2	1						3	
Lepomis sp.	sunfish	373	4	7	46			2	384	48
Total # of Individuals		1906	23	77	209	424	36	9	2006	678
Species Richness		11	12	14	8	9	5	5	17	14
Simpson's Diversity (1-D)									0.8	0.71

Database Sources: University of Michigan Museum of Zoology (UMMZ), Texas Natural History Collection (TNHC)

Appendix II. Collections for Reach 2 (Big Bend)

Scientific Name	Common Name	Year of Collection and Data Source																							
		1954-1956 (TNHC)	1960 (OKMNH)	1963 (TU)	1968 (TU)	1977 (Hubbs et al., 1977)	1977 (UMMZ)	1988 (TNHC)	1990 (TNHC)	1991 (TNHC)	1992 (TNHC)	1992 (IBWC, 1994)	1993 (Edwards et al., 2002)	1995 (TNHC)	1999 (TNHC)	1999 (USDOI, 2002)	2000 (TNHC)	2003 (TNHC)	2004 TNHC)	2004 (Moring, 2005)	2006 (Bonner 2006	2007 (Bonner 2007)	2009 (TNHC)	PRE (1954-1977)	POST (1988-2009)
Lepisosteus osseus	longnose gar	4				6				16	1	3		2		1	3			50	15	2	8	10	101
Dorosoma cepedianum	gizzard shad	1				77	4			38	3	7		25		4				1				82	78
Dorosoma petenense	threadfin shad									3				1											4
Campostoma ornatum	Mexican stoneroller	1	8			16		6		197														25	203
Cyprinella lutrensis	red shiner	3	32	31	16	651	350	422	137	2061	86	222	2681	3683	64	98	139	252	539	53	4895	32	1599	1083	16763
Cyprinus carpio	common carp	23	8		2	5				14		44				3		1		3	69		292	38	426
Hybognathus amarus	Rio Grande silvery minnow	3																						3	
Macrhybopsis aestivalis	speckled chub	5	6	47		149	17	3		32	53	7		49	4	42	73	1	27	4	333	1	102	224	731
Notropis braytoni	Tamualipas shiner	14	34	28	7	89		6	1	40	46	7	30	83	451	88	2399	750	62	15	3695	14	201	172	7888
Notropis chihuahua	Chihuahua shiner		9	1		2	1	2		74											13		5	13	94
Notropis jemezanus	Rio Grande shiner	48	1		82	151		1	13	40	41	2	3	108	6	35	13				5			282	267
Notropis stramineus	sand shiner												3						1						4
Pimephales promelas	fathead minnow					2				9				4										2	13
Pimephales vigilax	bullhead minnow								1	1															2
Rhinichthys cataractae	longnose dace				4	2583			68	1040	215	26	2	15	2	5	26		4	11	38		22	2587	1474
Carpiodes carpio	river carpsucker	41	16	46		22		1	28	1570	24	47		51	45	19	68		2	3	433	42	235	125	2568
Cycleptus sp.	Rio Grande blue sucker	6	15		9	170				951		37		26		2	11				22		10	200	1059
Ictiobus bubalus	smallmouth buffalo	1				2				35	9		3	10		1	13				2			3	73
Moxostoma austrinum	Mexica redhorse									21				2											23
Astyanax mexicanus	Mexican tetra	27	38			34		1		98	3			3	16		1	59	1	11	141	17	4	99	355
Ictalurus furcatus	blue catfish	27	2	56		59	1	1		30	53	19	2	13	1	9	9			60	171	20	6	145	394
Ictalurus lupus	headwater catfish													4											4
Ictalurus punctatus	channel catfish		3	6		27				10	1	4		129		11	4			60	249	24	9	36	501
Pylodictis olivaris	flathead catfish	1		3	1	14		1		63	14	1		28		12		1		8	31	2		19	161
Menidia beryllina	inland silverside					5	4	149	12	321	1			14							64			9	561
Fundulus zebrinus	plains killifish		1	1						31					4	6	17	1	1	2	54	5	24	2	145
Gambusia affinus	western mosquitofish	21	20	1	2	44		24	14	795	16	159	507	643	29	1	75	36	2		315	9	104	88	2729
Morone chrysops	white bass									1															1
Lepomis sp.	sunfish	4	2			7		2	3	30	66	1	1	49	1	3			2	2	20		2	13	182
Micropterus salmoides	largemouth bass					6				17														6	17
Aplodinotus grunniens	freshwater drum	10								18	2			2						4				10	26
Total # of Individuals		240	195	220	123	4121	377	619	277	7556	634	586	3232	4944	623	340	2851	1101	641	287	10565	168	2423	5276	36847
Species Richness		18	15	10	8	22	6	13	9	28	17	15	9	22	11	17	14	8	10	15	19	11	15	25	30
Simpson's Diversity (1-D)																								0.71	0.73

Database Sources: Texas Natural History Collection (TNHC), Oklahoma Museum of Natural History (OKMNH), Tulane University (TU), University of Michigan Museum of Zoology (UMMZ)

Appendix III. Collections for Reach 3 (Laredo)

Scientific Name	Common Name	Year Collected and Data Source												
		1938 (UMMZ)	1940 (UMMZ)	1953 (TNHC)	1954 (TNHC)	1954 (TU)	1980 (Contreras-Balderas et al., 2002)	1990 (TNHC)	1992 (IBWC, 1994)	1993 (Contreras-Balderas et al., 2002)	1993 (TNHC)	1995 (IBWC, 1997)	PRE (1938-1980)	POST (1990-1995)
Lepisosteus oculatus	spotted gar								1		3			4
Lepisosteus osseus	longnose gar			1	4						2	3	5	5
Dorosoma cepedianum	gizzard shad		1		30		7	33	55	49	5	44	38	186
Dorosoma petenense	threadfin shad			15			2	2					17	2
Campostoma anomalum	central stoneroller										50			50
Cyprinella lutrensis	red shiner	1	2	76	63	103	691	1805	598	228	710	39	936	3380
Cyprinella proserpina	prosperine shiner				1						21		1	21
Cyprinella venusta	blacktail shiner						1	674	344	47	1013	170	1	2248
Cyprinus carpio	common carp							1	81	27	4	12		125
Dionda episcopa	roundnose minnow								8		96			104
Hybognathus amarus	Rio Grande silvery minnow	1	232			7	1						241	
Macrhybopsis aestivalis	speckled chub		20	44	19	103		5	31	31	31		186	98
Notropis amabilis	Texas shiner							2	5		62	8		77
Notropis braytoni	Tamaulipas shiner	3	22	277	35	318	441	9	7		7		1096	23
Notrpois buchanani	ghost shiner		2	11	4	1							18	
Notropis jemezanus	Rio Grande shiner	38	9	131	66	102	7	3	47	1	47		353	98
Pimephales vigilax	bullhead minnow		7	38	20	14	232	200	47	39	75		311	361
Rhinichthys cataractae	longnose dace	2		2		1		1					5	1
Carpiodes carpio	river carpsucker		12	49	15	2				1	4		78	5
Cycleptus sp.	Rio Grande blue sucker	7							2		2		7	4
Moxostoma congestum	grey redhorse								62	7	135	5		209
Astyanax mexicanus	Mexican tetra	2	1	84	18		29		3	1	14	10	134	28
Ictalurus furcatus	blue catfish		30		2	10						1	42	1
Ictalurus punctatus	channel catfish				13	43	11	2	47	6	5	7	67	67
Pylodictis olivaris	flathead catfish		31		1	4	1		2	20	6	2	37	30
Menidia beryllina	inland silverside				9		7	15	10		289	2	16	316
Gambusia affinus	western mosquitofish	1	3	108	75		6	77	30	1	599		193	707
Morone chrysops	white bass							1	1					2
Lepomis sp.	sunfish	0	6	5	11	35	16	119	39	9	48	9	73	240
Micropterus dolomieu	smallmouth bass								5		8			13
Micropterus salmoides	largemouth bass				1		1	4	6	3	4	8	2	25
Etheostoma grahami	Rio Grande darter							6	4		23			33
Cichlasoma cyanoguttatus	Rio Grande cichlid				10		4				2	2	14	4
Oreochromis aureus	blue tilapia						1		2		87	2	1	91
Total # of Individuals		55	378	841	397	743	1458	2959	1437	470	3352	324	3872	8558
Species Richness		10	15	14	20	14	18	19	25	16	29	17	26	33
Simpson's Diversity (1-D)													0.8354	0.7622

Database Sources: University of Michigan Museum of Zoology (UMMZ), Texas Natural History Collection (TNHC), Tulane University (TU)

Appendix IV. Collections for Reach 4 (Brownsville)

Scientific Name	Common Name	Year Collected and Data Source											
		1953 (TNHC)	1954 (TNHC)	1954 (TU)	1971 (TNHC)	1975-1977 (Contreras-Balderas et al., 2002)	1981-1982 (Contreras-Balderas et al., 2002)	1983 (TNHC)	1992 (IBWC, 1994)	1995 (IBWC, 1997)	1997 (TNHC)	PRE (1953-1982)	POST (1983-1997)
Atractoseus spatula	alligator gar						1					1	
Lepisosteus oculatus	spotted gar						2		1	1		2	2
Lepisosteus osseus	longnose gar					1	1		1			2	1
Dorosoma cepedianum	gizzard shad	13	173	40		43	16		90	182		285	272
Dorosoma petenense	threadfin shad	1	72	13	10	534	238	19	8		299	868	326
Cyprinella lutrensis	red shiner		102		28	37	107	65	213		27	274	305
Cyprinus carpio	common carp						1		34	5		1	39
Hybognathus amarus	Rio Grande silvery minnow	51	20	4		16						91	
Macrhybopsis aestivalis	speckled chub		98	16	19	204		2				337	2
Notropis amabilis	Texas shiner					31						31	
Notropis braytoni	Tamaulipas shiner		57			67	6	67				130	67
Notropis jemezanus	Rio Grande shiner		377	85	2	55						519	
Notropis orca	phantom shiner		12			14						26	
Pimephales vigilax	bullhead minnow				21	30	41	4	5		49	92	58
Carpiodes carpio	river carpsucker		35			2	1	1	24	13		38	38
Ictiobus bubalus	smallmouth buffalo		13						5	2		13	7
Astyanax mexicanus	Mexica tetra		322	14	9	180	22	1	298		34	547	333
Ictalurus furcatus	blue catfish		13			28	1		4			42	4
Ictalurus punctatus	channel catfish				1	139	4		17	10		144	27
Mugil cephalus	striped mullet		204				10		6	8		214	14
Mugil curema	white mullett	16									27	16	27
Agonostomus monticola	mountain mullet						1	2	5	5		1	12
Membras martinica	rough silverside					72	17					89	
Menidia beryllina	inland silverside	106	141	29	3	253	72	16	65		585	604	666
Fundulus grandis	Gulf killifish				55	1	38		4		4	94	8
Lucania parva	rainwater killifish				12							12	
Gambusia affinus	western mosquitofish		143	31	119	40	19	2	6		89	352	97
Poecilia formosa	Amazon molly		1			83	1				36	85	36
Poecilia latipinna	sailfin molly		3			57	2	1	1		15	62	17
Cyprinodon variegatus	sheepshead minnow		5	8		20	3	1			5	36	6
Morone chrysops	white bass					1	1		8	3		2	11
Lepomis sp.	sunfish		1		7	11	22	4	86	1	19	41	110
Micropterus salmoides	largemouth bass		1			2	3		115	13	19	6	147
Pomoxus annularis	white crappie					2	11					13	
Aplodinotus grunniens	freshwater drum		5	5		9	2		4	1		21	5
Cichlasoma cyanoguttatus	Rio Grande cichlid		12		41	16	13		5		7	82	12
Oreochromis aureus	blue tilapia						237	2	13			237	15
Gobiomorus dormitor	bigmouth sleeper		6				1	1	52	13		7	66
Total # of Individuals		187	1816	245	327	1948	894	188	1070	257	1215	5417	2730
Species Richness		5	23	10	13	28	30	15	25	13	14	38	30
Simpson's Diversity (1-D)												0.92	0.88

Database Sources: Texas Natural History Collection (TNHC), Tulane University (TU)

REFERENCES

1906 Convention. Convention for the Equitable Distribution of the Waters of the Rio Grande for Irrigation Purposes, U.S.-Mexico, May 21, 1906, 34 Stat. 2953, available at http://www.ibwc.state.gov/Files/1906Conv.pdf (accessed June 4, 2010).

1938 Compact. Rio Grande Compact. H. Con. Res. 4997. 76th Cong. 53 Stat. 785 (1939).

1944 Treaty. Treaty between the United States of America and Mexico, February 3, 1944, U.S.-Mex. 59 Stat. 1219.

Alexander, K., Lopes, V. and W. Rast. 2012. Binational institutional development in the Rio Grande Basin: A social-ecological perspective. Manuscript in review.

Alexander Martin, K. 2010. Texas' boundary water agreements. In Water Policy in Texas: Responding to the Rise of Scarcity. Ed. Ronald Griffin. RFF Press.

Anderson, A., Hubbs, C., Winemiller, K. and R. Edwards. 1995. Texas freshwater fish assemblages following three decades of environmental change. *The Southwestern Naturalist* 40(3): 314-321.

Balmer, O. 2002. Species lists in ecology and conservation: Abundances matter. *Conservation Biology* 16(4): 1160-1161. August 2002.

Bond, N., Lake, P., and A. Arthington. 2008. The impacts of drought on freshwater ecosystems: an Australian perspective. *Hydrobiologia* 600:3-16.

Bunn, S. and A. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management* 30(4): 492-507.

Calamusso, B., Rinne, J. and R. Edwards. 2005. Historic changes in the Rio Grande fish fauna: Status, threats, and management of native species. In Historical Changes in Large River Fish Assemblages of the Americas. Ed. J. N. Rinne, R. M. Hughes, and B. Calamusso. American Fisheries Society, Symposium 45, Bethesda, Maryland. Pages 205-223.

Contreras-Balderas, S., Edwards, R., Lozano-Vilano, M., García-Ramírez, M. 2002. Fish biodiversity changes in the Lower Rio Grande/Rio Bravo, 1953-1996. *Reviews in Fish Biology and Fisheries* 12: 219-240.

Contreras-Balderas, S., Almada-Villela, P., Lozano-Vilano, M., García-Ramírez, M. 2003. Freshwater fish at risk or extinct in México. *Reviews in Fish Biology and Fisheries* 12: 241-251.

Contreras-Balderas, S., Ruiz-Campos, G., Schmitter-Soto, J., Díaz-Pardo, E., Contreras-McBeath, T., Medina-Soto, M., Zambrano-González, L., Varela-Romero, A., Mendoza-Alfaro, R., Ramírez-Martínez, C., Leija-Tristán, M., Almada-Villela, P., Hendrickson, D., and J. Lyons. 2008. Freshwater fishes and water status in México: A Country-wide appraisal. *Aquatic Ecosystem Health and Management.* 11(3): 246-256.

Cowley, David. 2006. Strategies for ecological restoration of the Middle Rio Grande in New Mexico and recovery of the Rio Grande silvery minnow. *Reviews on Fisheries Science* 14: 169-186.

Cowley, D., and Wissmar, R., and R. Sallenave. 2007. Fish assemblages and seasonal movements of fish in irrigation canals and river reaches of the Middle Rio Grande, New Mexico (USA). *Ecology of Freshwater Fish.* 16: 548-558.

Dudgeon, D., Arthington, A., Gessner, M., Kawabata, Z., Knowler, D., Lévêque, C., Naiman, R., Prieur-Richard, A., Stiassny, M., and C. Sullivan. 2006. Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Reviews of the Cambridge Philosophical Society.* 81: 163-182.

Drusina, E. 2012. Letter to Mr. Carlos Rubinstein, Commissioner, Texas Commission on Environmental Quality and the Honorable Todd Staples, Commissioner, Texas Department of Agriculture. April 5, 2012. Available at http://www.riograndeguardian.com/rggnews_story.asp?story_no=19. Accessed April 10, 2012.

Dudley, R. and S. Platania. 2007. Flow regulation and fragmentation imperil pelagic-spawning riverine fishes. *Ecological Applications* 17(7): 2074-2086.

Edwards, R. 2001. Ecological Profiles for Selected Stream-Dwelling Texas Freshwater Fishes III. A report to the Texas Water Development Board. TWDB Contract Number 95-483-107. December 2001.

Edwards, R. and S. Contreras-Balderas. 1991. Historical changes in the ichthyofauna of the Lower Rio Grande (Río Bravo del Norte), Texas and Mexico. *The Southwestern Naturalist* 36(2): 210-212.

________, Garrett, G., and E. Marsh-Matthews. 2002. Conservation and status of the fish communities inhabiting the Rio Conchos Basin and Middle Rio Grande, México and U.S.A. *Reviews in Fish Biology and Fisheries* 12:119-132.

Far West Texas Regional Water Planning Group. 2011. Far West Texas Water Plan.. Available at http://www.twdb.texas.gov/wrpi/rwp/3rdRound/2011_RWP/RegionE/

Hoagstrom, C. and J. Brooks. 2005. Distribution and status of Arkansas River Shiner *Notropis Girardi* and Rio Grande Shiner *Notropis Jemezanus*, Pecos River, New Mexico. *Texas Journal of Science.* 57(1): 35-58.

Hooper, D., Chapin, F., Eewl, J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J., Lodge, D., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A., Vandermeer, J., and A. Wardle. 2005. Effects of biodiversity on ecosystem functioning: A Consensus of current knowledge. *Ecological Monographs.* 75(1): 3-35.

Hubbs, C., Miller, R., Edwards, R., Thompson, K., Marsh, E., Garrett, G., Powell, G., Morris, D., and R. Zerr. 1977. Fishes inhabiting the Rio Grande, Texas-Mexico, between El Paso and the Pecos confluence. In *Importance, Preservation and Management of Riparian Habitat: A Symposium.* U.S.D.A. Forest Service, General Technical Report RM-43. Ed. R. Johnson and D. Jones. pp. 91-97.

Hubbs, C., Edwards, R., and G. Garrett. 2008. An Annotated Checklist of the Freshwater Fishes of Texas, With Keys to Identification of Species. Texas Academy of Science. Available at: http://www.texasacdemyofscience.org

Hundley, Norris. 1966. *Dividing the Waters: A Century of Controversy Between the United States and Mexico.* Berkeley and Los Angeles, CA: University of California Press.

International Boundary and Water Commission (IBWC). 1994. Binational Study Regarding the Presence of Toxic Substances in the Rio Grande/Rio Bravo and its Tributaries Along the Boundary Portion Between the United States and Mexico. Final Report, September 1994. Study and Report Undertaken by the United States and Mexico pursuant to IBWC Minute 289.

International Boundary and Water Commission (IBWC). 1997. Second Phase of the Binational Study Regarding the Presence of Toxic Substances in the Rio Grande/Rio Bravo and its Tributaries Along the Boundary Portion Between the United States and Mexico. Volume II of II.

International Boundary and Water Commission (IBWC). 2005. Flows of the Rio Grande and Related Data From Elephant Butte Dam, New Mexico to the Gulf of Mexico 2005. Water Bulletin No. 75.

Jelks, H., Walsh, S., Burkhead, N., Contreras-Balderas, S., Díaz-Pardo, E., Hendrickson, D., Lyons, J., Mandrak, N., McCormick, F., Nelson, J., Platania, S., Porter, B., Renaud, C., Schmitter-Soto, J., Taylor, E. and M. Warren. 2008. Conservation status of imperiled North American freshwater and diadromous fishes. *Fisheries* 33(8): 372.

Krebs, C.J., 1989. Ecological methodology. HarperCollins. New York.

La Paz Agreement. 1983. Agreement Between the United States of America and the United Mexican States On Cooperation For The Protection And Improvement Of The Environment In The Border Area. Treaties and Other International Acts Series 10827. Signed August 14, 1983. Available at http://www.epa.gov/border2012/docs/LaPazAgreement.pdf

Lake, P.S. 2003. Ecological effects of perturbation by drought in flowing waters. *Freshwater Biology* 48: 1161-1172.

Matthews, W. and E. Marsh-Matthews. 2003. Effects of drought on fish across axes of space, time and ecological complexity. *Freshwater Biology* 48: 1232-1253.

McCarthy, R. 2011. Executive authority, adaptive treaty interpretation, and the International Boundary and Water Commission, U.S. –Mexico. *University of Denver Law Review* 197:92. Spring 2011.

Moring, J. 2005. Status of fish communities in the Rio Grande, Big Bend National Park, Texas: Comparison before and after spring 2003 period of low flow. United States Geological Survey Scientific Investigations Report 2005-5209. 11 pages.

National Oceanic and Atmospheric Administration (NOAA). 2012. National Climatic Data Center. Available at http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp

Nature Conservancy. 2009. *Indicators of Hydrologic Alteration. Version 7.1 Users Manual*. With rPurview LLC – Ted Rybicki, Totten Software Design, and Smythe Scientific Software. April 2009.

Perkin, J. and T. Bonner. 2011. Long-term changes in flow regime and fish assemblage composition in the Guadalupe and San Marcos rivers of Texas. *Rover Research and Applications*. 27: 566-579.

Richter, B., Baumgartner, J., Powell, J. and D. Braun. 1996. A Method for assessing hydrologic alteration within ecosystems. *Conservation Biology* 10(4): 1163-1174.

Richter, B., Baumgartner, J., Wigington, R., and D. Braun. 1997. How much water does a river need? *Freshwater Biology* 37: 231-249.

Richter, B., Mathews, R., Harrison, D., and R. Wigington. 2003. Ecologically sustainable water management: Managing river flows for ecological integrity. *Ecological Applications.* 13(1): 206-224.

Rinne, J. and D. Miller. 2006. Hydrology, geomorphology and management: Implications for sustainability of native Southwestern fishes. *Reviews in Fisheries Science.* 14: 91-100.

Rio Grande Regional Water Planning Group. 2010. Rio Grande Regional Water Plan. Available at http://www.twdb.texas.gov/wrpi/rwp/3rdRound/2011_RWP/RegionM/

Schmandt, J. 1993. Water and Development: The Rio Grande/Rio Bravo. Lyndon B. Johnson School of Public Affairs, Austin, TX.

Schmandt, J., Aguilar-Barajas, I., Armstrong, N., Chapas-Aleman, L., Contreras-Balderas, S., Edwards, R., Hazleton, J., de Jesus Navar, J., Mathis, M., Vogel-Martinez, E. and Ward, G. 2000. Final Report: Water and Sustainable Development in the Binational Lower Rio Grande/Bravo Basin. United States Environmental Protection Agency. EPA Grant Number: R824799.

Schmidt, J., Everitt, B., and G. Richard, 2003. Hydrology and Geomorphology of the Rio Grande and Implications for River Rehabilitation. In Aquatic Fauna of the Northern Chihuahua Desert. Eds. G. Garrett and N. Allen. Contributed Papers from a Special Session of the Desert Fishes Council. Special Publications. Museum of Texas Tech University. Number 46. May 12, 2003.

Staples, T. and C. Rubinstein. 2012. Letter to Mr. Edward Drusina, Commissioner, United States Section International Boundary and Water Commission. April 3, 2012. On file with author.

Stotz, Nancy. 2000. Historic Reconstruction of the Ecology of the Rio Grande/Rio Bravo Channel and Floodplain in the Chihuahua Desert. Report prepared for the Chihuahuan Desert Program. World Wildlife Fund. June 14, 2000.

Texas Center for Policy Studies. 2001. The Rio Conchos: A Preliminary Overview. Prepared by Mary E, Kelly, Director. Available at http://www.texascenter.org/publications/rioconchos.pdf

TRC/Brandes, 2009. Evaluation of Alternate Water Supply management Strategies Regarding the Use and Classification of Existing Water Rights on the Lower and Middle Rio Grande. Rio Grande Regional Water planning Study 1st Phase, 3rd Round of Regional Water Planning. Prepared for Rio Grande Regional Water Planning Group. Report No. 0704830698. August 31, 2009.

Treviño Robinson. 1959. The Ichthyofauna of the Lower Rio Grande, Texas and Mexico. *Copeia.* 3:253-256. October 9, 1959.

Umoff, A. 2008. An analysis of the 1944 U.S.-Mexico water treaty: Its past, present, and future. *Environs: Environmental Law and Policy Journal* 69:218. Fall 2008.

United States Department of the Interior. 2012. Joint Statement on Cooperative Action for Conservation in the Big Bend/Río Bravo Region. Available at http://www.doi.gov/news/pressreleases/loader.cfm?csModule=security/getfile&pa page=262524

United States Department of the Interior. National Park Service. 2006. Investigators' Annual Report. Ecological Characterization of the Rio Grande Fish Assemblages in the Big Bend and Lower Canyon Areas. Timothy Bonner, P.I. OMB # (1024-0236).

United States Department of the Interior. National Park Service. 2007. Investigators' Annual Report. Ecological Characterization of the Rio Grande Fish Assemblages in the Big Bend and Lower Canyon Areas. Timothy Bonner, P.I. OMB # (1024-0236).

United States Fish and Wildlife Service (USFWS). 2009. Media Advisory: 500,000 Rio Grande Silvery Minnows Released Into River at Big Bend National Park. Available at http://www.fws.gov/southwest

United States Bureau of Reclamation (USBR). 2012. Rio Grande Project. Available at http://www.usbr.gov/projects/Project.jsp?proj_Name=Rio Grande Project

Utton, Albert E. 1999. Coping with drought on an international river under stress: The Case of the Rio Grande/Rio Bravo. *Natural Resources Journal* 39(1):27. Winter, 1999.

Walker, B. and D. Salt. 2006. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World.* Washington, D.C.: Island Press.

Williams, J., Bowman, D., Brooks, J., Echelle, A., Edwards, R., Hendrickson, D., and J. Landye. 1985. Endangered aquatic ecosystems in North American deserts with a list of vanishing fishes of the region. *Journal of the Arizona-Nevada Academy of Science* 20(1):1.

Williams, J. E., Johnson, J., Hendrickson, D., Contreras-Balderas, S., Williams, J. D., Navarro-Mendoza, M., McAllister, D. and J. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. *Fisheries* 14(6):2-20.

Williams, C and T. Bonner. 2007. Reproductive characteristics of three obligate riverine species from the Lower Brazos River. Annual Proceedings of the Texas Chapter, American Fisheries Society. Annual Meeting March 2-4, 2007. Lake Jackson, Texas.

Wolda, H. 1981. Similarity indices, sample size, and diversity. *Oecologia* 50: 296-302.

CHAPTER III

BOUNDARY WATER AGREEMENTS

The boundaries of natural resources, watersheds in particular, frequently do not coincide with political boundaries. Furthermore, the distribution of water resources among political subdivisions is rarely equal or unanimously agreed on. This can lead to conflict at both the interstate and international levels. A mechanism for resolving these types of conflicts at the interstate level in the United States is interstate compacts. At the international level, nations that share water resources often agree to allocation and joint administration of these resources through treaties between the national governments. The border waters of Texas are subject to both compacts and international treaties. Examination of the Texas experience provides evidence of both the difficulties of achieving agreement on water resource issues in the first place and subsequently administering those agreements in light of changing circumstances.

Texas shares significant water sources, both surface water and groundwater, with several other states: Colorado, New Mexico, Louisiana, and Oklahoma. The United States also shares certain waters with Mexico, both being sovereign nations. The U.S. share of these waters is either used by federal projects or allocated by Texas in accordance with state statutes. This chapter provides an account of the interstate compacts between Texas and other states. It also discusses the two international water treaties—one in 1906 and the other in 1944—involving the United States and Mexico.

These treaties have a profound impact on Texans residing in the border region. A brief commentary on each compact traces the formative events and discusses the issues and legal disputes that continue to affect these relationships. The two compacts and two international treaties involving allocation of the Rio Grande are then examined in more detail, noting that the lessons learned from the long history of conflict and cooperation in the Rio Grande basin can have broad applicability to other international river basins. Relevant details include the historical evolution of these interstate and international agreements, the status of unresolved issues hampering their administration, and initiatives for managing the river's water in the future.

Interstate Compacts

As with other western states, increasingly fierce disputes over shared water resources between Texas and its neighbors led to negotiations, culminating in agreements known as interstate compacts. In addition to efforts by the individual states, the federal government frequently encouraged settlement of such disputes by conditioning project subsidies on the ability of the involved states to finalize water allocation agreements. One deficiency of tying compact ratification to federal funding, however, was that the most contentious issues frequently were not addressed, leading to future litigation. In addition, Texas's interstate water compacts and treaties cover only surface-water allocations; groundwater was not explicitly included. The effect of increased groundwater pumpage on surface-water flows, however, was very important in disputes over water resources in the Pecos River basin. One likely reason for failure to include groundwater is the different legal framework for its administration. Texas's interstate compacts either addressed water quality issues at the outset or incorporated them at a later date. Water flows supporting aquatic species and other ecosystem uses were not originally included in Texas's interstate compacts, although these issues are currently being addressed through litigation under the Endangered Species Act or updated agreements between signatory states as part of compact administration.

Compact administration typically rests with a commission consisting of one or more representatives from each state and a nonvoting federal representative. In Texas, compacts are incorporated into state law, with the governor appointing commissioners for six-year terms. Decisions of the compact commissions must be made by unanimous vote, making decisions over controversial issues, particularly water allocation issues, difficult to resolve. When unanimity cannot be reached, disputes may be referred to the U.S. Supreme Court.[1] The high cost of litigation may tend to keep compact participants at the table. Requirements for unanimous decisions also allow recalcitrant states to thwart resolution of contentious issues in favor of the status quo.

Texas participates in the following compacts with the listed states (see Figures 3.1 and 3.2):

- Canadian River Compact: New Mexico and Oklahoma
- Red River Compact: Oklahoma, Arkansas, Louisiana
- Sabine River Compact: Louisiana
- Pecos River Compact: New Mexico
- Rio Grande Compact: New Mexico

The United States also signed a water treaty with Mexico regarding the Rio Grande, which determined the amount of water available for Texas water users.

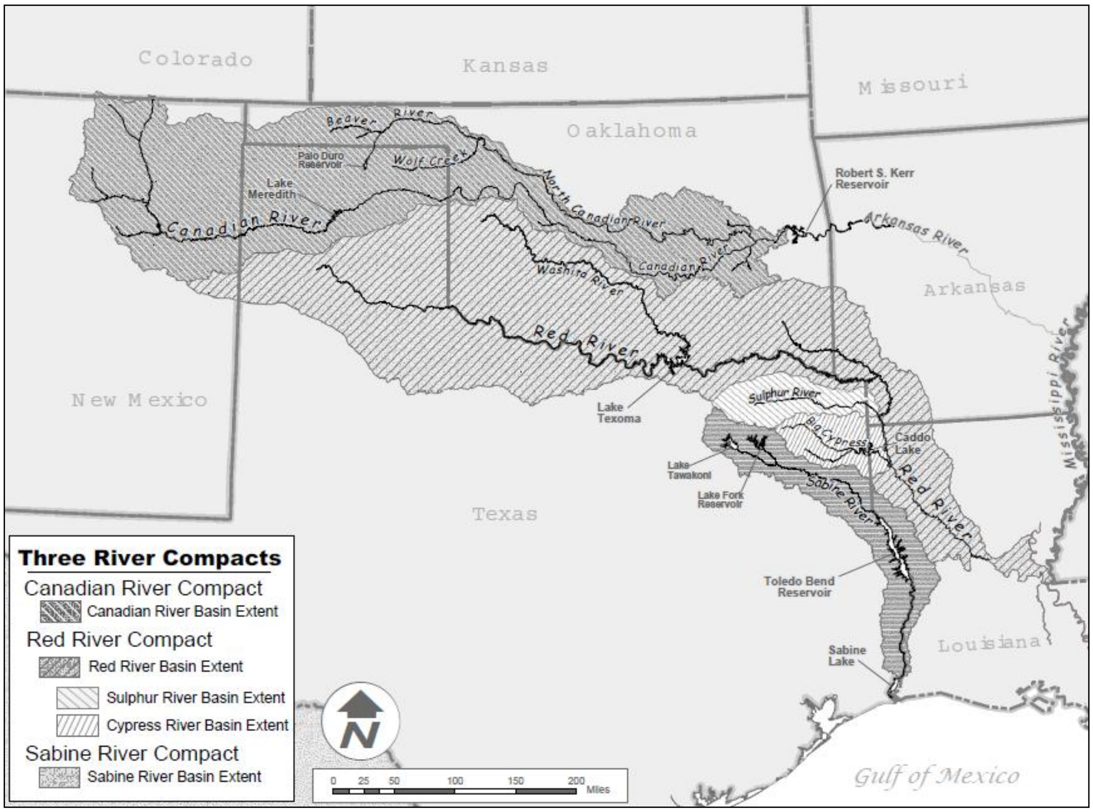

Figure 3.1. Canadian, Red, and Sabine River Compacts

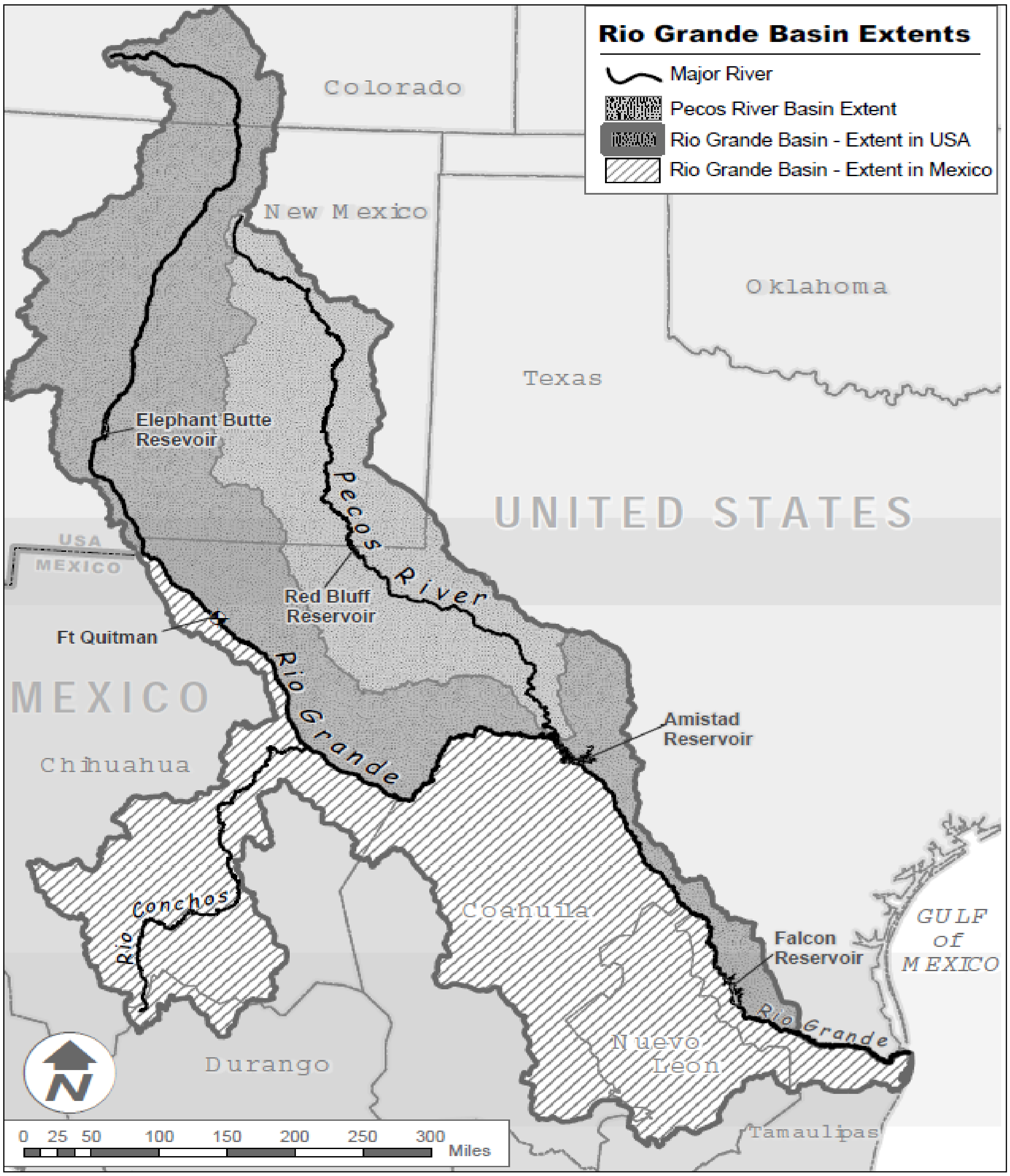

Figure 3.2. Rio Grande Compacts and Treaties, Including Pecos River Compact

Canadian River Compact

The Canadian River (see Figure 3.1) is a tributary of the Arkansas River, rising from its headwaters in the Sangre de Cristo Mountains in southern Colorado, near the state's boundary with New Mexico, then flowing south and southeast through New Mexico and Texas before entering Oklahoma and continuing to its mouth at the Arkansas River. The need to allocate the waters of the Canadian River was recognized in the early twentieth century. The Canadian River Development Association was formed in 1925 to begin work on flooding issues and irrigation projects, leading to an effort to negotiate a compact in 1926. Although the legislatures of New Mexico and Oklahoma ratified the compact, the Texas legislature failed to do so, with the result that this compact did not take effect.[2]

In 1938, the U.S. Army Corps of Engineers (USACE) received authorization from Congress to construct Conchas Reservoir in New Mexico for flood control purposes, thereby benefiting the basin states, and to provide irrigation water in New Mexico.[3] By the 1940s, declining water levels in the Ogallala Aquifer caused Texas farmers and cities to push for construction of Lake Meredith, in order to use the heretofore "wasted" surface waters of the Canadian River.[4] The combination of Texas's existing and future uses of surface water in the region, New Mexico's desire to protect existing rights and retain their ability to construct additional storage in the future, and Oklahoma's desire to lock up water for future projects[5] led to congressional approval for the three states to begin negotiation of the Canadian River Compact.[6] Texas, Oklahoma, and New Mexico signed the compact on December 6, 1950, and the U.S. Congress approved it in 1952.[7]

Provisions of the Compact

The Canadian River Compact is somewhat different from Texas's other compacts with respect to the manner in which the river water is apportioned. This compact contains no requirements for delivery of specified amounts of water to the state line. Instead, it allocates water to each state by limiting the amount of water New Mexico and Texas can hold in conservation storage in their reservoirs.[8] Free and unrestricted use of the water is allowed in Oklahoma, as the downstream state. The requirements for Texas and New Mexico are more complex.

New Mexico is entitled to all waters originating above Conchas Dam, as well as all waters originating below the dam subject to storage limitations.[9] The compact specifies circumstances under which New Mexico and Texas may impound water in excess of their described conservation storage limits.[10] Texas is entitled to free and unrestricted use of the water within the state, subject to storage limitations. Its use of the North Canadian River is subject to usage constraints.[11] Texas is limited to the impoundment of 500,000 acre-feet of water, subject to certain conditions relating to Oklahoma's impoundment of water.[12]

Post-Compact Administration

After the compact took effect, several disputes arose among the signatory states over interpretation of its requirements. Two disputes, relating to interpretation of Article V(b), were resolved via a resolution of the commission and memorialized by an agreement between Texas and Oklahoma in 1981.[13] The third dispute required judicial resolution in the U.S. Supreme Court.

Once the Canadian River Compact was signed, Congress authorized the Canadian River Project to construct Lake Meredith on the Canadian River in Texas, which was completed in 1964. In the meantime, New Mexico constructed Ute Reservoir, located below Conchas Dam, in 1963, and subsequently enlarged this reservoir in the early 1980s. Texas and Oklahoma objected to this enlargement because of its effects on their own downstream interests and took the dispute to the Supreme Court, arguing that the terms of the compact limited New Mexico's storage below Conchas Dam.[14]

Events in 1987, while the case was pending, exacerbated the dispute. A flood in the river above Conchas Dam resulted in a spill of approximately 250,000 acre-feet of water. New Mexico impounded 60% of this water in Ute Reservoir and passed only 40% downstream to Texas and Oklahoma. New Mexico asserted that compact limitations did not apply to the spilled waters because those waters originated above Conchas Dam. Texas and Oklahoma disagreed and amended their original complaint.[15] The court appointed a special master, who investigated the complaints and filed a report on October 15, 1990.[16] A judgment and decree entered on December 13, 1993, held that New Mexico had been in violation of the compact and ordered water releases from Ute Reservoir and that the state pay attorney's fees.[17]

Although there have been no recent court filings, issues over compact interpretation continue. Oklahoma contends that Texas is in violation of Article V(a) of the compact. Texas constructed Palo Duro Reservoir, which is used for recreational purposes and stops the flow of Palo Duro Creek as a result of its design.[18] Texas contends that Palo Duro Reservoir was constructed for municipal purposes and complies with the terms of the compact. The states discussed this issue in the 1990s, and in 2001, the

Oklahoma legislature adopted a resolution calling for that state's attorney general to proceed with a lawsuit over the issue, although no suit has yet been filed as of this writing.[19]

Red River Compact

The Red River (see Figure 3.1) is part of the Mississippi drainage, rising from headwaters in New Mexico, flowing through the Texas Panhandle, and becoming the border between Oklahoma and Texas. The river then flows through Arkansas and into Louisiana, where it empties into the Atchafalaya and Old Rivers. The basin drainage in Texas also includes the Sulphur River and Cypress Creek basins.[20]

Negotiations over the equitable apportionment of the waters of the Red River basin in Oklahoma, Texas, Arkansas, and Louisiana began in 1956, in response to the prolonged drought of the 1950s. Issues included water development (Texas and Oklahoma), shortages of water for industrial use (Arkansas), and flood control (Louisiana). The compact took more than 20 years to negotiate because of disagreements between Texas and Oklahoma, which were ultimately resolved in 1976. The U.S. Congress consented to the Red River Compact on December 22, 1980.[21]

Provisions of the Compact

The Red River Compact includes provisions unique among Texas's interstate compacts. The U.S. Supreme Court typically has original jurisdiction in suits between states. This compact allows U.S. district courts concurrent original jurisdiction in any disputes over compact interpretation.[22] In addition, it contains provisions expressly related to water pollution.[23] The compact does not require annual accounting for enforcement purposes at this time, but the states could agree to this in the future.[24] The states may incorporate water accounting as uses increase and water supply development continues.[25]

Because of the size of the basin and the involvement of multiple states, the apportionment of water flows is somewhat complex. The basin is divided into five reaches, three of which relate to Texas. In Reach I, flow in the interstate tributaries is apportioned 60% to Texas and 40% to Oklahoma. Intrastate streams are apportioned solely to the state in which they are located. The waters of the mainstem are divided equally between Texas and Oklahoma, including flow in the river and storage in Lake Texoma.[26]

In Reach II, Texas has free and unrestricted access to intrastate streams in Texas. For the mainstem of the Red River below Denison Dam and tributaries except for those already described in other subbasins, the four states have equal rights to the waters as long as specific flow requirements are met at the Arkansas-Louisiana border. No state is required to guarantee a minimum flow to any other compact state.[27]

In Reach III, which includes the Texas portion of streams crossing the Texas-Arkansas boundary and flowing into Cypress Creek–Twelve Mile Bayou watershed in Louisiana, the waters are apportioned 60% to Texas and 40% to Arkansas. For tributaries crossing the Texas-Louisiana boundary and flowing into Caddo Lake, Cypress Creek–Twelve Mile Bayou, or Cross Lake, Texas and Louisiana each have free and unrestricted access to flows originating within the respective state, subject to requirements related to water inflows into and use of Caddo Lake.[28]

Post-Compact Administration

No litigation has occurred to date among the states regarding interpretation of compact provisions. However, issues exist that potentially could affect relationships among the signatory states, particularly Texas and Oklahoma. Disputes between Texas and Oklahoma over the waters of Sweetwater Creek and the North Fork of the Red River predate the compact. In April 2008, this dispute was resolved with the adoption of administrative rules. The new resolution states that Texas did not violate the compact, and that water flows in both streams would be divided 60% to Texas and 40% to Oklahoma.[29]

A current controversy involves a Dallas-area entity's desire to divert water in Oklahoma. In January 2007, the Tarrant Regional Water District (TRWD) requested a permit from the Oklahoma Water Resources Board to divert 460,000 acre-feet of water from three basins in Oklahoma. However, once the water enters the mainstem of the Red River, it becomes saline. Thus TRWD wants to divert the water in Oklahoma before it enters the river. In 2002, Oklahoma imposed a moratorium on water sales until completion of a 50-year water plan.[30] TRWD filed suit against the Oklahoma Water Resources Board and Oklahoma Water Conservation Storage Commission, challenging the moratorium and alleging its right to apply for, and be granted, a permit pursuant to the Red River Compact and the Commerce and Supremacy Clauses of the U.S. Constitution. The district court ruled that the lawsuit could continue, with the 10th Circuit Court of Appeals upholding the decision in 2008.[31] To further complicate the issue of Texas's diversions of Oklahoma water, the city of Irving, Texas, entered into a contract with the city of Hugo, Oklahoma, and filed suit challenging the moratorium. Irving's actions fueled disputes among the Texas entities seeking Oklahoma water.[32] Three of the major entities signed a historic agreement to share any water from Oklahoma, including the costs of infrastructure associated with the transfer.[33]

Sabine River Compact

The Sabine River (see Figure 3.1) originates in northeast Texas and flows southeasterly through Panola County, where the river forms the boundary between Texas and Louisiana. The Sabine then flows into Sabine Lake, at the confluence of the Sabine and Texas's Neches River, and then through Sabine Pass into the Gulf of Mexico. As with most interstate compacts, the Sabine River Compact arose in response to competing claims for water. Louisiana claimed title in 1949 to all of the water below the point where the river becomes the boundary between Texas and Louisiana. Subsequent negotiations between the two states proceeded rapidly, with congressional approval in 1951, the onset of negotiations in 1952, and congressional ratification of the compact in 1954.[34]

Provisions of the Compact

The Sabine River Compact recognizes existing uses in both states, with any water withdrawals being subject to water availability, as determined by the compact.[35] The Stateline Reach, that portion of the river beginning at the point where it becomes the boundary between the states and ending in Sabine Lake, is apportioned equally between the two states.[36] The compact also requires both states to use water flows as they occur,[37] and it allows both states to use the bed and banks of the Sabine River to convey stored water without losing ownership of that water.[38] Water uses in both states are subject to the maintenance of a minimum flow of 36 cubic feet per second (cfs) at the state line.[39]

Post-Compact Administration

To date, all disputes between the two states have been resolved through negotiations. In fact, Texas and Louisiana cooperated in the construction of Toledo Bend Reservoir, said to be the only public water conservation and hydroelectric project in the United States built without federal funding.[40] Current issues include ongoing efforts in Texas to determine ecological in-stream flow uses in the Sabine River, which has caused concern among water users in Louisiana. Local entities there are monitoring the Texas in-stream flow process.[41]

Overview of Rio Grande Basin Agreements

The Rio Grande and Pecos Compacts, as well as two international agreements between the United States and Mexico, govern allocation of water flow in the Rio Grande (see Figure 3.2). The river drains two countries, the United States and Mexico, and eight states within these countries: Texas, New Mexico, Colorado, Chihuahua, Coahuila, Durango, Nuevo Leon, and Tamaulipas. The Rio Grande is the fifth-longest river in North America, with a drainage area of approximately 355,000 square miles. The basin covers 11% of the continental United States and 44% of the land area in Mexico.[42]
The Rio Grande headwaters originate in the San Juan Mountains of Colorado. The river enters the San Luis Valley of southern Colorado, where it has supported extensive irrigated agriculture since 1851.[43] After entering New Mexico, most of the river's flow is diverted for agricultural purposes, with a large portion of this use being managed through various federal projects administered by the U.S. Bureau of Reclamation (BOR). After passing through central New Mexico, the river is impounded by Elephant Butte Reservoir. Elephant Butte stores water for irrigation uses in New Mexico and farther

downstream in Texas, as well as providing delivery of 60,000 acre-feet of water in Mexico for irrigation use, pursuant to the Convention of 1906.

At a point approximately 23 miles north of El Paso, the river enters Texas and becomes the boundary between the United States and Mexico. The river at this point is severely degraded and frequently dries up during the winter months. Intensive agricultural diversions by irrigation districts on both sides of the border have resulted in severe alteration of the natural water flow regime of the river. For example, the average annual water flow at Fort Quitman was reduced 96% between 1884 and 1964.[44] The river then flows through a reach known as the "Forgotten River" from below Fort Quitman to Big Bend National Park, located at the confluence of the Rio Grande and Mexico's Rio Conchos. Because of upstream diversions and the construction of Elephant Butte Reservoir, the river's flow is often reduced to zero at times when its flow would have occurred historically. When the Rio Grande reaches Presidio and Ojinaga, flow from the Rio Conchos in Mexico replenishes the mainstem of the river. Historically, the Rio Conchos contributed approximately two-thirds of the flow of the Rio Grande below its confluence. This water contribution declined over the last 10 years, however, leading to water disputes between the United States and Mexico.

The river then enters a reach extending from Amistad Reservoir to the Gulf of Mexico. The Pecos and Devil's Rivers, both tributaries on the Texas side, enter the mainstem of the Rio Grande at Amistad. The river is heavily regulated in this segment, with water quality being an issue. Pressures on the river system are primarily a function of explosive population growth on both sides of the border. The population of the Lower Rio Grande Valley on the Texas side, for example, is at least 1.2 million people, and the population on the Mexican side of the border has been estimated to be at least three times greater.[45] The total population could exceed 11 million people in 2030. In addition to high population growth rates, the border region is one of the poorest in the United States, with the border counties on the Texas side having the lowest per capita income in the country. Most river water in the Lower Rio Grande is used for irrigation. The amount of irrigated land, however, is steadily declining as a result of urbanization.[46]

Water supply historically has been an issue in the Rio Grande basin, generating conflict at the local, state, and international levels. Although land use in the basin is primarily agricultural, rapidly urbanizing areas are stressing the water resource base. Basin problems include habitat loss and endangered species management, water quality degradation, and water management issues resulting from shifts in water usage from agricultural to municipal. Although numerous programs address basin problems, fragmented authority at all governmental levels and a reluctance to address water quality concerns constitute ongoing binational challenges.

The international character of the Lower Rio Grande basin introduces added complexity, as national foreign policy interests are involved. Thus control over the U.S. share of the waters in the river vests at the federal level, with those interests and allocation of the waters of the main channel being managed by the U.S. section of the International Boundary and Water Commission (USIBWC). The USIBWC assists in determining the flow in the river and apportioning the national shares between the United States and Mexico. Once the national flows are allocated, the remaining water flow is available for Texas users in accordance with state statutes. Hence the actual water flow allocated in any given year and issues that could arise if treaty provisions are violated are outside the control of the state. Because of this reality, the interests of Texas water users are subordinate to the national interests of the United States.

The 1906 Convention

Water supply problems in the Rio Grande basin were apparent by 1878. Texas complaints of excessive Mexican diversion in 1888, plans by the United States to construct a storage reservoir in the El Paso area in 1890, and complaints by Mexico over upstream diversions in the United States in 1894 all led to a joint investigation of water supply by the two countries, beginning in 1896. The International Boundary Commission (IBC) investigated the feasibility of constructing an international reservoir above El Paso. Mexico supported construction of the reservoir, claiming monetary damages resulting from increased U.S. diversions upstream and suggesting that the United States should fund construction of the reservoir to settle this debt. In November 1904, at the 12th International Irrigation Congress in El Paso, representatives of Texas, New Mexico, and Mexico reached a compromise, endorsing the Elephant Butte dam site.[47]

Once the parties reached a tentative agreement, several obstacles still remained. The BOR would construct the project, but the Reclamation Act of 1902 did not authorize construction of projects in Texas.[48] Numerous federal agencies and other interests supported construction of the reservoir, and Congress approved construction in 1905 and extended the Reclamation Act to cover Texas in June 1906.[49] U.S. concerns about allocating water to Mexico, however, threatened to delay construction of the project. In addition, during negotiations, Mexico requested a survey of irrigable lands, different water allocation amounts, and division of water flows below El Paso. Despite Mexico's concerns with the proposed treaty, they withdrew their requests, United States interests agreed to a defined allocation to Mexico, and the 1906 Convention was ratified by the two countries.[50]

The purpose of the 1906 Convention was equitable distribution of the waters of the Rio Grande for irrigation purposes, as well as removal of all causes of controversy with respect to its distribution.[51] The 1906 Convention provided for the delivery of 60,000 acre-feet of water per year to Mexico on completion of the Elephant Butte Dam.[52] Article II provided for delivery of this water in the same proportions as water delivered to U.S. users in El Paso. In the case of extraordinary drought, however, deliveries to Mexico would be reduced in the same proportion as deliveries to U.S. users. This method of allocation provides for risk sharing between the two countries during droughts. The remaining articles state the following:

- that the United States incurs all costs of storing, delivering, and measuring deliveries of water in the bed of the river at the head of the Mexican canal;
- that Mexico waives all claims of damages for previous delivery shortages; and
- that Mexico relinquishes any claim to waters of the Rio Grande between El Paso–Juarez and Fort Quitman, Texas.[53]

Pecos River Compact

The Pecos River (see Figure 3.2) is a major tributary of the Rio Grande, originating in the Santa Fe Mountains in New Mexico, flowing south and entering Texas near the 104th meridian, and then flowing into the backwaters of the Rio Grande at Lake Amistad.[54] The river suffers from large water withdrawals for irrigation, as well as increased groundwater pumping in New Mexico's Roswell area.[55] Additionally, the Pecos is naturally saline, and salt cedar infestations throughout its watershed have increased salinity even further by transpiring much of the available water. Large-scale irrigation projects on the Pecos River in Texas date back to the mid-1800s on the tributaries and the late 1800s for mainstem projects.[56] Because of these dams, irrigation projects, and groundwater pumping in New Mexico, water flows in the Pecos River are substantially reduced, with estimates of these reductions being as high as 99% of the flow.[57]

Efforts to negotiate a compact between Texas and New Mexico began in 1923 to facilitate Texas's plans to construct Red Bluff Reservoir, located downstream of the state line. The compact was signed by the states but subsequently vetoed by the governor of New Mexico.[58] New Mexico's interest in developing Alamogordo Reservoir led to a compromise in 1935, but the state again did not ratify the agreement, continuing to develop groundwater in the Roswell area. The issue of groundwater development in New Mexico, as well as problems with salinity, led to the Pecos River Joint Investigation under the auspices of the federal government. On conclusion of the investigation, and armed with data relating to water use and supply, salinity, and flooding, Texas and New Mexico once again began compact negotiations in 1942 and finally reached an agreement in 1948.[59]

Provisions of the Compact

The Pecos River Compact allocates waters of the Pecos River between Texas and New Mexico, based on a formula summarized as follows:

- New Mexico shall not deplete the flow of the Pecos River at the state line below a quantity equivalent to that available to Texas under 1947 conditions.
- Texas receives the flow of the Delaware River.
- Water salvaged in New Mexico is allocated 43% to Texas and 57% to New

Mexico.

- Unappropriated floodwaters are allocated 50% to Texas and 50% to New Mexico.[60]

Salvage water is additional water in the stream resulting from eradication of salt cedar in New Mexico. The “1947 conditions” noted in the compact are based on the results of investigations conducted in support of the negotiations, which led to the development of an *Inflow-Outflow Manual* outlining the quantity of water New Mexico should deliver under varying circumstances.[61]

Post-Compact Administration

Within a year after the compact was signed, issues arose over how to account for each state's water use and interpretations of compact provisions relating to the 1947 condition.[62] Deliveries to Texas pursuant to the compact were substantially less than should have occurred based on the *Inflow-Outflow Manual*.[63] Texas filed suit against New Mexico, requesting that deliveries be made in accordance with the terms and conditions of the compact, and the court appointed a river master to determine New Mexico's compact delivery obligations with this system still in place.[64] In addition, the court required New Mexico to pay Texas $14 million for previous compact under-deliveries of water.[65] Since the litigation, New Mexico has tried numerous times to revise the methods used to determine the quantity of water it is required to deliver to Texas. To date, Texas has not been in agreement with these revisions. New Mexico also has taken steps to retire existing water rights and augment river flows with groundwater to meet its delivery obligations.[66]

In addition to disputes over water deliveries, compliance with the Endangered Species Act (ESA) complicates administration of the compact. One year after settlement of the lawsuit over water allocations, the U.S. Fish and Wildlife Service (FWS) listed the Pecos bluntnose shiner as a threatened species under the ESA. Water flow regimes necessary to maintain this fish require a continuous flow at lower rates, leading to increased evaporative loss in a river where water quantity has been the predominant concern. Solutions to the problem include additional purchases of water rights and, according to some, renegotiation of the compact under the theory that water flows necessary to maintain the shiner serve a national interest. Under this theory, Texas would share the burden of the additional allocation with New Mexico.[67] Texas's position with respect to these issues is that compact deliveries must be protected.[68]

Rio Grande Compact

The jurisdiction of the Rio Grande Compact begins at the headwaters of the river in Colorado, extends through New Mexico, and ends at Fort Quitman, Texas (see Figure 3.2). Early water disputes in this region involved irrigators in New Mexico and below El Paso–Juarez in the United States and Mexico. The 1906 Convention and construction of Elephant Butte Dam partially resolved the dispute. The convention, however, did not address water allocations farther upstream in the Middle Rio Grande Valley, and even farther upstream in the San Luis Valley in Colorado. Resolution of the dispute between upper and lower water appropriators began in 1896, with the U.S. Department of the Interior enacting an embargo on the use of public lands for water diversions from the Rio Grande or its tributaries in Colorado and New Mexico.[69] The purpose of the embargo was to protect the water yield of Elephant Butte Reservoir and ensure that water obligations to Mexico under the 1906 Convention were fulfilled.

Success in interstate compact negotiations over Colorado River water encouraged New Mexico and Colorado to begin discussions over Rio Grande water allocations. At the time, these states were opposed to the participation of Texas in the talks, mainly because it might give water users below Elephant Butte Reservoir more power in determining the negotiation outcome. Many upper basin users also felt that the inclusion of Texas would lead to calls for allocating water as far downstream as Brownsville, thereby also opening the door for participation by Mexico.[70] Texas eventually did join the negotiations, however.

By 1922, there were calls for lifting the Rio Grande embargo, with a study by the BOR concluding that additional upstream water storage would not substantially reduce the yield of Elephant Butte Reservoir. In 1925, the Interior Department approved a reservoir in Colorado. Texas and New Mexico were outraged, with many calling for Supreme Court adjudication of rights to the river's water. In addition, the Secretary of the Interior lifted the embargo, stating that it was an improper exercise of federal authority, in that water management within a state should be the responsibility of that state. New Mexico withdrew from compact negotiations and began preparing a lawsuit. The time and money required to mount such a suit, however, encouraged the state to return to the negotiation table. Negotiations began, and a temporary compact was signed in 1929 (the 1929 Compact), allowing talks to continue until 1935.[71]

Negotiations progressed slowly, and as a result of drought conditions in the 1930s, Texas filed suit against New Mexico in 1935 to force the water allocation issue.[72]

One effect of this suit was federal reinstatement of the Rio Grande embargo because of jurisdictional conflicts among the federal agencies charged with administration of the river.[73] The states agreed to extend the 1929 Compact until 1937 to allow for a federal study of the Upper Rio Grande. The results of this joint investigation provided the data needed to determine water allocations among the states. The Rio Grande Compact Commission assigned the task of ironing out compact details to the Engineer Advisors, with the states subsequently reaching agreement and signing the Rio Grande Compact of 1938.[74]

Provisions of the Compact

The Rio Grande Compact allocates water flows from the headwaters in Colorado through New Mexico to Elephant Butte Reservoir to the three states, based on a formula that can be summarized as follows:

- Deliveries of water from Colorado to New Mexico are measured at the state line and are based on water flows in the Rio Grande and one of its tributaries, according to a defined schedule. Any additional water pumped into the Rio Grande for purposes of meeting delivery requirements can only be credited to Colorado, if the water meets specific water quality parameters.
- New Mexico's deliveries of Rio Grande water to Texas are measured at Elephant Butte and based on water flows at index gages.
- Determinations of water delivery shortages and credits are based on a formula specified in the compact, which contains provisions to determine methods of repayment of water shortages. The compact also contains provisions limiting water storage in reservoirs constructed after 1929 in Colorado and New Mexico,

based on credit amounts.[75]

Post-Compact Administration

Compact operations began in 1940. New Mexico accrued water shortages of 331,800 acre-feet by 1951, and Texas filed suit. The Supreme Court appointed a special master, but the court dismissed the case in 1957 because the United States was not a party.[76] Meanwhile, the region was in the midst of an extreme drought, with the water debt of both Colorado and New Mexico mounting. New Mexico began efforts to increase the water flows delivered to Texas. Colorado continued to use more water than authorized, however, and New Mexico and Texas sued that state in 1966 for violation of the compact. The litigation was suspended when Colorado agreed to begin making water deliveries to meet its obligations. It also agreed to curtail water diversions within its boundaries to ensure that it met its compact obligations. Elephant Butte Reservoir spilled in 1985, subsequently relieving Colorado of its water debt. Colorado remains in compliance to the present time.[77]

As in the Pecos River, endangered species issues are assuming a growing role in compact administration. The FWS listed the Rio Grande silvery minnow as an endangered species in 1994.[78] The agency subsequently designated a reach of the Rio Grande in New Mexico as critical habitat for the fish in 1999. Maintenance of habitat for the silvery minnow has changed the manner in which New Mexico and the BOR manage the dams in the middle reaches of the Rio Grande in New Mexico. Keeping the water flow constant has eliminated several management options previously used to reduce water evaporation and other losses associated with water releases from upstream reservoirs for delivery downstream. Texas is working with New Mexico on this issue, having agreed to allow the other state to relinquish accrued credit water according to a schedule such that New Mexico could store water upstream of Elephant Butte to meet flow requirements for the silvery minnow.[79]

The 1944 Treaty Between the United States and Mexico

Inadequate water supplies have been an issue in the Lower Rio Grande Valley for more than 100 years. Settlement in the Valley began after the Civil War, primarily because of the attraction of the fertile soils in the Rio Grande delta. The first efforts to manage water supply were primarily allocative, focusing on quantification of the water available to both the United States and Mexico.

As settlement of the area intensified, periodic water scarcity and the highly variable flows of the then unregulated river made it clear that the full potential of this region would not be realized without storage for water supply and flood control.[80] Efforts to obtain federal assistance began in 1902, with a petition presented to the U.S. Secretary of State requesting that an agreement be reached with Mexico on the distribution of the waters of the Rio Grande between its confluence with the Devil's River and the Gulf of Mexico. At that time, however, the State Department was involved with issues surrounding competing claims to waters of the Rio Grande upstream at El Paso and did not address water allocation issues in the lower basin.

In 1909, the Rio Grande Commission was established to study water allocation in the Lower Rio Grande. The two U.S. commissioners were also considering water apportionment issues and claims for allocation of Colorado River water, and thus consideration of the allocation of Rio Grande waters was not a priority for them. Further, the Mexican position on this issue was that the United States should not get one drop of water from the Rio Grande until all Mexican uses were satisfied. Texas farmers in the Lower Valley also were reluctant to begin negotiation of any treaty for allocation of Rio Grande water until Texas had developed as much irrigation use as possible, under the premise that any treaty would protect existing uses.[81]

Funds were appropriated to the International Boundary Commission (IBC) between 1910 and 1920 for studies of the Rio Grande, although no studies subsequently were generated. Irrigation development on Mexican tributary streams, however, contributed to increased attention to Rio Grande issues.[82] Congress established the Commission on Equitable Use of Water in the Rio Grande below Fort Quitman in December 1924.[83] Mexico refused to cooperate unless discussions on the Colorado River also were included. The United States agreed in 1927 to consider Colorado River issues, participating in the creation of a joint commission to address Rio Grande, Colorado, and Tijuana River issues. The commissioners agreed to gather data on stream flows, water diversions, acreage under irrigation, possible future water uses, and flood control for the three rivers. The results of this study for the Lower Rio Grande established that the population in the region was 200,000, that 350,000 acres were under irrigation, that Mexican tributaries contributed 70% of the flow below Fort Quitman, and that Texas was using 70% of the flow of the river for irrigation.[84]

The Mexican and American representatives held competing positions on allocation of water flows in the Rio Grande. The parties could not reach agreement on the substantive issues at that time, and both sides agreed to further study. Irrigation by Texas farmers in the Lower Rio Grande Valley was indeed threatened at that time as it was increasing. On the Texas side of the border, 370,000 acres were under irrigation, while

4,300 acres were irrigated on the Mexican side. Further, Mexico had begun constructing dams on the Rio Conchos, Rio Salado and Rio San Juan, and spent large sums on irrigation works.[85]

The negotiation process moved slowly, accomplishing little until 1932, when the American section of the International Water Commission merged with the USIBC. The Mexican government was instituting agrarian reforms during this period, including redistribution of land and socialization of agriculture.[86] Mexico also constructed a gravity canal, the Retamal, capable of diverting the entire low flow of the Rio Grande. The United States initiated studies in 1936 of water use in the Rio Grande, to form a basis for planning water storage facilities. The study expanded in 1938 to include flood control and water conservation. By 1940, 583,000 acres were under irrigation in Texas, with water supply becoming critical to continued development in the region. The 1938 study advocated construction of an American canal and two off-channel water storage facilities to ensure a firm supply to U.S. irrigators in the Lower Valley.[87]

From the 1920s until the early 1940s, Colorado River issues overshadowed negotiations on the Rio Grande, effectively preventing any progress toward an equitable distribution of the latter's waters. As politicians wrangled over Colorado River issues, however, a crisis situation developed on the Rio Grande. Mexico proposed development of El Azucar Dam in 1937, with the goal of forcing resolution of water allocation issues for the Colorado River. Further, a flood occurred in the region, followed by a drought so severe there was inadequate water supply for domestic use. Water for municipal use, for example, was shipped into Brownsville and Matamoros.[88] Saline irrigation return flows contributed to water quality problems in the river, and some thought that construction of reservoirs would alleviate the problem by diluting the saline waters.[89]

The Texas Board of Water Engineers presented a resolution to the U.S. State Department in 1938, endorsed by 152 irrigation districts, service clubs, chambers of commerce, and municipal users, urging action on Rio Grande issues and construction of water storage facilities.[90] In response to construction of Mexico's Retamal project, the United States proposed construction of an American canal upstream of the Mexican diversion facility. Threats from both sides of the border finally forced resolution of water allocation issues involving the Colorado River and Rio Grande, and the United States and Mexico signed a treaty in 1944 dividing the waters of the two rivers between them. At the time of the treaty, no precedent existed in international law regarding the apportionment of a boundary river with irrigation use on both sides.[91]

Provisions of the Treaty

The area governed by treaty allocations encompasses the mainstem of the Rio Grande and its tributaries, from Fort Quitman to the Gulf of Mexico (see Figure 3.2).[92] The 1944 Treaty established an allocation priority for joint water use, beginning with domestic and municipal use, and ending with other beneficial uses as determined by the International Boundary and Water Commission (IBWC). The treaty did not explicitly mention environmental flows, although fishing and hunting were included, but with a low use priority.[93] The treaty assigned water flows between the United States and Mexico as follows:

- Mexico would receive all water from the San Juan and Alamo Rivers, including return flows; 50% of the flow below the lowest major storage reservoir (Falcon

Reservoir), as long as that water was not already allocated; 66% of the flow from six measured Mexican tributaries, including the Rio Conchos, subject to certain conditions; and 50% of all other water flows, including ungaged tributary inflows occurring between Fort Quitman and the Amistad Reservoir.

- The United States would receive all waters of the Pecos and Devils Rivers, Goodenough Spring, and Alamito, Terlingua, San Felipe, and Pinto Creeks; 50% of the water flow below the Falcon Reservoir that was not already allocated; 33% of the flow of the six measured Mexican tributaries, provided such flow was not less than an annual minimum flow of 350,000 acre-feet in any five-year accounting period; and 50% of tributary inflows occurring between Fort Quitman and the Amistad Reservoir.[94]

The terms of the treaty included construction of shared storage reservoirs.[95] It also added oversight of accounting for water resources to the IBC, creating the International Boundary and Water Commission (IBWC). The IBWC includes a Mexican section, Comision Internacional de Limites y Aguas (CILA), and a U.S. section, USIBWC.[96] The IBWC is currently responsible for measuring Rio Grande waters, allocating these waters between the United States and Mexico, as well as flood control, water quality, and sanitation issues.

The treaty assigned the IBWC authority to handle disputes arising from interpretation and application of the treaty, subject to the approval of the governments of the signatory nations. In the event of a lack of agreement by the commissioners of the two sections, treaty provisions called for both commissioners to inform their respective governments, and the two governments then to pursue resolution of the dispute through diplomatic channels and other means pursuant to treaties between them.[97] The 1944 Treaty stipulated that the commissioners record any decisions in the form of minutes, which are essentially clarifications or interpretations of treaty provisions. Further, both governments would have what is essentially a veto power over any minutes agreed to by the commissioners. In the event that one of the governments disagreed, the two nations would negotiate an agreement, with the agreement then communicated back to the commission.[98] The treaty also provided that in the event of extraordinary drought that prevents Mexico from meeting delivery requirements of tributary waters, deficiencies could be made up in the next five-year accounting cycle.[99]

The IBWC coordinates with the other federal entities to participate in sanitation projects and assists with annual scheduling of deliveries of 60,000 acre-feet of Rio Grande–Rio Bravo water to Mexico, in accordance with the Convention of 1906.[100] In addition to allocating Rio Grande waters, the treaty included provisions for allocating the waters of the Colorado and Tijuana Rivers.[101] Allocations of Colorado River water are germane to any discussion of Rio Grande issues, because any evaluation of fairness of the Rio Grande water allocations under the 1944 Treaty must consider the parallel issue of Colorado River water allocations.

The fact that the treaty linked allocation of the waters of both rivers helps ensure that Mexico will remain at the negotiating table to address any issues. At the time the treaty was signed, the two nations were involved in ongoing disputes over water allocation for both river systems. Users of Colorado River water, particularly California, were reluctant to acknowledge any Mexican rights to the river's water out of fear that such recognition would substantially reduce their own water allocations. Users of the Rio

Grande in Texas were concerned that substantial investments and historical irrigation uses in the Lower Rio Grande Valley would be irreparably harmed if the river waters were divided fifty-fifty.[102]

As previously mentioned, Mexican tributaries, particularly the Rio Conchos, provide most of the water flow to downstream users in the Lower Rio Grande Valley. The agreement on the division of border waters essentially stipulated a quantifiable amount of Colorado River water to be delivered to Mexico, while protecting water users in the Lower Rio Grande Valley by apportioning a quantifiable amount of tributary inflow from the Rio Conchos and other Mexican tributaries to the United States for use in Texas. The minimum quantity of an average of 350,000 acre-feet per year of tributary water over a five-year period prevented Mexico from fully developing tributary waters in such a way as to keep sufficient water from reaching downstream users in the United States.

Post-Treaty Administration: Texas's Share

After the 1944 Treaty was signed, conflicts among water users in Texas became violent, and the Texas Supreme Court intervened.[103] The court held that lands adjacent to a stream carried implied rights of irrigation. In spite of the court's ruling, issues relating to Rio Grande riparian water rights remained unresolved.[104]

As a result of Rio Grande water shortages during the drought of the 1950s, various lawsuits were filed, with the Texas Supreme Court taking control of the administration of the state’s use of the waters of the Rio Grande.[105] By the 1950s, the population of the Lower Rio Grande Valley on the U.S. side had increased to 450,000, and more than 700,000 acres were under irrigation.[106] Falcon Dam, jointly constructed by the United States and Mexico, was completed in 1954, enhancing the ability of Texas users to obtain water supplies.[107] Shortly thereafter, an extreme rainfall event filled the reservoir to capacity. The U.S. share of Falcon Lake water storage at that time was about 1.3 million acre-feet.

By January 1956, less than two years after it filled, the U.S. share declined to less than 700,000 acre-feet. Water storage continued to decline until, by June, only 50,000 acre-feet remained.[108] Because of declines in the U.S. share of Lake Falcon water storage, the Texas Board of Water Engineers determined that water remaining in storage would be limited to releases for domestic and municipal uses. Various legal suits and countersuits were filed. Of special concern was the idea that if more water were released than could be used, the excess water would flow into the Gulf of Mexico, thereby being "wasted."[109] The lawsuits included a request for the court to determine the quantities of water to be allocated to the competing users, as the available water from the U.S share of the Rio Grande was sufficient to cover only 50% of water uses. A final determination of water rights was essential for the future economic well-being of the Lower Rio Grande Valley, with the court apportioning the waters of the Lower Rio Grande among the various users.[110]

A Watermaster program was created in the Lower Rio Grande Valley, pursuant to the rulings in the alley lawsuits described above. This was not the first time water use in the Valley was allocated by a Watermaster. In addition to the special master that allocated the U.S. share among water diverters during the several years of court proceedings, the users also attempted to create an informal Watermaster program themselves. Because of problems caused by diversion of all water flows by upstream users, many Valley irrigation districts signed an agreement in 1953, known as the Falcon Compact. Although it created an allocation mechanism, it was doomed to failure because compliance was voluntary.[111] Today the Rio Grande Watermaster, appointed by the Executive Director of the Texas Commission on Environmental Quality (TCEQ), is responsible for day-to-day operations, accounting, and compliance.[112] As water enters the system, the IBWC allocates the shares, based on a formula that includes apportioning to Mexico the quantity of water granted by the 1944 Treaty. The Watermaster allocates Texas's use of the U.S. share, based on the quantity of water stored in the Falcon-Amistad reservoir system and inflows into the reservoirs. Texas's water is then divided among certain reserves. Each water right owner is allotted an "account" against the system storage.

At the time of the original lawsuit, the first 125,000 acre-feet of inflows were dedicated to the domestic, municipal, and industrial (DMI) reserve. This volume has since increased to the first 225,000 acre-feet of inflows. The DMI reserve is determined by rule.[113] After allocation of water flow to the DMI reserve, any water remaining in the irrigation accounts is reserved for their future use. The Watermaster then creates an operating reserve, based on remaining water storage and including deductions for evaporation, channel losses, and any other water losses. Any water remaining after the above allocations is placed in the irrigation accounts. If there are additional water inflows during the accounting period, this water also is allocated to the irrigation accounts. The Watermaster rules provide for a modified version of "use it or lose it." If an irrigator does not use the allocated water in his or her account within a two-year period, the account is reduced to zero and is not restored until the water right holder notifies the Watermaster that he or she intends to begin using the water.[114]

Although the Watermaster rules do not explicitly mention water marketing, the rules pertaining to water contracts allow some flexibility in water administration in the Middle and Lower Rio Grande. In other parts of the state, if a water right owner wants to change the place of use, diversion point, or diversion rate of his or her water, a permit amendment is required.[115] In the Middle and Lower Rio Grande, the water right owner need only file a copy of the contract with the TCEQ.[116] The only requirements are that the contract must be for purposes of use already authorized by the water right, and if not, a permit amendment is needed, although such amendments are treated as administrative in nature in the Rio Grande and are processed rapidly by the TCEQ. The absence of the amendment process for the Lower Rio Grande is justified by the region's unique hydrology and water rights framework.

Even after years of litigation and negotiation, resulting in the creation of a system for managing water rights in the Lower Rio Grande, water shortages still occur. The 2006 Regional Water Plan for the Rio Grande indicates serious challenges, with predicted water shortages in all areas by 2050. The population projections in the plan suggest that the population in the Lower Rio Grande will triple over the next 50 years. The plan also identifies reductions in firm yield of the Amistad-Falcon system over the planning horizon due to sedimentation, estimating a decrease in firm yield of about 10%. Because of pro-marketing rules used to allocate shares of the U.S. portion of reservoir storage, irrigation users will absorb water shortages caused by this decrease.[117]

Another major concern is reduced tributary inflows from Mexican tributaries. Uncertainty over volumes of water available from Mexico pursuant to the treaty and a repayment schedule for deficits directly affect water planning in the Lower Rio Grande. Because of the presumed resolution of allocation issues embodied in the 1944 Treaty and the accounting procedures resulting from the Lower Rio Grande Valley lawsuits, water supply calculations should be straightforward. This is due to the strict state and international accounting schemes incorporated into these instruments. However, treaty compliance issues and absence of a definition of "extraordinary drought" hamper the ability of planners to project the quantity of water available under various hydrologic conditions, particularly drought, which is an important consideration for future planning.

Post-Treaty Administration: International Issues

Partially as a result of a severe drought beginning in the late 1990s, a dispute arose between the two nations over Mexico's delivery of tributary waters, as required by the 1944 Treaty. Mexico's position was that Article IV of the treaty allowed diminished water deliveries in times of extraordinary drought. The IBWC and the two governments resolved disputes as they arose during the extended drought and continued to negotiate when changes in circumstances warranted. The process, however, led to acrimony among local stakeholders on both sides of the border. Local politicians and the media in Mexico called for renegotiation of the treaty during this period.[118]

This dispute began as a consequence of the onset of a basinwide drought in the early 1990s. Not only did the drought result in reduced rainfall and streamflows (hydrologic drought), but also inefficient irrigation practices and actions of water managers on both sides of the border (human-caused drought) may have contributed to the severity and duration of drought impacts. This combination led to the failure of Mexico to meet delivery requirements of tributary waters during the 1992–1997 accounting cycle. Specifically, the United States claimed that Mexico failed to meet delivery requirements of an annual minimum flow of 350,000 acre-feet of water from the Rio Conchos and the other Mexican tributaries. Mexico claims its water deliveries were reduced in accordance with treaty provisions relating to extreme drought.

There is little debate over whether drought conditions existed. Both the United States and Mexico issued drought disaster declarations numerous times throughout the 1990s and early 2000s.[119] Aside from the lack of a precise definition of extraordinary drought in the 1944 Treaty, which in itself has contributed to the present controversy, the treaty also does not adequately specify a repayment scenario in the event that treaty obligations are not met. The treaty states that any deficiencies in deliveries from one five-year accounting cycle should be made up in the next five-year cycle.[120] It does not, however, address how deficits should be met in the event of a drought lasting longer than five years. Specifically, what is to be done when, in the five-year period following a drought, Mexico is unable to deliver the current five-year amount in addition to the quantity of water necessary to satisfy the previous shortage?

Mexico's position was that water deliveries from all the measured tributaries and reallocation of water in storage in Amistad and Falcon Reservoirs were sufficient to meet its deficits incurred during the 1992–1997 accounting cycle, and that any deficiencies incurred during the 1997–2002 cycle were repayable during the 2002–2007 cycle. The U.S. position was that the treaty obligates Mexico to satisfy underdeliveries from the

1992–1997 cycle, as well as any deliveries required during the 1997–2002 cycle, during the 1997–2002 cycle.[121]

When the 1997 accounting concluded, Mexico proposed a method to repay deficits in that accounting cycle by releasing tributary waters when the flows exceeded a specified level. The United States rejected the offer and requested information on conditions in the tributaries. The two sides then began a series of technical meetings.[122] After two years of negotiation and an interim agreement transferring ownership of some water storage in treaty reservoirs from Mexico to the United States, the two nations signed Minute 307 on March 16, 2001. This minute called for water deliveries from Mexico based on rainfall projections, with assignment of specified quantities of water from Mexican tributaries.

Minute 307 also mentioned water releases from Carranza Dam in Mexico, as well as opening the possibility of releases from other Mexican reservoirs.[123] Local interests in Mexico strenuously objected to water releases from Carranza Dam, asserting that such releases would affect the local economy. The national government ignored the local interests, however, and Mexico released Carranza water to partially fulfill its obligations pursuant to Minute 307.[124] In addition to specifying methods for Mexican repayment of water deficits, Minute 307, recognizing the "spirit of friendship" between the two countries and their joint desire to prevent a recurrence of the events leading up to the agreement, committed the two nations to "identify measures of cooperation on drought management and sustainable management" of the Rio Grande basin.[125]

As a result of Mexico's increasing inability to comply with water delivery terms under the treaty, and as part of the cooperation called for in Minute 307, representatives of the two nations, in conjunction with their commissions, issued a joint memorandum agreeing to tour Mexican dams followed by another meeting in Austin. They also agreed to form a binational work group, for the purpose of initiating a summit on sustainable management in the basin, and to exchange data and ensure public access to IBWC data.[126]

Minute 308, signed June 28, 2002, contained provisions for assignment of Mexican water storage in Amistad and Falcon Reservoirs to the United States.[127] This agreement also included comments from the Mexican government that it intended to finance modernization of irrigation operations in the Rio Conchos watershed, with a goal of passing the conserved water downstream to the United States in order to reduce Mexico's treaty deficits. Minute 308 reiterated the two governments' support for the sustainability initiatives in Minute 307.[128] Minute 308 mentioned the formation of an International Advisory Council, composed of governmental and nongovernmental organizations, to act as a forum for exchange of information and provision of advice to the two countries,[129] but the formation of such a council was not included in the minute's recommendations. Minute 308 did include recommendations on agreement between the two governments on collection and exchange of drought-planning information, as well as having a binational summit of experts to address sustainable management.[130] Another agreement, Minute 309, was signed on July 3, 2003, and detailed proposed savings from water conservation initiatives.

Although the diplomatic negotiation process embodied in the IBWC minutes signed during the drought crisis did represent progress toward long-term resolution of basin issues, Texas water users excluded from the process were unhappy with the outcome. The U.S. section of the IBWC, although a federal agency, previously had been very responsive to border states' congressional delegations, whereas the IBWC's foreign policy component more closely resembled the domestic policy of the affected states.[131] This situation may be changing, however. During the water dispute, Texas farmers appealed to members of their congressional delegation, the Texas governor, the State Department, and George W. Bush, then President of the United States, all to no avail.[132] As a result of the lack of response from elected officials, 17 Texas irrigation districts along with 16 individuals and 13 other entities (which together are hereinafter referred to as the Districts), filed a claim under Chapter 11 of the North American Free Trade Agreement (NAFTA), alleging that Mexico's failure to deliver treaty water was a 'taking,' and asked for financial compensation of 500 million dollars.[133] During the NAFTA proceedings, the TCEQ submitted a letter stating that claims of individual water users were not within the scope of negotiations over the water debt between the United States and Mexico. Mexico's position was that the claim fell outside the scope of NAFTA. The United States submission in the case also stated the claims were outside NAFTA's jurisdiction. Federal intervention likely resulted from fear that a favorable ruling in the water case could affect a ruling in a similar type of case against the United States.[134] Other Texas politicians filed a letter in support of the claim.[135]

One issue brought before the arbitration panel was whether or not the water was a "good in commerce." The claimants made the argument that the Rio Grande was no longer a free-flowing river, and that the rivers' water was bought, sold, and traded; thus, the water was a good in commerce. Mexico's position was that the tributary waters were subject to Mexican law, were not the property of the United States and, therefore, were not in commerce.[136] The Arbitration Tribunal found that NAFTA Chapter 11 did not apply in this case, meaning the tribunal had no jurisdiction. NAFTA rules allow the judicial appeal of an arbitration ruling, and the Districts appealed the ruling to a court in Canada, which upheld the arbitration panel's ruling.[137]

As outlined in the preceding section, the current dispute resolution process consists of negotiation by the U.S. and Mexican sections of the IBWC in order to reach a decision. The decision is then incorporated into the treaty as a minute. Any substantial changes to the treaty would require approval by the legislative bodies of the two countries. Previous discussion of the negotiations over allocations suggests that the minute system works fairly well and is sufficient to resolve conflicts as they occur. During times when municipal water use in Mexico was threatened, for example, the United States expressed concern for human water uses of the Mexican people, as evidenced in Minutes 240, 293, and 308. Minute 240, issued in response to drought affecting the municipal water supply of Tijuana, temporarily altered established water allocation mechanisms embodied in the treaty. Minute 293 contained provisions ensuring that municipal water uses were fulfilled in the Rio Grande basin. Minute 308 recognized Mexico's minimum water uses for human populations.[138]

Although the outcomes of the dispute resolution processes incorporated in the 1944 Treaty do indicate a history of resolving conflict and maintaining relationships between the two countries at an international level, relationships between state and local stakeholders suffer as a result of continuing disputes over interpretation of treaty provisions. This is due partly to shortcomings in the current dispute resolution process. One individual commenting on western water disputes recommended that basin processes be evaluated on the basis of the efficiency and fairness of the process and the durability of the outcome.[139]

In regard to efficiency (a process element), the first measure of evaluating negotiated agreements, an efficient process would resolve the dispute in a timely, cost-effective manner. One element of an efficient process involves data sharing. With the current process, the two national sections conduct independent investigations and then share the data. However, no provisions call for sharing data with a broader spectrum of stakeholders. Although gages maintained by the IBWC provide easily accessible data about streamflows and reservoir water volumes, little data sharing takes place between the two sections regarding water use issues. The lack of publicly available data resulted in major disagreements among local stakeholders on both sides of the border over how much water was available to users and served to intensify conflicts over water deliveries at the local and state levels in both Texas and Mexico.

A specific example where data sharing could have played a role in attenuating transboundary conflicts is open sharing of water use information between the two countries. Irrigation water allotments in the Delicacias Irrigation District in the Rio Conchos watershed decreased 31% over the period 1993–2000, falling below those during the period prior to 1992.[140] In all years but 1997, no water releases were made for winter crops. Water storage in Mexican reservoirs in 2000 was about 26% for the Conchos basin and 11% for the Salado. Farmers in the Lower Rio Grande Valley in Texas began receiving reduced water deliveries from the international storage reservoirs for irrigation.[141] Both sides believed the other had an advantage, because neither had access to the other country's data on reservoir conditions and usage. Texas farmers believed that Mexican farmers were using water in the Rio Conchos that should have passed to Texas pursuant to the terms of the 1944 Treaty. Texas interests asserted, among other things, that Mexican reservoirs were full and irrigation in the Rio Conchos basin was increasing. Mexican farmers in Tamaulipas, downstream on the Rio Grande, believed that water transferred to the United States came at the expense of their allotments for irrigation.

The disagreement over who was using whose water led to increasingly acrimonious statements from local politicians on both sides of the border. The governor of Texas threatened an end to diplomatic efforts, while the Mexican Congress passed a resolution stating that no water deliveries would be made because Mexican water uses came first.[142] Texas's commissioner of agriculture handed Mexican President Vicente Fox satellite imagery purportedly showing water in Mexican reservoirs that Mexico could pass downstream to Texas.[143] Lack of discussion between the two sides and the failure to share information from the outset of the dispute exacerbated the conflict. Further, no forum existed to allow for input from local citizens or environmental groups concerning factual information.

Minute 308 indicates the intent of the IBWC to foster data sharing between the two countries, but it retains the current system whereby the parties work separately and forward their data and reports to each other in a "timely manner."[144] Data sharing certainly is a step forward, but this minute does not include any objective criteria for joint decisionmaking. It merely states that Mexico will provide a progress report on drought planning to the commission, in order to support the commission as a forum under which proper authorities in each country can coordinate drought management.[145] Although

Minute 308 is evidence of the desire of the two nations to enhance data sharing, the structure of the agreement perpetuates the top-down decision making style that appears to have contributed to problems at the state and local levels during the water dispute.

The second measure of evaluating negotiated agreements involves assessment of the fairness of the dispute resolution process. One obvious attribute of a fair process would be a forum allowing all interests to be heard, including accountability to the public. Interests that should be at the table might include water users, nongovernmental organizations, and representatives of the public at large. In the case of the 1944 Treaty process, few avenues exist for water users to participate directly in negotiations, except perhaps for communicating their concerns to their section of the IBWC. Evidence of the futility of this method of inclusion is found in the rhetoric employed by state-level politicians, answerable to local interests, in a somewhat futile effort to influence negotiations over the Mexican water debt. Because the formal negotiation process has no mechanism to include stakeholder concerns, the communication of local stakeholder interests can degenerate into name-calling and threats. With Texas interests on water allocation issues subordinate to broader U.S. interests, as evidenced by the U.S. filing in the NAFTA case, and with water issues considered less important than other issues, such as illegal immigration, to the foreign policy of the United States, the reaction of Texans was understandable. The only forum in which to air concerns was the local media.

To add to issues regarding stakeholder representation, there are no established procedures for inclusion of the interests of environmental groups. Environmental groups from both nations convened their own summit to discuss sustainable basin management and drought planning. The groups issued a binational declaration calling for increased water use efficiency, drought planning, and inclusion of environmental flows as part of any plan for sustainable management of the basin.[146]

However, one sector's interests appear to be adequately represented in the current conflict resolution process. That sector is federal governments on both sides of the border, through the IBWC and the two countries' State Departments. The interests of the United States and Mexico, insofar as those interests are limited to maintain a cordial relationship, are well served by the current process. The various minutes issued during the conflict attest to continued friendship, and there is a definite tendency to state overarching interests, such as the fundamental human right to water for basic uses. Thus the process appears to be fair, at least at the international and national levels, in the sense that the national governments are able to agree, maintain cordial relationships, and set aside differences in the broader public interest.

The final measure of a negotiated agreement is durability. Negotiated agreements should set the stage for a comprehensive solution, be equitable to both current and future generations, and allow for continuing dialogue among the parties as circumstances change. All relevant parties should be included to ensure fairness of the process. This is necessary so that all issues are addressed during the negotiations, and it allows for sufficient buy-in from every stakeholder in order to facilitate implementation of any agreement. The USIBWC has instituted Citizens' Forums to aid in the exchange of information about its activities in all border regions, including both the Lower and Upper Rio Grande.[147] Although this is a step in the right direction and points to efforts by the USIBWC to make the process more transparent, the process itself is not formalized to the extent that stakeholder concerns are required to be considered in the operations of this institution. Note that a comprehensive solution does not mean that all problems are immediately solved in a single negotiation. Rather, it means that the door is open so that a comprehensive agreement can be reached over time through further negotiation. Thus a comprehensive agreement sets the stage for a continuing dialogue, and a durable agreement should contain provisions for intergenerational equity.

Minutes 307 and 308 do allow for both continuing dialogue and addressing intergenerational equity, in the guise of initiating discussion of sustainable water use in the Rio Grande basin. The minutes did not define either sustainable water use or sustainability in general, and they did not establish concrete processes to achieve these goals. The basinwide summit, agreed on in 2002, occurred in November 2005.[148] The conference was organized as a series of presentations followed by issue-oriented work groups on such topics as finance, environment and water quality, and legal and institutional issues. The work group recommendations were not available until August 2007. Although organization of the summit was a step in the right direction, lack of an overarching framework for incorporation of recommendations, timeliness of issues related to information availability, or a concrete public plan for moving forward tend to blunt the effectiveness of this mechanism.

An additional shortcoming of Minute 308 is the two governments' tepid endorsement of the suggestion to establish an International Advisory Council. By failing to include a mechanism to ensure that all stakeholders interests are accounted for in the negotiation process, any negotiated settlements generated to try to address issues resulting from the latest conflict, as well as conflicts over other issues that may occur in the future, likely would fail to meet the standard of comprehensiveness. This would tend to reduce the probability that any negotiated agreement would be durable in the long term.

Post-Treaty Administration: Water Quality Issues

The 1944 Treaty also grants the IBWC authority to address water quality issues.[149] The first real efforts of the IBWC to address water quality occurred in the late 1960s, when a salinity crisis occurred involving the Colorado River. Although the United States complied with treaty requirements related to quantity, the water was unusable because of elevated salinity attributed to U.S. agricultural return flows. The issue was resolved via negotiations, resulting in Minute 242, which established a salinity requirement for treaty water deliveries.

Minute 261, signed in 1979, began the process of addressing border sanitation issues. Issues related to water quality also can be contentious, as they frequently involve competing interest groups and differing regulatory regimes in both countries.[150] The United States signed an agreement in 1983 to address border environmental issues, known as the La Paz Agreement.[151] A direct result of this agreement was Border 2012, a program jointly managed by the U.S. Environmental Protection Agency (EPA) and Mexican Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT). Border 2012 uses a bottom-up approach to address environmental and public health issues in the U.S.-Mexico border region.[152] Furthering progress in the area of water pollution, through establishment of the Border Environmental Cooperation Commission (BECC) and the North American Development Bank (NADBank), NAFTA provides venues for project proposals and financing. Minute 279 provided for an international wastewater treatment plant at Nuevo Laredo. In Minute 289, the United States and Mexico began investigations related to the presence of toxic substances in the Rio Grande.

Conclusions

Water allocation frameworks designed for past conditions may not be adequate for twenty-first-century problems. Although Texas's post-compact relationships with its neighbors could be characterized as litigious, interstate compacts do provide a level of certainty with respect to water allocations. Indeed, the threat of litigation, including the costs associated with resorting to this alternative, often acts to keep states participating at the negotiating table. In addition to cost factors related to litigation, the court process also is time-consuming, contributing to policy lags, which may not be in the best interest of local Texas water users subject to the compacts.

Compacts in geographic areas more subject to the vagaries of climate, particularly drought, typically experience more issues related to enforcement of compact requirements. Relevant examples include the Rio Grande, Pecos, and Canadian basins. Although endangered species issues currently are being handled within the current structure of the compacts, the next severe drought could propel administration of these agreements back into the legal realm. Further, water marketing across interstate boundaries is a developing issue, as thirsty Texas cities attempt to procure water across state lines.

With respect to Texas's relationships with its international neighbor, some aspects are working relatively well, an example being the management of water quality problems. Reluctance to define extreme drought and to incorporate mechanisms for joint drought management inevitably will return Texas water users to the same state of affairs that existed for 10 years during the previous drought. Some progress has been made, such as binational initiatives addressing sustainable use of the Rio Grande. Lack of a comprehensive framework and process to address this issue, however, may hamper such efforts. Efforts between the United States and Mexico to undertake a Transboundary Diagnostic Analysis and implement a Strategic Action Plan for the Rio Grande basin, currently under way through the auspices of the Global Environment Facility and United Nations Environmental Program, may assist in this regard.

Two problem areas the region is most likely to have to deal with in the future are binational groundwater issues and environmental flows. Groundwater issues in the Rio Grande region, even for transboundary aquifers, currently are addressed by each state. The role of the USIBWC to date has been to gather information on these shared water resources. If negotiations of surface-water allocation are any indication, mechanisms for shared aquifer management face hurdles, in view of current Texas groundwater law and the extended time frames required to negotiate agreements. Incorporating environmental flows into the treaty framework also is likely to be many years in the future, although Texas's Instream Flow Programs may provide information useful in such an endeavor. Climate change may have unforeseen impacts in the Rio Grande basin, particularly because current water allocation and supply management regimes are governed by compacts and treaties that require delivery of specific volumes of water to downstream states. This raises the question of whether the existing legal framework is sufficiently flexible to address the possible effects of climate change. These effects may include variations in existing precipitation patterns; decreased snowmelt in Colorado; earlier snowmelt; increased winter rains, which could severely affect the seasonality of the river's flow regime; or increased temperatures, which may have a drastic impact on water supplies by increasing the volume of water lost to evaporation. In addition to exacerbating water scarcity, climate change also could cause increased flooding. This could be a major issue in low-lying areas in the Rio Grande Valley on both sides of the border.

International law, as reflected in the 1997 United Nations Convention on the Non-Navigational Uses of International Watercourses, is relatively undefined in the area of water reallocation resulting from climate change. Further, the 1944 Treaty and the river compacts are fairly inflexible with respect to water reallocation issues, containing no provisions that allow adaptation in the event of altered circumstances such as climate change, water to protect in-stream uses and aquatic species, or population growth. Moving forward on any of these issues is a major challenge for the future of the Rio Grande Basin.

ENDNOTES

[1] For a detailed discussion of general legal issues related to compacts, see Priscilla Hubenak and Tom Bohl, Multi-jurisdictional Water Rights, in *Essentials of Texas Water Resources*, ed. Mary K. Sahs, 235 (Austin, TX: State Bar of Texas Environmental and Natural Resources Law Section, 2009).

[2] Texas State Historical Association, Handbook of Texas Online, www.tshaonline.org/handbook/online/articles/CC/mgc1.html (accessed June 1, 2010).

[3] U.S. Bureau of Reclamation, http://www.usbr.gov/projects/Project.jsp?proj_Name=Tucumcari Project&pageType=ProjectPage (accessed June 4, 2010).

[4] P.L.81-898, Canadian River Reclamation Project, Texas, Senate Report No. 81-2110, July 20, 1950 (to accompany HR 2733).

[5] Paul Elliott, Texas's Interstate Compacts, *St. Mary's Law Journal* 17 (1986): 1261.

[6] Act of April 29, 1950, ch. 135, P.L. 81-491, 64 Stat 49.

[7] Act of May 17, 1952, ch. 306, P.L. 82-345, 66 Stat. 74.

[8] Texas Water Code Ann, § 43.006, art. II(d), (West 2008).

[9] Ibid., art. IV(a), (b).

[10] Ibid., art. VII.

[11] Ibid., art. V(a).

[12] Ibid., art. V(b).

[13] Elliott, Texas's Interstate Compacts, 1262.

[14] *Oklahoma v. New Mexico*, 501 U.S. 221, 111 S. Ct. 2281, 226–27.

[15] Ibid.

[16] Ibid., 228.

[17] *Oklahoma v. New Mexico*, 510 U.S. 126, 114 S. Ct. 628, 629.

[18] Oklahoma Water Resources Board, , Resolution asks support in Compact dispute, Board convinced all other remedies are exhausted in securing Oklahoma's share of Palo Duro water, Oklahoma Water News, May-June 2000, http://www.owrb.ok.gov/news/news2/pdf_news2/WaterNews/WaterNews2000-3.pdf (accessed June 4, 2010).

[19] Hubenak and Bohl, Multi-jurisdictional Water Rights.

[20] Handbook of Texas Online, s.v. "Red River," available at http://www.tshaonline.org/handbook/online/articles/RR/rnr1.html (accessed June 4, 2010).

[21] Elliott, Texas's Interstate Compacts, at 1273; Pub. L. 96-584, 94 STAT. 3305, December 22, 1980.

[22] Texas, Ann § 46.013, art. XIII, § 13.03, (West 2008).

[23] Ibid., art. XI.

[24] Ibid., art. II, § 2.11.

[25] Red River Compact Commission, Agency Strategic Plan for the Fiscal Years 2005–2009 Period, 2005. http://www.tceq.state.tx.us/assets/public/permitting/watersupply/water_rights/splan.red.pdf (accessed June 4, 2010).

[26] Texas Water Code Ann, § 46.013, art. IV, §§ 4.01–4.04, (West 2008).

[27] Ibid., art. V, §§ 5.01–5.05.

[28] Ibid., art. VI, §§ 6.01–6.03.

---

[29] Red River Compact Commission, *Resolution to Adopt Rules and Regulations to Compute and Enforce Compact Compliance Reach I, Subbasin 1-Sweetwater Creek and North Fork Red River*, adopted April 22, 2008 at Marshall, TX (on file with author).

[30] Jim Williamson, Texas Goes Shopping for Water, *Texarkana Gazette*. January 23, 2007.

[31] *Tarrant Regional Water District v. Rudolf Herrmann et al*., WL 3226812, W.D. Okla., 2007; *Tarrant Regional Water District v. Sevenoaks*, F. 3d. WL 4694903, C.A. 10 (Okla.), October 27, 2008.

[32] Max Baker, Irving Criticized as It Plots Its Own Course to Get Water from Oklahoma, *Fort Worth Star-Telegram*, August 10, 2008.

[33] Rudolph Bush, Lawsuit Ruling Edges Tarrant, Dallas Districts Closer to Oklahoma Water Supply, *Dallas Morning News*, October 28, 2008.

[34] Elliott, Texas's Interstate Compacts, 1263.

[35] Texas Water Code Ann, § 44.010 at art. III, (West 2008).

[36] Ibid., art. V(a).

[37] Ibid., art. V(i).

[38] Ibid., art. V(e).

[39] Ibid., art. V(b).

[40] Sabine River Authority of Texas, Toledo Bend Project, http://www.sratx.org/projects/tbp.asp (accessed June 4, 2010).

[41] Vickie Welborn, Texas Water Meetings Could Impact Toledo Bend, *Shreveport Times*, May 5, 2008.

[42] David J. Eaton and John M Andersen, *The State of the Rio Grande/RioBravo: A Study of Water Resource Issues along the Texas/Mexico Border* Tucson, AZ: University of Arizona Press, 1987).

[43] Norris Hundley, Jr., *Dividing the Waters: A Century of Controversy between the United States and Mexico* (Berkeley, CA: University of California Press, 1966), 19.

[44] Jurgen Schmandt, *Water and Development: The Rio Grande/Rio Bravo* (Austin, TX: Lyndon B. Johnson School of Public Affairs, 1993).

[45] Texas Water Development Board (TWDB), Region M Water Plan, 2006, http://www.twdb.state.tx.us/RWPG/main-docs/2006RWPindex.asp (accessed June 4, 2010).

[46] Jurgen Schmandt, Ismael Aguilar-Barajas, Neal Armstrong, Liliana Chapas-Aleman, Salvador Contreras-Balderas, Robert Edwards, Jared Hazleton, Jose de Jesus Navar, Mitchell Mathis, Enrique Vogel-Martinez, and George Ward, *Final Report: Water and Sustainable Development in the Binational Lower Rio Grande/Bravo Basin*, EPA Grant No. R824799 (The Woodlands, TX: Houston Advanced Research Center, Center for Global Studies, 2000).

[47] William Paddock, The Rio Grande Convention of 1906: A Brief History of an International and Interstate Apportionment of the Rio Grande, *Denver University Law Review* 77 (1999): 287, 295–296, 297, 300.

[48] Act of June 17, 1902, 57th cong. (1st sess.) ch. 1093, 32 Stat. 388, codified at 43 U.S.C. § 371.

[49] U.S. Bureau of Reclamation, Rio Grande Project: History, http://www.usbr.gov/projects/Project.jsp?proj_Name=Rio Grande Project&pageType=ProjectHistoryPage (accessed June 4, 2010).

[50] Paddock, Rio Grande Convention of 1906, 305.

[51] Convention for the Equitable Distribution of the Waters of the Rio Grande for Irrigation Purposes, U.S.-Mexico, May 21, 1906, 34 Stat. 2953, available at http://www.ibwc.state.gov/Files/1906Conv.pdf (accessed June 4, 2010).

[52] Ibid., art. I.

[53] Ibid., arts. III, IV.

[54] Handbook of Texas Online, s.v. "Pecos River," available at http://www.tshaonline.org/handbook/online/articles/PP/rnp2.html (accessed June 4, 2010).

[55] G. Emlen Hall, *High and Dry: The Texas–New Mexico Struggle for the Pecos River* (Albuquerque, NM: University of New Mexico Press, 2002).

[56] Ric Jensen, Will Hatler, Mike Mecke, and Charlie Hart, The Influences of Human Activities on the Waters of the Pecos Basin of Texas: A Brief Overview, 2005, available at http://twri.tamu.edu/reports/2006/sr2006-03.pdf (accessed June 4, 2010).

[57] Elliott, Texas's Interstate Compacts, at 1252.

[58] Ibid., 1253.

[59] Robert Lingle and Dee Linford, *The Pecos River Commission of New Mexico and Texas, A Report of a Decade of Progress 1950–1960* (Santa Fe, NM: Rydal Press, 1961), 125, 134, 136–38.

[60] Texas Water Code Ann, § 42.010, (West 2008).

[61] Hubenak and Bohl, Multi-jurisdictional Water Rights.

[62] Elliott, Texas's Interstate Compacts, at 1255.

[63] *Texas v. New Mexico,* 462 U.S. 554, 103 S. Ct. 2258 at 2563 (1983).

[64] Ibid., 564; Hubenak and Bohl, Multi-jurisdictional Water Rights.

[65] *Texas v. New Mexico*, 494 U.S. 111, 110 S. Ct. 1293.

[66] Pecos River Compact Commission, Texas, *Agency Strategic Plan for the 2005–2009 Period*, 2005, available at http://www.tceq.state.tx.us/assets/public/permitting/watersupply/water_rights/splan.pecos.pdf (accessed June 4, 2010).

[67] Douglas L. Grant, Interstate Water Allocation Compacts: When the Virtue of Permanence Becomes the Vice of Inflexibility, *University of Colorado Law Review* 74 (2003): 111–12.

[68] Pecos River Compact Commission, *Strategic Plan for 2005–2009*.

[69] Douglas Littlefield, The Rio Grande Compact of 1929: A Truce in an Interstate River War. *Pacific Historical Review* 60, no. 4 (1991): 497–515.

[70] Ibid., 503.

[71] Ibid., 504, 508, 513.

[72] Ibid., 514.

[73] William Paddock, The Rio Grande Compact of 1938, *University of Denver Water Law Review* 5, no. 1 (2001): 17.

[74] For a detailed description of the negotiations, see ibid., 18–27.

[75] Texas Water Code Ann, § 41.009, (West 2008).

[76] Elliott, Texas's Interstate Compacts, 1250.

[77] Paddock, Rio Grande Compact of 1938, 42–44.

[78] 59 *Federal Register* 36988. Final rule listing the Rio Grande silvery minnow as an endangered species.

---

[79] Grant, Interstate Water Allocation Compacts, 105; Rio Grande Compact Commission, Strategic Plan and Compact with Texans, 2004, www.tceq.state.tx.us/assets/public/permitting/watersupply/water_rights/splan.rio.pdf (accessed June 4, 2010).

[80] Hundley, *Dividing the Waters*, 30–31.

[81] Ibid., 39–40.

[82] Ibid., 76–77.

[83] Charles A. Timm, *The International Boundary Commission: United States and Mexico,* Publication No. 4134 (Austin, TX: University of Texas, 1941).

[84] Ibid.

[85] Hundley, *Dividing the Waters*, 93–94.

[86] Ibid., 41–42.

[87] Timm, *International Boundary Commission*.

[88] Hundley, *Dividing the Waters*, 94.

[89] Timm, *International Boundary Commission*.

[90] Hundley, *Dividing the Waters*, 94.

[91] Timm, *International Boundary Commission*.

[92] Treaty between the United States of America and Mexico, February 3, 1944, U.S.-Mex. 59 Stat. 1219 (referred to in the text as the 1944 Treaty), art 4.

[93] Ibid., art. 3.

[94] Ibid., art. 4.

[95] Ibid., art. 5.

[96] Ibid., art. 2.

[97] Ibid., art. 24.

[98] Ibid., art. 25.

[99] Ibid., art. 4.

[100] International Boundary and Water Commission (IBWC), *Commission Report, United States and Mexico* (El Paso, TX: IBWC, 1998).

[101] 1944 Treaty, arts. 10–16.

[102] Hundley, *Dividing the Waters*, 93–97.

[103] John Haywood, *A Brief Legal History of the Irrigation Rights Controversy of Land Originating in Spanish and Mexican Grants in the Rio Grande Valley of Texas* (n.p., 1974).

[104] *Motl v. Boyd*, 116 Texas 82, 286 S.W. 458.

[105] *State of Texas v. Valmont Plantations*, 163 Tex. 381, 355 S.W.2d 502.

[106] Matthews, Nowlin, MacFarlane, & Barrett, *Water Rights in the Lower Rio Grande Valley: An Outline of the Principle Issues of Law and Fact in the Case of the State of Texas vs. Hidalgo County Water Control and Improvement District No. 16, et al. in the District Court of Hidalgo County, Texas*, 1957.

[107] 1944 Treaty, art. 5.

[108] Matthews, Nowlin, MacFarlane, & Barrett, *Water Rights*.

[109] Ibid.

[110] *State of Texas v. Hidalgo County*, WCID No. 18, 443 S.W.2d 7281 (1969).

[111] Jurgen Schmandt, Chandler Stolp, and George H. Ward, *Scarce Water: Doing More with Less in the Rio Grande*, Report for the Binational Assessment of Water and Development in the Lower Rio Grande/Rio Bravo Basin, U.S.-Mexican Policy Report No. 8 (Austin, TX: Lyndon B. Johnson School of Public Affairs, 1988).

[112] Texas Water Code Ann, § 11.326, (West 2008).

[113] 30 Texas Administrative Code, § 303.21(b)(1).

[114] Ibid., § 303.22c.

[115] Texas Water Code Ann, § 11.122, (West 2008).

[116] 30 Texas Administrative Code, § 303.53.

[117] Rio Grande Regional Water Planning Group, Rio Grande Regional Water Plan, January 5, 2005, available at http://www.riograndewaterplan.org (accessed June 4, 2010).

[118] Damien Schiff, Rollin', Rollin', Rollin' on the River: A Story of Drought, Treaty Interpretation, and Other Rio Grande Problems. *Indiana International and Comparative Law Review* 14 (2003): 26.

[119] Texas Center for Policy Studies, The Dispute over the Shared Resources of the Rio Grande/Rio Bravo: A Primer, 2002, available at http://www.texascenter.org/borderwater (accessed June 4, 2010).

[120] 1944 Treaty, art. 4.

[121] House Research Organization, Behind the U.S.-Mexico Water Treaty Dispute, *Interim News* 77-7 (April 30, 2002). For a detailed accounting of deliveries and deficits, see Joe G. Moore, Jr., Walter Rast, and Warren Pulich, Proposal for an Integrated Management Plan for the Rio Grande/Rio Bravo, in *First International Symposium on Transboundary Waters Management, Avances en Hidraulica 10, XVII Mexican Hydraulics Congress*, ed. A. Aldama, F. Aparicio, and R. Equihua, 189–204 (Monterrey, Mexico: November 18–22, 2002).

[122] Texas Center for Policy Studies 2002, 11.

[123] 1944 Treaty, min. 307.

[124] Texas Center for Policy Studies 2002, at 13.

---

[125] 1944 Treaty, min. 307, #3.

[126] IBWC, *Report of the United States Section International Boundary and Water Commission Deliveries of Waters Allotted to the United States under Article 4 of the United States Mexican Water Treaty* (El Paso, TX: IBWC, 2002).

[127] 1944 Treaty, min. 308.

[128] Ibid., rec. 5.

[129] Ibid., part G.3.

[130] Ibid., rec. 5.

[131] Stephen P. Mumme, Revising the 1944 Water Treaty: Reflections on the Rio Grande Drought Crises and Other Matters, *Journal of the Southwest* 45, no. 4 (2003): 649–70.

[132] Paul Krza, Texas Water Case Is “Takings” on Steroids, *High Country News*, February 21, 2005.

[133] *Bayview Irrigation District et al. v. United Mexican States*, ICSID Case No. ARB(AF)/05/01, before the Arbitral Tribunal Constituted under Chapter XI of the North American Free Trade Agreement, Award June 19, 2007.

[134] Luke E. Peterson, Texas Farmers Sue Mexico in Ontario for Water, *Embassy*, November 17, 2007.

[135] *Bayview et al. v. United Mexican States*.

[136] Ibid.

[137] *Bayview Irrigation District No. 11 and ors v. Mexico*, Judicial Review, 07-CV-340139-PD2;IIC 323 (2008), May 5, 2008.

[138] 1944 Treaty, min. 308, part A.

[139] Barbara Cosens, Water Dispute Resolution in the West: Process Elements for the Modern Era in Basin-Wide Problem Solving, *Environmental Law* 33 (2003): 949.

[140] Texas Center for Policy Studies 2002, 8.

[141] Ibid., 11.

[142] Ibid., 14.

[143] South Texans Take Water Fight with Mexico to Canada Court, *Dallas Morning News*, February 19, 2008.

[144] 1944 Treaty, min. 308, rec. 4.

[145] Ibid., part G.

[146] Environmental Defense Fund, Discovering the Rio Conchos, May 3, 2002, http://www.edf.org/article.cfm?ContentID=2915 (accessed June 4, 2010).

[147] U.S. Section of the International Boundary and Water Commission (USIBWC). For available information regarding meeting minutes and presentations, see USIBWC, Lower Rio Grande Citizens' Forum Meetings, http://www.ibwc.gov/Citizens_Forums/CF_Lower_RG.html (accessed June 4, 2010).

[148] Conference proceedings and recommendations are available at USIBWC, Binational Rio Grande Summit Recommendations, http://www.ibwc.gov/Organization/rg_summit_recommendations.html (accessed June 4, 2010).

[149] 1944 Treaty, art. 3.

[150] William Wilcox, Mexico and the United States: The Trans-boundary Water Quality Issues That Lie Ahead, *Western Water Law & Policy Reporter* (April 1999): 137–41.

[151] Agreement on Cooperation for Protection and Improvement of the Environment in the Border Area, August 14, 1983, United States–Mexico, 22 I.L.M. 1025.

[152] Specific information on Border 2012 can be found at U.S. EPA, U.S.-Mexico Border 2012 Program, http://www.epa.gov/usmexicoborder/index.html (accessed June 4, 2010).

CHAPTER IV

BINATIONAL INSITUTIONAL DEVELOPMENT AND EVOLUTION IN THE RIO GRANDE BASIN: A SOCIAL-ECOLOGICAL PERSPECTIVE

Introduction

Given the magnitude of basin-wide problems and the inability of existing institutions to resolve many of them effectively, it is apparent that the institutional structure for water resource management in the Rio Grande Basin has not created a climate that encourages sustainable resource use. This does not mean that there has not been a veritable explosion of research and other efforts in this basin. However, these initiatives tend to lack focus, coordination, and buy-in from those responsible for managing the river and its resources. Thus there have been few tangible results in terms of creating an institutional climate that fosters sustainable use of the Rio Grande for both humans and ecosystems.

For example, there have been a number of stakeholder forums in recent years. However, many were not explicitly basin-wide in scope; others focused on discrete watersheds or segments of the river, or were not inclusive of all interests. In addition, many focused on single interests, including agriculture (Joint Rio Grande Basin Initiative 2006; Environmental Defense and Woodrow Wilson International Center for Scholars Mexico Institute 2004), legal aspects (CLE International 2004), and "state of the knowledge" (National Heritage Institute 2001; First International Symposium on

Transboundary Waters Management 2002). Two recent conferences explicitly addressed sustainable management (IBWC 2005; Project Rio 2006). The conference held by the International Boundary and Water Commission (IBWC), the binational institution responsible for administering water allocations under a 1944 Treaty, was inclusive insofar as stakeholder representation was concerned and involved more than 200 participants; nevertheless, it took two years for a complete list of conference recommendations to be made available to the public. Project Rio included a much smaller subset of stakeholders (40) dominated by federal and international agencies and academics, raising questions related to inclusiveness. Post-Project Rio activities are still ongoing, so conclusions as to whether or not this initiative will be successful in bringing together basin stakeholders to produce meaningful results is unknown at present.

Model explorations of the basin are rapidly becoming ubiquitous. For example, the Findings and Conclusions of a “State of the Knowledge” Conference lists 10 models developed by different interests (state and federal agencies, academic institutions, etc.) (National Heritage Institute 2001). There is no evidence of any studies that explicitly incorporate historical profiling in order to evaluate basin conditions, with the possible exceptions of Cowley (2006), who gives a high-level overview of management history in the Middle Rio Grande and its effects on aquatic species, Scurlock (1998), who presents an environmental history of the Middle Rio Grande, Hundley (1966), who details the history of current water allocation schemes at the interstate (U. S.) and international (U.S. and Mexico) scales, and Donahue and Klaver (2009) who examined temporal shifts in water management and how these shifts were influenced by social and cultural factors.

None of the stakeholder processes, model explorations, or other research efforts focused on social-ecological resilience or examined basin institutions from a complex adaptive systems perspective. The purpose of this study was to examine the historical evolution of institutions and organizations in the Rio Grande Basin, using a conceptual model for social-ecological systems based on insights from complex adaptive systems theory.

The Rio Grande Basin

The Rio Grande/Rio Bravo Basin drains two countries, the United States and Mexico, and eight states within the two countries: Texas, New Mexico, Colorado, Chihuahua, Coahuila, Durango, Nuevo Leon and Tamaulipas (Figure 4.1). It is the fifth longest river in North America, flowing over 1,885 miles from its headwaters in Colorado to its outlet at the Gulf of Mexico. The drainage area of the basin is approximately 355,000 square miles, with a contributing area of 176,000 square miles. The basin covers 11% of the continental United States and 44% of the land area in Mexico. The climate is arid to semi-arid, with precipitation ranging from less than 8 inches per year in the San Luis Valley of Colorado to 10 inches per year near Ciudad Juarez/El Paso to approximately 24 inches per year at Brownsville/Matamoros (Eaton and Andersen 1987).

Historically, attaining adequate water supplies for agricultural use and the needs of rapidly growing human populations has been the predominant focus of both riparian countries, generating varying degrees of conflict at the local, state, and international level. These conflicts are often rooted in a fundamental belief that the river exists solely for the use of humans, with ecosystem needs not usually being considered. As an example, current water supply management paradigms, such as Regional Water Planning in Texas, identify water needs for human consumptive uses, but typically do not identify flows to sustain riverine ecosystems as a water need (Far West Texas Planning Group 2006; Region M Water Planning Group 2006). Another driver for conflict is the

Figure 4.1. Rio Grande Basin Extent

assumption that human use can be guaranteed under all conditions. The Texas planning model assumes, for example, that the worst case scenario for river flow is the drought of record and contains no contingency planning or strategy development for a drought that could be worse. (Far West Texas Planning Group 2006; Region M Regional Water Planning Group 2006).

Unfortunately, the institutional structure in the basin does not include or foster mechanisms or institutions to resolve conflicts or address water related issues in ways that result in sustainable use of the river. Early conflict resolution efforts, such as the 1944 Treaty, and the institutions that arose from them, resolved allocation issues based on conditions existing at the time these agreements were reached. However, the world, and the Rio Grande Basin, are constantly changing. Extraordinary drought, growing populations and the deterioration of riverine ecosystems have strained the existing agreements and institutions, which have thus far proven ineffective for resolving the more complex issues associated with sustainable use of the river and its resources. A growing movement towards the recognition of instream rights for ecosystem needs, both for aquatic organisms and for the river itself, will likely exacerbate existing disputes such as disputes over Rio Grande Compact deliveries and efforts to re-establish populations of the endangered Rio Grande silvery minnow. These types of disputes may further strain an institutional structure that essentially lacks the ability to deal with such issues.

In addition to allocation issues for both humans and the environment, basin problems include (i) habitat loss, (ii) lack of a unified cross-sectoral, cross-jurisdictional forum to address ecosystem management, (iii) reliance on litigation pursuant to the Endangered Species Act to protect the growing numbers of species at risk in reaches of the river subject to the jurisdiction of the United States, (iv) legal and financial issues related to listing and evaluation of risk to listed species in Mexico (Contreras-Balderas et al. 2003), (v) population growth and associated social and economic issues, and (vi) water quality concerns. There are numerous individual programs addressing these issues, examples being Regional Water Planning efforts in Texas and New Mexico, Border Environmental Programs administered by the U. S. Environmental Protection Agency, institutions originating from the North American Free Trade Agreement (NAFTA), and irrigation and legal reforms in Mexico. However, fragmented authority at all governmental levels, and a reluctance to address water allocation frameworks codified in existing treaties and interstate compacts, make sustainable management of water resources within this basin a formidable challenge.

Adaptive Cycles and Panarchies

The institutional structure and 100 years of management of the Rio Grande system was based in "command and control." "Command and control" management assumes that problems are easily identifiable, have clear boundaries, and that cause-and-effect relationships are linear. This type of management led to allocation agreements and structural controls, such as the construction of dams, to produce a reliable and quantifiable water supply for human needs. The result of this type of management, and the institutions designed to promulgate it, is reduced natural variation in ecosystem functions, leading to less resilient social-ecological systems (Holling and Meffe, 1996).

There are alternatives to the command and control approach that could result in a more resilient and sustainable system. Developing these alternatives should be based on an examination of the pathways and processes which led to the current system configuration. However, examining the system by using the framework of the optimization based paradigm that created it is unlikely to generate alternatives that are significantly different from the present system configuration.

One emerging analysis framework that may provide insights into developing an alternate future for this river system is the complex adaptive systems approach. A complex adaptive system perspective means analyzing a given system as a social-ecological system (SES). In an SES, social systems are linked to the ecological systems that provide the services needed to sustain them. Changes in either the social or the ecological system can affect the other system. In other words, one cannot consider either the social or ecological system in isolation. Furthermore, SESs are not predictable and do not respond to perturbations linearly or incrementally.

SESs also exhibit emergent properties and have the ability to transform into alternate configurations. In an SES, emergent properties can originate either from outside or inside the system. Networks outside the system, such as non-governmental organizations (NGOs,) can develop alternate views of the system. These alternatives have the potential to function as an emergent property within the SES. However, if the legal and institutional structure of a system do not have the capacity to embrace these emergent properties, it is unlikely that the system will undergo a resilient transformation, and highly likely that the system will ultimately collapse.

Holling and Gunderson (2002) propose a conceptual model for social-ecological systems based on insights gained from ecological research. They suggest that three properties determine system outcomes: potential for change; connectedness between processes; and resilience. The conceptual model consists of a cycle of four phases;

- r, which is characterized by resource availability and increasing structure,
- K, the conservation phase, where growth slows, and flexibility and vulnerability decrease,
- Ω, where disturbances occur leading to collapse of structural attributes,
- α, characterized by reorganization, renewal and possibly transformation to another state.

For institutions, the phases of the adaptive cycle could be viewed as policy (r), implementation (K), crisis (Ω), and alternatives (α) (Janssen 2002).

Panarchies are, at the simplest level of explanation, a nested set of adaptive cycles at different scales. Added complexity occurs as a result of interactions within the panarchy, i.e., between different scales. Conceptually, panarchies reflect the notion that complex systems are constantly changing and that social and ecological systems interact across spatial and temporal scales in a dynamic fashion. Yet despite this theoretical perspective, practical application of this conceptual model necessitates determining boundaries, arbitrary though they may be, between system components. The purpose of analyzing adaptive cycles, and their changes and interactions is not just a descriptive task, because the challenge is not to merely describe what exists. Instead, the challenge is to identify processes and interactions that provide insight on the evolving nature of the system with a goal of defining conditions that shape future opportunities for change.

Historical Profiles

Development of water management institutions within the binational Rio Grande resulted from the interplay of geographic and jurisdictional scales, as well as the intersection of those scales with temporal changes in the legal and regulatory focus of management strategies. For example, institutional mandates to promote and encourage agricultural development in an arid environment resulted in an era of reservoir construction throughout the basin in both countries in order to stabilize water supply. The cumulative effects of reservoir construction, and their associated management for human supply, led to negative impacts on aquatic species and their habitat (Anderson et al. 1995; Cowley 2006; Calamusso et al. 2005; Dudley and Platania 2007).

Understanding institutional changes through time is an important first step in identifying disturbances, institutional response, and the effectiveness of those institutional responses. The Resilience Alliance (2007) recommends construction of a timeline to identify significant events and allow classification of the historical period into discrete time periods. The Alliance further advocates use of the timeline to identify the differences between time periods, and to promote understanding of events that led to changes between those time periods.

The first step in developing historical profiles is to determine the focal scale. The focal scale for this analysis is the binational level. However, the Resilience Alliance (2007) notes the importance of developing the profile at scales above and below the focal scale in order to identify cross-scale connections. In the case of institutional regimes in the Rio Grande, there is no scale above the focal scale, while the scale below the focal scale is a series of two or more lateral interconnected national scales. Based on this, three sequences were developed, one at the binational level, and one for each of the two nations. The time lines were used to delineate eras of water management and the creation of corresponding institutions.

Binational Time Line

At the binational level, water management can be divided into three distinct eras. The first, Dividing the Waters, lasted from the 1830s to 1944 and is reflective of water use development and conflicts culminating in a 1944 water allocation treaty (1944 Treaty). The second represents Business as Usual, wherein the two countries set about using their allocated water. The third, Addressing Environmental Issues (still ongoing), represents recognition of environmental issues and institutional responses to those issues. The binational cycles with their respective eras, policies, implementations, crises, and alternatives are shown in Table 4.1.

Table 4.1. Binational Adaptive Cycles

ERA	POLICY	IMPLEMENTATION	CRISIS	ALTERNATIVE
Dividing the Waters (1854-1944)	Use all available water	Increase irrigated lands to the maximum extent possible	Water demands exceed water supply	1944 Treaty
Business as Usual (1945-1982)	Address water supply issues	Reservoir Construction	Water quality and sanitation Issues arise	La Paz Agreement
Addressing Environmental Issues (1983-Present)	A healthy environment is important for economic and social well being	NAEEC, BEC and CEC created, Border Environmental Initiatives, Minutes 307 and 309	Drought, Environmental Flows and Species concerns	????

The first cycle was characterized by increasing basin populations and conflict and uncertainty over water supply. Alexander Martin (2010) and Hundley (1966) provide detailed accounts of water use development in the two countries, and events leading up to the final division of waters between them in 1944. A binational institution, the International Boundary and Water Commission (IBWC), was created to administer the treaty, and basin interests on both sides of the border set about using their allocated water. During the post-treaty period, Business as Usual, relations between the countries exhibited aspects of both conflict and cooperation. Two major reservoirs were jointly constructed (Amistad and Falcon) and the two countries settled a long standing boundary issue, the Chamizal case, which was of great concern to Mexico (CILA 2009). In addition, the two countries continued to cooperate on flood control initiatives (IBWC 2003 and Minute 238 of the 1944 Treaty).

However, water quality and sanitation soon became binational issues and led to an era of Addressing Environmental Concerns. Both Mexico and the United States passed legislation to address water quality concerns, and created institutional mechanisms to prevent further degradation of water quality in the Rio Grande. These efforts culminated in the signing of the La Paz agreement in 1983 (La Paz Agreement). In the La Paz Agreement, the two countries recognized that a healthy environment was important for economic and social well being and agreed to cooperate on environmental protection. Unfortunately, the La Paz Agreement, and its annexes, clearly delineated the institutional boundaries between the 1944 Treaty and the Agreement by stating that the nothing in the agreement could prejudice or jeopardize the ability of the International Boundary and Water Commission (IBWC) to carry out its allocative functions under the treaty. The La Paz Agreement effectively separated water quality from water quantity. In other words, if a sustainable resolution of a water quality problem meant modifications to the allocative framework or its implementation, a non-sustainable alternative would likely be the only option.

Olsson et al. (2006) examined how actions undertaken by resource managers can transform a social-ecological system when the opportunity arises. These opportunities for regime shifts often occur in periods of rapid non-linear change that are characteristic of SESs. The degradation of water quality provided an opportunity for such a regime shift to occur in the Rio Grande with respect to a coordinated approach to water quality and water supply. However, the La Paz Agreement, which emphasized concerns of some stakeholders to changes in the status quo in water allocation, did not result in development of an innovative approach to integrated basin management. In this case, the window of opportunity for transformation and innovation was lost.

In addition to a failure to take advantage of opportunities for system transformation, the La Paz Agreement did not resolve environmental issues, nor did it provide a mechanism to address new issues that might arise. Indeed, because a treaty was signed, the problems were assumed to be solved. The failings of the La Paz agreement became immediately apparent, however, with annexes being adopted in 1985 to address sanitation problems in Tijuana, 1986 to address pollution by hazardous substances, and 1987 and 1989 for air quality (La Paz Agreement). The Integrated Border and Environment Plan, developed in 1992, in part addressed inadequacies with the La Paz framework (HARC and ITESM 2000). The plan resulted from a series of public meetings that identified concerns regarding the lack of data on toxic substances in the river (IBWC 1994). Specifically, the plan required the two countries to identify contaminated transboundary waters, or transboundary waters where contamination could occur in the future, and a study was approved by Minute 289 (IBWC 1994). This also heralds an era wherein the allocative framework created under the 1944 Treaty begins to address environmental issues, albeit on a limited basis.

Despite ongoing issues with the first environmental agreement between the two countries, the North American Free Trade Agreement (NAFTA) was signed in 1993 by the US, Canada, and Mexico. Although trade issues are arguably deserving of attention, the most salient aspect of NAFTA, in the context of this discussion, is the environmental side agreement, the North American Agreement on Environmental Cooperation (NAAEC 1993). This agreement between the three countries established a Commission for Environmental Cooperation (CEC) which consists of a Secretariat, a Council composed of cabinet level officials from the signatory states, a Joint Public Advisory Committee and Governmental Advisory Committees for each country (CEC 2009a). Although NAFTA could be considered a step forward with respect to issue linkage in that it couples trade and environmental issues, there is little evidence that NAFTA and its side agreements led to improving environmental conditions in Mexico (Gallagher 2005).

NAFTA essentially created another set of unconnected institutions within the context of the Rio Grande. Of course, the inclusion of Canada as a signatory presents confounding issues with respect to interrelatedness and linkages between the IBWC and NAFTA institutions. In addition, there is no statutory or jurisdictional mandate requiring cooperation between these entities, although in practice they do cooperate on a wide range of water quality and infrastructure issues.

One important feature of the NAFTA-generated NAAEC is the inclusion of a public participation component. The NAAEC provides a framework to address evolving environmental issues related to water and air quality through a process allowing citizens to submit complaints against one or more of the signatory nations related to failure to enforce environmental laws. This process has generated 71 complaints, with 15 requiring a factual record, 13 currently active and the remainder closed for procedural reasons such as failure to respond in accordance with timelines or incomplete submissions (CEC

2009b). Although the NAEEC included public participation, based on the number of complaints, that participation appears to be negligible for a basin the size of the Rio Grande. In addition, important issues have not been brought forward through this process, an example being that none of these complaints addressed aquatic species declines in the Rio Grande.

The Governmental Advisory Committee for the United States recommends (USGAC 2009) that, although pursuant to Article 10 of the NAAEC the Council may undertake projects related to promotion of public awareness regarding the environment and protection of endangered and threatened species, these types of projects should not be considered because the signatory nations are unilaterally addressing them. However, the USGAC does recommend that reporting on water resources issues be a priority of the CEC. It is unclear how a water resource policy priority that does not include public awareness or endangered and threatened species concerns would promote good environmental governance, or how addressing these issues unilaterally will lead to a sustainable future for the Rio Grande Basin. Dependence on unilateral action for resolution of ecosystem issues by the respective countries is perplexing, given that the Rio Grande is a transboundary basin, with a side-by-side geography, so these issues are inextricably linked. Thus, a binational response would seem appropriate.

Border 2012, administered by the United States Environmental Protection Agency (EPA) and the Secretaría de Medio Ambiente Y Recursos Naturales (SEMARNAT), was created in 2001 to protect the environment and public health in the U.S.-Mexico Border Region, consistent with the principles of sustainable development. The IBWC is a partner in this endeavor, along with a number of state and federal agencies on both sides of the border. However, as with the La Paz Agreements, there are no legal or jurisdictional mandates formalizing this cooperative mechanism. Border 2012 did represent progress in the evolution of binational consideration of the pollution-related subset of environmental concerns. Ongoing drought issues, however, overshadowed this initiative.

As often happens in the Rio Grande Basin, a drought sequence began in 1993, diverting attention back to water allocation issues that most thought were resolved by the 1944 Treaty. The drought was so severe that the Basin outlet to the Gulf of Mexico was closed in 2001. One property of a complex adaptive system is the ability of the system to reconfigure itself in response to change. These changes typically occur in three phases: preparation; transition to a new social context; and building resilience for the new direction (Olsson et al. 2006). A window of opportunity for transformation occurs between the preparation and transition phase. In this case, water supply and economic impacts of the drought, coupled with the seeming inability of basin institutions to respond to these concerns, provided the preparation and created a brief window of opportunity. Sustainable development came to the forefront of the binational agenda, culminating with a Binational Summit in 2005 (IBWC 2005). However, the drought ended and no further action was taken, with respect to either unresolved allocation issues or to the cross-sectoral issues raised at the summit. Thus, the window of opportunity for system transformation again closed.

There are, however, some initiatives underway for collaboration on protection of the aquatic ecosystem although, as with pollution-related concerns, coordination across agencies is lacking. In 2000, the Department of the Interior and SEMARNAT signed a

Joint Declaration, acknowledging declines in habitat, water quality and quantity, and establishing a binational task force to address these issues (Kelly 2002). In addition, a complementary initiative, led by the World Wildlife Fund, was developed to foster collaborative management and conservation of natural resources in the Chihuahuan Desert Transboundary Corridor (WWF 2002, Kelly 2002). Recently, the United States Section of the IBWC has undertaken responsibility for the Texas Clean Rivers Program for the Rio Grande (IBWC 2009a). These initiatives could function as either a nascent preparation phase, or a developing emergent property. At this time, however, there is no indication that system change can or will occur at the international level.

Adaptive Cycles at Smaller Scales

The importance of interplay between management scales is well documented (for example, see Cash et al. 2006, Kinzig et al. 2006, Young 2006). As mentioned previously, the Resilience Alliance (2007) suggests that levels below the focal level be included in constructing an historical profile. These smaller focal scales in an international river basin could extend downward through national, state, county, and community to an individual farm. Although considering the myriad of smaller scales in the Rio Grande could potentially provide texture and meaning to the overall institutional landscape as it has evolved through time, the reality is that most of the significant changes in institutional structure occurred because of the interaction of forces at the national scales in the two countries. One could argue of course that these smaller scale effects are among the primary drivers in national responses. In the Rio Grande Basin, these interactions are complex. In the case of the water debt crisis, local interests encountered difficulties elevating their concerns to higher-scale institutions (Alexander

Martin 2010). In addition, the current institutional structure, and its historical antecedents, is heavily influenced by external drivers such as the influence of Colorado River issues on the evolution of the 1944 Treaty (Hundley 1966). Thus, the lower focal scale considered here is that of the United States and Mexico.

Even limiting the lower focal scale to solely the United States and Mexico presents some conceptual difficulties. In the United States system, for instance, the states are responsible for managing water resources with respect to water use and allocation. In Mexico, however, this task is assigned to federal level institutions, although there has been a shift in recent years to devolution of authority and more decentralized management in the water sector (www.conagua.gob.mx). These complexities point to the fact that even a seemingly straightforward task, such as constructing a timeline at the "national" scale, or even defining the "national" scale, is complicated in a complex system. When institutional boundaries are not static across spatial scales, there are limitations to the utility of the adaptive cycle framework. Because of these complexities, and for simplicity, the meaning of "United States" includes elements of a lower focal scale, the state or multi-state scale.

United States

As with the binational cycle, drivers for change in the system were increasing basin populations, and conflict and uncertainty over water supply. To illustrate conceptual issues related to defining boundary conditions, there was uncertainty related to how much water was available for use by United States interests as a whole, as well as uncertainty over how the United States share would be split among local users in Texas.

This is important from a legal perspective because, although the water allocation is to the United States, its use and control is ceded to Texas users.

As at the binational level, water use and allocations dominated the earlier period, Dividing the Waters. However, because of the interplay between the national and local scales, this cycle does not coincide with the binational cycle and there is overlap between Dividing the Waters and The Environment Matters. The adaptive cycles for the United States are shown in Table 4.2.

Table 4.2. United States Adaptive Cycles

ERA	POLICY	IMPLEMENTATION	CRISIS	ALTERNATIVE
Dividing the Waters (1848-1982)	Use every drop, water flowing to the outlet is “wasted”	Full development of water diversions	Water demands exceed water supply	Adjudication of Texas water rights
The Environment Matters (1969-Present)	NEPA, ESA, CWA	Water Quality Initiatives, Endangered Species Listings	Drought, environmental flows, potential species concerns	??

Once water allocations were settled at the international scale, the IBWC transitioned into “Business as Usual”, wherein the two countries cooperated in the construction of several water resource projects. However, on the United States side of the border, for the water users themselves in Texas, instead of moving forward, collapse occurred, leading to a lag-induced overlap in adaptive cycles.

By the 1950s, the population of the Lower Rio Grande Valley on the U.S. side of the border increased to 450,000 people, with over 700,000 irrigated acres (Matthews et al. 1957). Pursuant to the 1944 Treaty, Falcon Dam was completed in 1954, and an extreme rainfall event filled the reservoir to capacity. The Unites States share of Falcon storage at that time was about 1,300,000 acre-feet (Matthews et al. 1957).

By January of 1956, less than two years after it filled, the U.S. share declined to less than 700,000 acre-feet of stored water. Water storage continued to decline, until only 50,000 acre-feet remained by June of that year (Matthews et al. 1957). After the reservoir filled, diverters in the Lower Rio Grande Valley requested releases of the United States share of stored water in Falcon Reservoir for agricultural needs. However, because of declines in the U.S. share of Falcon reservoir storage, releases of the remaining water were limited to releases for domestic and municipal needs (Matthews et al. 1957).

The State of Texas and cities in the Lower Valley subsequently initiated litigation against numerous water users in a lawsuit that included about 3,000 defendants (State of Texas v. Hidalgo County Water Control and Improvement District No. 18, 443 S.W. 2d 728, hereinafter State v. Hidalgo County). The suit alleged that water released from storage and intended for the City of Brownsville had been illegally diverted by agricultural users. The suit requested that the court take custody of the remaining U.S. share of Falcon storage and appoint a Watermaster to ensure the defendants did not illegally divert water released to the municipalities. The Court agreed, and on October 17, 1956 assumed control of water supply management of the United States share in the Lower Rio Grande (State v Hidalgo County at 738).

In September of 1956, two additional lawsuits were filed by some of the defendants in the earlier case, alleging illegal diversion of released water. The suit asked the court to determine amounts of water to be allocated to the competing users, because water available from the United States share of the Rio Grande under the 1944 Treaty was only sufficient to cover 50% of the demand for such water. The suit further alleged that a final determination of rights to water was essential for the future economic well-being of the Lower Rio Grande Valley (Matthews et al. 1957). The court in State v Hidalgo County concurred with this assessment, noting that Texas had granted permits for water use in such numbers and in such quantities that every drop of water in the river would be used.

These lawsuits eventually led to proceedings that determined Texas user rights to water in the segment of the river from below Falcon Dam to the Gulf of Mexico. In October of 1954, another suit was filed by the City of Laredo, claiming that upstream diverters were harming its municipal supply. Further, another suit was filed in 1956, alleging that users upstream of Falcon Reservoir were diverting more water than they were authorized, and requested that water rights in the reach between Fort Quitman and Falcon reservoir be adjudicated as well. The court took control of the reach from Zapata County to the Maverick County headworks, and instituted equitable distribution, pending a final adjudication of water rights. In 1982, water rights in the Middle Rio Grande Basin, i.e., from Amistad Dam downstream to Falcon Reservoir, were adjudicated. Water users located in the reach between Amistad and Falcon reservoirs that were dependant on reservoir storage were given water rights based on the same principles used to assign rights in the Lower Rio Grande Valley. In these decisions, the Courts opted for a modified version of equitable apportionment, rather than the prior appropriation system used in the rest of the river basins in Texas.

Once allocation issues were deemed settled for United States/Texas uses of water, the next era is characterized by increasing environmental concerns, and leading to an era where The Environment Matters. This cycle does overlap with the preceding cycle.

Donahue and Klaver (2009) note that temporal shifts between management eras are indeed sequential, but there also are areas of overlap. The concept of overlap applies here, in part, because of scale considerations for the United States. In other words, allocations were settled at the national scale, rather than at the lower scale where actual use of the water occurs. The lag effect resulted in not only an overlap, but effectively created a discontinuity in terms of focus on issues of concern on the United States side of the border. At the same time that Texas users were finalizing internal allocations, broader trends were emerging across the United States.

In the 1970s, environmental issues began to gain prominence on the United States national agenda. Starting with the National Environmental Policy Act (NEPA) in 1969, and continuing with the creation of the United States Environmental Protection Agency in 1973 and the Clean Water Act amendments in 1977, water quality considerations in water resource management were incorporated into the federal legal framework. The Endangered Species Act of 1973 is of particular importance with respect to emerging trends on the United States side of the river. Species concerns are an ongoing issue in administration of interstate compacts governing the allocation of the river's water (Alexander Martin 2010). More importantly, although a factor in the legal framework for water management in both the United States and Mexico, species concerns have yet to be added to the water agenda at the international scale.

Although there is a well-developed legal and institutional framework for environmental protection, the effectiveness of that framework is hampered by political interference. For example, a 2005 survey of scientists at the United States Fish and Wildlife Service indicated that over half of the respondents involved in endangered species work indicated they were directed to produce findings at odds with scientific data (Union of Concerned Scientists 2005). A similar survey conducted for the United States Environmental Protection Agency indicates that political interference, motivated by economic pressures from regulated entities and commercial interests, often played a larger role in agency decisions than scientific findings, leading to alterations of scientific findings (Union of Concerned Scientists 2007). From a practical standpoint, although decisions about the environment are often balanced with competing interests, this process may be circumvented when the basic scientific data is compromised or altered.

With respect to balancing competing needs for water and planning for the future, the Texas Legislature passed Senate Bill 1 (75^{th} Legislature) in 1996 in response to statewide drought conditions. This legislation changed the face of water planning on the United States side of the border, and in Texas as a whole. The new paradigm incorporated public participation at the Regional level in order to create a water plan with wide popular support. The 2002 Water Plan (Texas Water Development Board 2002) was the first plan completed in accordance with Senate Bill 1 procedures. The 2002 Plan states that the Rio Grande Basin faces serious water shortage challenges in all areas by 2050, including population projections for Mexico's portion of the basin, a welcome addition not considered in previous plans (TWDB 2002). The 2002 Plan makes note of reductions in firm yield of the Amistad/Falcon system over the planning horizon because of sedimentation, and estimates a decreased firm yield of about 10%. Because of the accounting method used to allocate shares of the American portion of reservoir storage, any decrease in firm yield will disproportionately affect irrigation users (TWDB 2002). With respect to environmental flows, the Regional Planning Group recommends that wildlife and environmental needs should be established as a category of water use. A subsequent plan created in 2006 echoed these same issues, and recommended consideration of groundwater development and desalination of brackish groundwater to meet increasing water demands (Region M Water Plan 2006).

As of 2009, new trends are emerging regarding consideration of environmental flows and stakeholder driven water planning. In Texas, the 80th legislature passed Senate Bill 3, establishing a stakeholder-driven process to determine how much water the river needs. Local scientific panels determine a science-based answer, and develop a recommendation for a flow regime adequate to support a sound ecological environment. Local stakeholder groups, a statewide Science Advisory Committee and others reviewe the proposals and made additional recommendations. The Texas Commission on Environmental Quality then uses rulemaking to adopt environmental flow standards to be used in water rights permitting. The Rio Grande science team process will likely conclude in 2012, with adoption of standards to occur in 2013. By statute (Tex Water Code Ann § 11.02362(m)), the local science group in the Rio Grande cannot consider uses attributable to Mexican water flows, and must exclude them from the flow regime. In addition, the local stakeholder groups had to take into account treaty-accounting requirements and allocation of Texas' share by the Rio Grande Watermaster (Tex Water Code Ann § 11.02362(o)). As with endangered species issues at the international level, wherein each country applies its own laws to the same river, the legal structure for determining environmental flows in the Rio Grande may vitiate the outcome of this process. However, from another perspective, this legal structure is necessary because local Texas users do not have the legal authority to alter terms of a binational treaty. This has the potential to foster a continuing disconnect between managers and users of the river, and the river actually being managed.

Mexico

In Mexico, the first cycle, Water for Development, was characterized by increasing basin population and efforts by Mexico to obtain an equitable allocation of river flows through diplomatic channels. Scarcity played a role in early institutional development. For example, The National Irrigation Commission was established in 1926 in response to the need for irrigation infrastructure in water-scarce northern Mexico (HARC and ITESM 2000). After the 1944 Treaty, Mexico participated in construction of international reservoirs and flood control projects, and began constructing reservoirs on Mexican tributaries to allow further development of water resources for agricultural and other uses. The adaptive cycles for Mexico are shown in Table 4.3.

Table 4.3. Mexico's Adaptive Cycles

ERA	POLICY	IMPLEMENTATION	CRISIS	ALTERNATIVE
Water for Development (1880-1970)	National Commission for Irrigation, Agrarian Reform	Increase irrigated lands	Water demands exceed water supply	Reservoir Construction
Towards Consideration of the Environment (1971-Present)	National Law to Prevent and Control Environmental Pollution, National Water Plan Commission	Creation of institutions, reorganization of institutions	Drought, water demands exceed supply, potential species concerns	??

Similar to the United States, the next era (Towards Consideration of the Environment) was characterized by the emergence of environmental institutions. The trajectory in Mexico, however, was somewhat different, particularly with respect to longer time frames for development of these institutions. In addition, many of the institutions were reorganized during the 1980s and 1990s. Other factors influenced institutional evolution, including a trend towards decentralization starting in the 1980s, and the 1992 water debt crisis (HARC and ITESM 2000). SEMARNAP, established in 1994, and reorganized as SEMARNAT in 2000, is the primary agency responsible for environmental affairs. Consolidation has the advantage of creating consistent policies. However, some commenters raise issues related to the complexity of SEMARNAT's coordination tasks and posit that this task in Mexico may be beyond the abilities of one institution (HARC and ITESM 2000). Furthermore, the lack of institutional capacity is also seen as a deterrent to effective administration of environmental programs in Mexico (Gallagher 2005).

In 2004, Mexico recognized the environment as a legal user of water, creating the potential for transformation to a new era of more sustainable management of water resources (Ley de Aguas Nacionales 2004). Although this era represents a strengthening of institutional capacity and the legal framework for environmental protection, the lack of institutional attention to aquatic ecosystems is noteworthy. The Instituto Nacional de Ecología (INE) is responsible for applied environmental research in support of conservation and restoration of the environment in Mexico (INE 2009). Review of this institution's web site, however, did not reveal any research directly related to aquatic issues in rivers and streams, although there were programs for coastal and wetland systems. The Ministry of Fisheries (CONAPESCA) is within the purview of the Agricultural Ministry (SAGARPA). Measures to protect and conserve biodiversity within this agency are geared towards conservation of the genetic diversity of food species (CONAPESCA 2009).

Panarchies and Cross-Scale Interactions

Holling et al. (2002) represent a panarchy as a set of nested adaptive cycles across space and time scales. Kinzig et al. (2006) provide evidence of interactions between scales and domains that can lead to regime shifts at higher scales. These types of shifts are indicative of scaling effects in a spatial hierarchy. For example, in the case of the Rio Grande Basin, changes in institutions with mandates at smaller spatial scales, i.e., state and national, can cascade upward and provide the impetus for change at the international scale. Conversely, actions at the international scale can influence actions at smaller scales. Figure 4.2 illustrates a comparison between the eras at the international scale and those at the national scales.

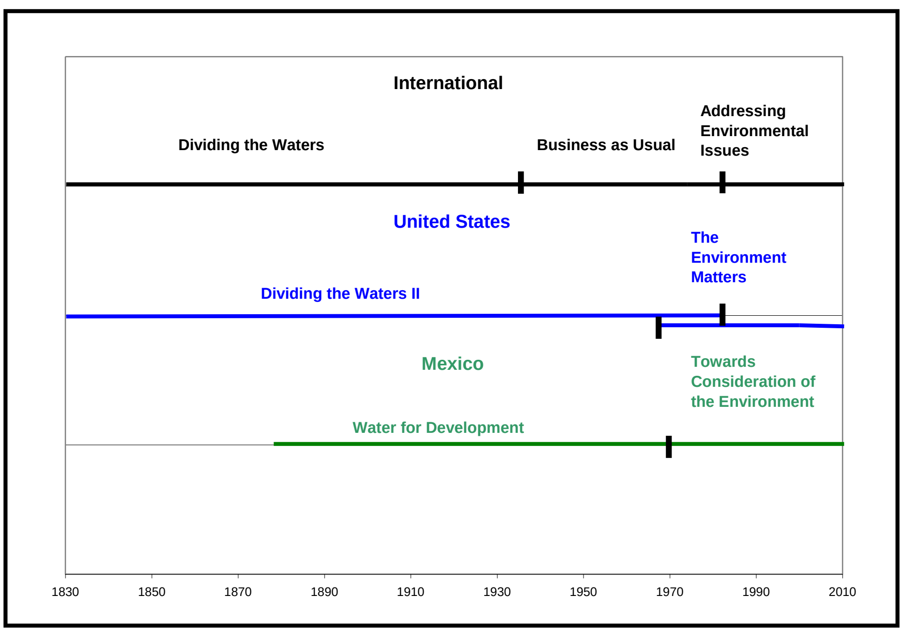

Figure 4.2 Comparison of Eras Across Scales

Examining the binational timeline and timelines at lower focal scales illustrates cross-scale impacts in the binational Rio Grande Basin. Although the 1944 Treaty settled issues at the international level, it forced system change at the national/state level where the water was being used. Once the United States share was determined under the 1944 Treaty, legal and institutional adjustments and transitions occurred at the lower level. Unfortunately the outcome was, in a sense, pre-determined because the provisions of the Treaty and its strict allocation format set the system trajectory at the smaller scale. Texas followed the same type of strict allocation format embodied in the 1944 Treaty. In recent years, however, there is some evidence of change. Increased municipal water demands on the Texas side of the border, and strategies to meet those demands, are an integral part of Texas' planning process.

With respect to incorporation of environmental concerns into binational water management in the Rio Grande Basin, both Mexico and the United States began addressing environmental concerns in the 1970s. The way in which these issues are addressed was largely influenced by forces at smaller scales in the United States and Mexico and these changes, in turn, influenced events at the international scale. The 1944 Treaty (Article 3) lays out the legal basis for the IBWC to involve itself in border sanitation issues. Starting with Minute 261 (Recommendations for the Solution to the Border Sanitation Problems 1979), the IBWC began to take actions on sanitation issues, although the process did not proceed smoothly. The effectiveness and timeliness of IBWC responses to border issues is rooted in an institutional history of technical and diplomatic responses outside the public domain (Kelly and Székely 2004). With respect to border sanitation issues, the United States section of the IBWC (USIBWC) underwent a shift to more transparent decision-making as a result of input (and lawsuits) from environmental groups and the EPA in the United States (Wilcox 1999).

With respect to flood control issues and impacts to riparian areas, the United States and Mexico agreed in 1932 to initiate a flood control plan for the Lower Rio Grande (IBWC 2003). Flooding in 1958 led to Minute 212 (Improvement of the Channel of the Lower Rio Grande 1961), after which the IBWC began clearing vegetation from riparian areas to improve channel conveyance capacity. Up until 1989, the USIBWC did not take into account environmental concerns (Wilcox 1995). A lawsuit by the Sierra Club and the Audobon Society alleged that the vegetation removal practices violated both NEPA and the ESA. The Court issued a Consent Decree, requiring the USIBWC to enter into consultation with the U.S. Fish and Wildlife Service, and to prepare an Environmental Impact Statement (EIS) pursuant to NEPA (IBWC 2003). The USIBWC requested funding for the EIS for 6 years before it was finally made available (Wilcox 1995).

This experience did promote a shift in the way the USIBWC considered environmental issues. In the case of the canalization project above Elephant Butte Reservoir, the USIBWC took action as soon as they received a NOI (Notice of Intent to Sue), and began consultation with the Southwest Environment Center, leading to a Memorandum of Understanding (MOU) for this series of projects. The MOU process affords the USIBWC more latitude to fulfill its mission related to flood control than the Court-ordered Consent Decree in the Lower Rio Grande Valley (Wilcox 1995). The IBWC then embarked on a series of stakeholder meetings and created an EIS. In an assessment of the use of NEPA for the Rio Grande Canalization project, however, Smith and Fernald (2006) present the case that creation of an EIS pursuant to NEPA is inappropriate for existing projects with a history of environmental impacts preceding a proposed action.

In 2009, the USIBWC published the Record of Decision River Management Alternatives for the Rio Grande Canalization Project (IBWC 2009b). The selected decision was not the environmentally preferable alternative, i.e. Targeted River Restoration, because this alternative was deemed to contain actions outside the jurisdiction of the USIBWC and also included increased water use. The selected alternative does present some small shifts in consideration of environmental concerns by the USIBWC. For example, the selected alternative includes measures that extend beyond the USIBWC's historic institutional jurisdiction, in providing limited increases in water use for the environment, including targeted listed species. One element of the proposed plan, which is definitely a new direction for the USIBWC, is the use of targeted restoration flows purchased or leased from willing sellers. The selected alternative also includes elements of adaptive management (IBWC 2009). It is unclear whether these types of changes in the USIBWC are mirrored by concomitant changes in the Mexican Section of the IBWC (CILA).

Conclusion

The historical profile of institutional development and organizational change in the Rio Grande Basin exhibits a seeming anomaly with respect to cross-scale interaction, particularly when this method is applied to institutional change. Typically, cross-scale interactions are assumed to occur between contiguous spatial and temporal scales. However, evidence from the Rio Grande indicates that interaction between scales occurs in a complex dynamic of both spatial and temporal scale effects. In the case of the Rio Grande, events from earlier time periods at different scales emerged to impact events during current time periods, particularly when durable and equitable resolution of those preceding era events did not occur.

This is the case with drought and allocation issues. After 50 years of negotiations, the United States and Mexico signed the 1944 Treaty and completed allocation of the waters of the binational Rio Grande Basin. In many arenas, this agreement has proven somewhat flexible with respect to issues related to water quality and sanitation, although salinity issues are emerging in the lower basin (Drusina 2012) . However, allocation issues, once thought resolved, have again risen, particularly with respect to drought-related water shortages and deliveries of water under the 1944 Treaty (Alexander Martin 2010) and the 1906 Convention (Staples and Rubinstein 2012). To further complicate matters, environmental flows, species concerns, and sustainable development are not formally part of the policy dialog or actions, and initiatives are occurring in networks outside the formal institutional structure. At this point, a potential preparation phase may be occurring. The question is whether or not issues related to drought and water deliveries will open a window of opportunity, since such windows have occurred previously in this river basin with no subsequent transition phase. Accordingly, the Rio Grande social-ecological system is again at a crossroads wherein a window of opportunity could open and result in system transition towards a more sustainable future condition.

REFERENCES

Alexander Martin, K. 2010. Texas Boundary Water Agreements. In *Water Policy in Texas: Responding to the Rise of Scarcity*, Ed. Ronald Griffin. RFF Press.

Anderies, J, Walker, B. and A. Kinzig. 2006. Fifteen weddings and a funeral: Case studies and resilience-based management. *Ecology and Society* 11(1):21. Available at http://www.ecologyandsociety.org/vol11/iss1/art21/.

Anderson, A., Hubbs, C., Winemiller, K. and R. Edwards. 1995. Texas freshwater fish assemblages following three decades of environmental change. *The Southwestern Naturalist* 40(3):314-321.

Calamusso, B., Rinne, J. And R. Edwards. 2005. Historic changes in the Rio Grande fish fauna: status, threats, and management of native species. In *Historical Changes in Large River Fish Assemblages of the Americas.* Ed. John N. Rinne, Robert M. Hughes and Bob Calamusso. American Fisheries Society Symposium 45.

Carpenter, S., Westley, F., and M. Turner. 2005. Surrogates for resilience of social-ecological systems. *Ecosystems* 2005(8):941-944.

Cash, D., Adger, W., Berkes, F., Garden, P., Lebel, L., Olsson, P., Pritchard, L., and O. Young. 2006. Scale and cross-scale dynamics: Governance and information in a multi-level world. *Ecology and Society* 11(2):8.

CLE International. 2004. Rio Grande Super Conference. Albuquerque, New Mexico. February 5-6, 2004.

Comisión Internacional de Límites y Aquas Entre México y Los Estados Unidos Sección Mexicana (CILA). 2009. El Caso del Chamizal. Available at http://www.sre.gob.mx/cila/

Comisión Nacional de Acuacultura y pesca (CONAPESCA). 2009. Available at http://www.conapesca.sagarpa.gob.mx/wb

Commission for Environmental Cooperation (CEC). 2001. North American Boundary and Transboundary Inland Water Management Report. North American Environmental Law and Policy Series 7. Available at http://www.cec.org/files/PDF/ECONOMY/NAELP7e.pdf

Commission for Environmental Cooperation (CEC). 2009a. Available at http://www.cec.org/home/index.cfm?varlan=english

Commission for Environmental Cooperation Citizen Submissions (CEC). 2009b. Available at http://www.cec.org/citizen/status/index.cfm?varlan=English

Contreras-Balderas, S., Almada-Villela, P., Lozano-Vilano, M., and M. García-Ramírez. 2003. Freshwater Fish at Risk or Extinct in México. *Reviews in Fish Biology and Fisheries* 12:241-251.

Cowley, D. 2006. Strategies for ecological restoration of the Middle Rio Grande in New Mexico and recovery of the Rio Grande silvery minnow. *Reviews on Fisheries Science* 14:169-186.

Donahue, J. and I. Klaver. 2009. Sharing water internationally, past, present, and future – Mexico and the United States. *Southern Rural Sociology* 24(1): 7-20.

Drusina, E. 2012. Letter to Mr. Carlos Rubinstein, Commissioner, Texas Commission on Environmental Quality and the Honorable Todd Staples, Commissioner, Texas Department of Agriculture. April 5, 2012. Available at http://www.riograndeguardian.com/rggnews_story.asp?story_no=19

Dudley, R. and S. Platania. 2007. Flow regulation and fragmentation imperil pelagic-spawning riverine fishes. *Ecological Applications* 17(7): 2074-2086.

Eaton, D. J. and J.M. Andersen. 1987. *The State of the Rio Grande/Rio Bravo: A Study of Water Resource Issues Along the Texas/Mexico Border*. Tuscon: The University of Arizona Press.

Environmental Defense and Woodrow Wilson International Center for Scholars Mexico Institute. 2004. Agricultural Production Trends and the Future of the Trans-boundary Río Grande/Río Bravo Basin. San Antonio, Texas. September 2004.

Far West Texas Planning Group. 2006. Far West Texas Water Plan. Prepared for the Texas Water Development Board by the Far West Texas Planning Group. January 2006.

First International Symposium on Transboundary Waters Management. 2002. Monterrey, N.L., Mexico. November 2002.

Gallagher, K. 2005. Economic Integration and the Environment in Mexico. Working Papers Series. Center for Latin American Studies. University of California, Berkeley.

Holling, C.S. and G. Meffe. 1996. Command and control and the pathology of natural resource management. *Conservation Biology* 10(2):328-337.

Holling, C.S. and L. Gunderson. 2002. Resilience and adaptive cycles. In *Panarchy: Understanding Transformations in Human and Natural Systems*. Edited by C.S. Holling and Lance Gunderson. pp. 25-62.

Houston Advanced Research Center (HARC) and Instituto Tecnológico de Estudios Superiores de Monterrey (ITESM). 2000. *Water and Sustainable Development in the Binational Lower Rio Grande/Rio Bravo Basin*. Final Report. EPA Grant No. R 824799-01-0.

Hundley, N. 1966. *Dividing the Waters: A Century of Controversy Between the United States and Mexico.* Berkeley and Los Angeles, CA: University of California Press.

Instituto Nacional de Ecología. 2009. Available at http://www.ine.gob.mx/index.php

International Boundary and Water Commission (IBWC). 1994. Binational Study Regarding the Presence of Toxic Substances in the Rio Grande/Rio Bravo and its Tributaries Along the Boundary Portion Between the United States and Mexico. Final Report, September 1994. Study and Report Undertaken by the United States and Mexico pursuant to IBWC Minute 289.

International Boundary and Water Commission (IBWC). 2003. Hydraulic Model of the Rio Grande and Floodways Within the Lower Rio Grande Flood Control Project. June 2003. Available at http://www.ibwc.state.gov/Files/LRGFCPHydModRpt.pdf

International Boundary and Water Commission (IBWC). 2005. BiNational Rio Grande Summit. Reynosa, Tamaulipas and McAllen, Texas. November 17-18, 2005.

International Boundary and Water Commission (IBWC). 2009a. 2009 Basin Highlights Report for the Rio Grande Basin. Annual Report for the Rio Grande in Texas. May 2009.

International Boundary and Water Commission (IBWC). 2009b. Record of Decision River Management Alternatives for the Rio Grande Canalization Project. Available at http://www.ibwc.state.gov/Files/ROD_River_Mgnt_Alt_RGCP.pdf

Janssen, M. 2002. A Future of surprises. In *Panarchy: Understanding Transformations in Human and Natural Systems*. Edited by C.S. Holling and Lance Gunderson. pp. 241-260.

Joint Rio Grande Basin Initiative. 2006. Ruidoso, New Mexico. March 27-30, 2006. Available at http://riogrande-conference.tamu.edu

Kelly, M. 2002. Water Management in the binational Texas/Mexico Rio Grande/Rio Bravo Basin. In *Human Population and Freshwater Resources: U.S. Cases and International Perspectives.* Ed. Karin Krchnak. Bulletin Series. Yale School of Forestry and Environmental Studies. Number 107.

Kelly, M. and A. Székely. 2004. *Modernizing the International Boundary and Water Commission*. Center for Latin American Studies. CLAS Policy Papers. Paper 1.

Kinzig, A., Ryan, P., Etienne, M., Allison, H., Elmqvist, T. and B. Walker. 2006. Resilience and regime shifts: Assessing cascading effects. *Ecology and Society* 11(1): 20. Available at http://www.ecologyandsociety.org/vol11/iss1/art20/

La Paz Agreement. 1983. Agreement Between the United States of America and the United Mexican States On Cooperation For The Protection And Improvement Of The Environment In The Border Area. Treaties and Other International Acts Series 10827. Signed August 14, 1983. Available at http://www.epa.gov/border2012/docs/LaPazAgreement.pdf

Ley de Aguas Nacionales DOF 29 de Abril 2004. Available at http://www.semarnat.gob.mx/leyesynormas/Leyes%20del%20sector/LEY%20DE%20AGUAS%20NACIONALES%2029%20ABRIL%202004.pdf

Matthews, Nowlin, MacFarlane and Barrett. 1957. Water Rights in the Lower Rio Grande Valley: An Outline of the Principle Issues of Law and fact in the Case of The State of Texas vs. Hidalgo County Water Control and Improvement District No. 16, et al in the District Court of Hidalgo County, Texas. Prepared under Employment by the Trustees of the Falcon Water Compact.

National Heritage Institute. 2001. Findings and Conclusions. “State of the Knowledge” Conference at Instituto Tecnológico de Estudios Superiores de Monterrey (ITESM). Monterrey, Mexico. June 4-5, 2001.

North American Agreement on Environmental Cooperation Between the Government of Canada, the Government of the United Mexican States and the Government of the United States of America (NAAEC). 1993. Available at http://www.cec.org/pubs_info_resources/law_treat_agree/naaec/index.cfm?varlan=english

Olsson, P., L. H. Gunderson, S. R. Carpenter, P. Ryan, L. Lebel, C. Folke, and C.S. Holling. Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems. *Ecology and Society* 11(1):18. Available at http://www.ecologyandsociety.org/vol11/iss1/art18/

Project Rio Conference. 2006. Juarez, Mexico. October 3-6, 2006. Available at http://www.rivers.txstate.edu/rio/index.htm

Resilience Alliance. 2007. Assessing Resilience in Social-Ecological Systems: A Workbook for Scientists. Available at http://www.resalliance.org/3871.php

Staples, T. and C. Rubinstein. 2012. Letter to Mr. Edward Drusina, Commissioner, United States Section International Boundary and Water Commission. April 3, 2012. On file with author.

Scurlock, D. 1998. *From the Rio to the Sierra: An Environmental History of the Middle Rio Grande Basin*. General Technical Report RMRS-GTR-5. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Smith, L. L. and A. G. Fernald. The Ineffectiveness of using the National Environmental Policy Act of 1969 to implement environmental enhancement in the Rio Grande Canalization Project. *Reviews in Fisheries Science* 14:139-167.

State of Texas v. Hidalgo County Water Control and Improvement District No. Eighteen. 443 S.W.2d 728. 1969.

Texas Water Development Board (TWDB). 2002. Water for Texas-2002. Austin: Texas Water Development Board. Available at http://www.twdb.state.tx.us/publications/reports/State_Water_Plan/2002/FinalWaterPlan2002.asp

Region M Regional Water Planning Group,. 2006. *Region M Regional Water Plan*. Prepared for the Texas Water Development Board by the Region M Regional Water Planning Group. January 2006. Available at http://www.riograndewaterplan.org/waterplan.php

Treaty Between the United States of America and Mexico, February 3, 1944. U.S.-Mex, 59 Stat. 1219 (noted in the text as the 1944 Treaty).

Union of Concerned Scientists. 2005. U.S. Fish and Wildlife Service Survey Summary. February 2005. Available at http://www.ucsusa.org/assets/documents/scientific_integrity/fws_survey_summary_1.pdf

Union of Concerned Scientists. 2007. Interference at the EPA: Science and Politics at the U.S. Environmental Protection Agency. Available at http://www.ucsusa.org/assets/documents/scientific_integrity/epa-report-executive-summary.pdf

United States Governmental Advisory Committee (USGAC). 2009. Letter to The Honorable Lisa Jackson, Administrator, U.S. Environmental Protection Agency. June 4, 2009.

Walker, B. and D. Salt. 2006. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World.* Washington, D.C.: Island Press.

Wilcox, W.. 1995. Western flood management in the 21st Century: A Tightrope between competing values. *Western Water Law and Policy Reporter.* March 1995: 153:158.

Wilcox, W. 1999. Mexico and the United States: The Trans-Boundary water quality issues that lie ahead. *Western Water Law and Policy Reporter*. April 1999:137-141.

Young, O. 2006. Vertical interplay among scale-dependent environmental and resource regimes. *Ecology and Society* 11(1): 27. Available at http://www.ecologyandsociety.org/vol11/iss1/art27/

CHAPTER V

CREATING SPACE FOR ENVIRONMENTAL CONCERNS IN BINATIONAL WATER MANAGEMENT

Introduction

Resilience is the ability of the social component of a complex social-ecological system to amicably and efficiently adapt to changing conditions across the system. However, adapting to changing conditions often leads to conflicts among competing interests. With respect to water resources, existing allocations among competing uses and evolving water needs are often the underlying cause of these conflicts. Balancing human needs with the needs of the environment to create a resilient system is difficult. Balancing these needs in an international river basin can be further confounded by treaties governing allocation for human use only and lack of dispute resolution processes that allow for the inclusion of stakeholders. This combination of factors contributes to an inability to effectively consider all uses of a river and resolve resource allocation conflicts.

The Rio Grande/Rio Bravo Basin drains two countries, the United States and Mexico, and eight states within the two countries: Texas, New Mexico, Colorado, Chihuahua, Coahuila, Durango, Nuevo Leon and Tamaulipas. In addition to being a major boundary between the two countries, it is the fifth longest river in North America, flowing over 1,885 miles from its headwaters in Colorado to its outlet at the Gulf of Mexico. The climate is arid to semi-arid, with precipitation ranging from less than 8 inches per year in the San Luis Valley of Colorado, to 10 inches per year near Ciudad Juarez/El Paso, to approximately 24 inches per year at Brownsville/Matamoros.

Historically, attaining adequate water supplies for agricultural use and the water needs of rapidly-growing human populations has been the predominant management focus, generating varying degrees of conflict at the local, state and international level. These conflicts are often rooted in a fundamental belief, founded in nationalism, that the river exists solely for satisfaction of human water needs according to an allocation formula, with ecosystem needs not usually being considered. As an example, current water supply management practices in the Rio Grande are geared towards water needs for human consumptive uses, but typically do not allow for flows to sustain riverine ecosystems. The institutional structure in the basin also does not include or foster mechanisms to resolve conflicts in ways that result in sustainable use of the river. Early conflict resolution efforts, based on diplomatic negotiation, resolved water allocation issues on the basis of conditions existing at the time these agreements were reached. However, the world is constantly changing. Extraordinary drought and growing populations on both sides of the border have strained the existing agreements, and they have thus far proven ineffective for dealing with the human water needs they were designed to address. Without substantive process changes it is unlikely that the current institutional structure can achieve sustainable use of the river and its resources.

Specifically, current efforts to balance irrigation needs with increasing municipal demands in the Rio Grande basin fail to address the instream needs of the riverine ecosystem. This is not surprising, however, given that the underlying water allocations did not recognize these needs, and because the institutions designed to manage the allocations do not have mandates that allow consideration of this issue in their activities. A growing movement towards recognition of instream water rights for meeting ecosystem needs, both for aquatic organisms and for the river itself, will likely exacerbate existing disputes over water allocations. However, negotiations on these types of issues rarely occur until the issues are salient.[1] In other words, until riverine ecosystems become completely degraded, and this degradation becomes a source of concern among the signatory countries, the current system of diplomatic negotiation is not likely to begin addressing these issues.

The Woodrow Wilson Center proposes public policies that could facilitate transformation of existing legal and institutional systems.[2] With respect to transboundary water disputes, they are:

i. Creation of appropriate environmental dispute resolution methods; and

ii. Enhancing public participation in negotiating and implementing transboundary water agreements.[3]

In the Rio Grande, dispute resolution practices rely solely on diplomacy and do not include a full range of process alternatives. Examining conflict through the lens of dispute resolution processes may provide insight into possibilities for creation of less adversarial more open institutions and mechanisms for resolution of water disputes in this basin. In addition, incorporation of public participation in water management decisions

---

[1] Nina Burkhardt, Burton Lamb, and Jonathan Taylor, *Desire to bargain and negotiation success: Lessons about the need to negotiate from six hydropower disputes,* 22 ENVTL. MGMT., no. 6, 877, (1998).
[2] Woodrow Wilson Memorial Act of 1968, Public Law 90-637, 82 Stat. 1356, (1968).
[3] Ken Conca, *The new face of water conflict*, Navigating peace, (November 2006), www.wilsoncenter.org/water.

may create opportunities to avoid these conflicts in the first place. Ultimately, conflict transformation could facilitate consideration of ecosystem needs thereby allowing more sustainable and effective management of water resources.

This paper addresses conflict transformation in the binational Rio Grande by evaluating how the current dispute resolution process could be changed from a rights-based process to one based on interests, thereby allowing ecosystem water needs to be included in binational water management. First, problems with relying solely on diplomatic negotiation are discussed. Second, applicability of current environmental laws on the United States side of the border are evaluated in the context of whether legal remedies under these laws can operate as a BATNA (best alternative to a negotiated agreement) in a binational river. Finally, this paper explores dispute resolution options in the Rio Grande and concludes with a proposal for change that could create space for consideration of issues that heretofore have not occupied space in the policy agenda, i.e. ecosystem needs, and facilitate involvement of stakeholders who have largely been excluded from decision making.

Dispute Resolution Methods and Practices

Dispute resolution processes range from approaches where the disputants control the process (negotiation) to those where outside parties such as the courts decide the outcome (litigation). [4] A list of dispute resolution processes, and an explanation of each, follows:

---

[4] More detailed explanations of the most common processes can be found at Alternate Dispute Resolution Committee of the Colorado Bar Association, *Manual on alternative dispute resolution*, http://www.cobar.org/index.cfm/ID/211/subID/1244/Manual-on-Alternative-Dispute-Resolution/, *See also* U.S. Agency for International Development, *Alternate dispute resolution practitioner's guide*, Technical Publication Series, (March 1998), http://www.usaid.gov/our_work/democracy_and_governance/publications/pdfs/pnacb895.pdf.

- Negotiation: Two parties resolve their differences through discussion and the parties create the solution;
- Fact-Finding: A third party determines and evaluates the facts in dispute. This is useful because it provides the parties with an impartial view of the issues and may provoke movement towards resolution of the issues;
- Mediation: Includes the services of an impartial third party to facilitate the relationship between the principals. The principals agree to the outcome but relinquish control over the process to a neutral third party;
- Non-Binding Arbitration: An impartial third party produces a decision or evaluation of the dispute, based on evidence provided during the negotiation. Often this is used so that both parties have an indication of the likely outcome of higher-level proceedings such as litigation;
- Arbitration: The dispute is submitted to an impartial third party, whose decision is binding on the participants. The decision is not easily subject to successful appeal and is enforced by the courts;
- Mediation/Arbitration: The process starts with a mediation and the parties agree that should the mediation be unsuccessful, the dispute will be submitted to an arbitrator for binding arbitration; and
- Litigation: The parties file a complaint in the appropriate court; the process is formal, with depositions, discovery, pre-trial motions, etc. The court renders a judgment that can be appealed until appeals are exhausted.

Of the standard dispute resolution methods described above, negotiation, joint fact finding, mediation and arbitration are commonly used to attempt to resolve water resource disputes. Diplomatic solutions are a special case of negotiation.

There are a number of dispute resolution processes embedded in water management agreements governing water use in transboundary basins around the globe. Processes range from no set procedure to a strictly delineated process which could culminate in referral to an outside entity.[5] For international river disputes there is no court of last appeal, unless the underlying treaties or agreements specifically allow for appeal to the International Court of Justice, or other recognized legal authority. One international legal authority is The Permanent Court of Arbitration (PCA) at The Hague, which resulted from the 1899 Convention for the Pacific Settlement of International Disputes and a revised Convention signed in 1907. Both the United States and Mexico are signatories to this agreement. The PCA oversees arbitration, conciliation and fact-finding when requested. With respect to the relative merits of negotiation/mediation and adjudication type proceedings in a forum such as the PCA, more powerful nations tend to prefer the negotiation/mediation paradigm while less powerful nations are more inclined to favor a more judicially oriented solution.[6]

Regarding potential referral of Rio Grande water disputes to the PCA, the United States is often reluctant to participate in proceedings of international judicial panels. Submitting disputes to arbitration means that the participants relinquish the ability to decide the outcome. Reluctance to engage in arbitration type proceedings occurred

---

[5] Kathy Alexander, Vicente Lopes, and Walter Rast, *Comparative analysis of international water resource institutional regimes*, Manuscript in review, (2012).
[6] Laura Nader and Elisabetta Grande, *Current illusions and delusions about conflict management- in Africa and elsewhere*, 27 LSINQ 573, 581, (2002).

concurrently with the rise of Alternate Dispute Resolution (ADR) in domestic affairs.[7] In addition to a reluctance to participate in international judicial proceedings, the United States has also withdrawn from active participation in many international treaties, including active participation in some aspects of the water sharing agreement with Canada on its northern border.[8]

Diplomatic Negotiation and the Binational Rio Grande

In diplomatic negotiation, disputes are settled at the international level between the countries involved in the dispute. The presumption is that the dispute is only between the countries, diplomats act as agents for the national interests, and the diplomat/agent can truly represent the interests of all of the disputants. Resolving problems by diplomatic negotiation results in a focus on the issue at hand rather than underlying related systemic problems or potential future concerns.[9] In the Rio Grande, the focus of diplomatic efforts tends to be allocation of water and conflict avoidance, which does not necessarily address environmental issues. In addition, potential future concerns such as species declines and ecosystem degradation are not addressed because they are not considered by the countires to be dire emergencies today.

Externalities can also play a role at the diplomatic level by bringing outside concerns into the discussions or by placing water resource issues on the back burner of policy agendas. For example, in the Rio Grande, outside issues such as immigration, economic upheaval in both countries, and the current era of drug related violence along the United States/Mexican border diminishes the likelihood of binational initiatives to

---

[7] *Id.* at 581.
[8] Austen L. Parrish, *Mixed blessings: The Great Lakes Compact and Agreement, the IJC, and international dispute resolution*, 2006 MICH. ST. L. REV., 1299, (2007).
[9] Marit Brochmann and Paul Hensel. *The effectiveness of negotiations over international river claims.* 55 INT'L STUD Q. 859-882.

resolve long standing water resource problems because they are overshadowed by basic security concerns.

The Role of Power

A major problem with diplomatic negotiation is that it tends to produce outcomes driven more by power relationships than by principles of justice, equity or fairness. A process that is not grounded in these basic principles may not create sustainable or equitable resolution of water resource disputes.[10] It is more likely that diplomatically negotiated agreements serve to entrench the more powerful special interest groups because they tend to favor well organized and funded participants.[11] Diplomatic negotiation also may not sufficiently account for the role of inequities in power and financial status between participants in a conflict resolution process.[12] Unequal power relationships between disputants could certainly be an argument against using negotiation or mediation techniques in a dispute. The influence of differential power in diplomatic negotiations, as it relates to water resource disputes, can be overt or covert.[13] Overt disputes such as armed warfare rarely if ever occurred historically, and are unlikely to occur in the future.[14] Covert use of power is much more likely, although this type of power use, and its impacts, is also difficult to identify or quantify.[15]

The United States and Mexico do participate in creating shared benefits, for example the joint construction of Lakes Amistad and Falcon. However, both countries as they are represented by the IBWC (International Boundary and Water Commission/

[10] Conca, *supra* note 3.
[11] Nader, *supra* note 6. *See also* Mark Zeitoun and J. A. Allan, *Applying hegemony and power theory to transboundary water analysis*, 10 WAT. POL'Y, Supp. 2, 3, (2008).
[12] Nader, *supra* note 6.
[13] Melvin Woodhouse and Mark Zeitoun, *Hydro-hegemony and international water law: grappling with the gaps of power and law*, 10 WAT. POL'Y , Supp. 2, 103, (2008).
[14] Aaron T. Wolf, *Shared waters: Conflict and cooperation*, 32 ANN. REV. ENVTL. RES. , 241, 252, (2007).
[15] Woodhouse, *supra* note 13.

Comisión Internacional de Límites y Aguas) often privately fail to fully participate in initiatives to improve binational water management, even when they publically would appear to do so. For example, in 2005, the United States and Mexican Sections of the IBWC facilitated a meeting of multiple stakeholders to address issues related to the river.[16] On its face, this initiative would appear to represent a step forward to a more collaborative future. The summit began with invited presentations on legal, financial, and environmental issues. The intent was to follow the informational sessions with facilitated break-out groups on specific topics to provide feedback to the binational IBWC on a path forward to a more sustainable water management regime.

In any facilitated process, a key component is impartiality of the facilitator.[17] In other words, the facilitator should not have a vested interest in the outcome of the discussions. In the case of the summit, the moderators and recorders were either agency representatives or university researchers on Rio Grande issues.[18] As such, these facilitators would not be considered to be neutral. The lack of appropriate facilitation and limits on the openness of the discussions is an example of the exercise of covert power in the form of agenda setting, which limited the utility of this endeavor. The process was intended to allow all concerns to be brought forward, but some concerns were eliminated from the discussion by the facilitators. For example, comments in the legal and institutional forum were limited to those within the scope of the current legal and institutional framework. This is not surprising, one way to exercise power is to

---

[16] Information about the summit can be found at http://www.ibwc.state.gov/Organization/rg_summit.html.
[17] Herman Karl, Lawrence Susskind, and Katherine Wallace, *A Dialogue not a diatribe: Effective integration of science and policy through joint fact finding*, 49 ENV'T. SCI. FOR SUSTAINABLE DEV., no. 1, 20, (2007).
[18] http://www.ibwc.state.gov/Organization/rg_summit.html

decide which issues are subject to discussion and which do not reach the table.[19] This type of power is known as ideational power, which, when implemented, would be considered an exercise of covert power. Ideational power is often insidious in that the less powerful are convinced that their concerns are not valid.[20] There were suggestions to continue the dialog by holding annual summits, but none have been scheduled.

Exercise of power is also reinforced when the focus of negotiations is limited to a quantification of the "rights" of the participants. Overall, from a global perspective, negotiations over water typically shift from a rights based perspective to one based on needs and interests.[21] The situation in arid land systems is often different because availability of water is tied to economic development. In the Rio Grande, the original negotiations began from the basis of rights to water, based on the history of irrigated agriculture on both sides of the border. One hundred years after the first agreement was signed (1906 Convention)[22], this focus is unchanged, as evidenced in the response of both countries to the Mexican water debt crisis from 2000-2005. Both the United States and Mexico asserted their "rights" under the 1944 Treaty and little regard was shown for the impact of the dispute on the interests of users on both sides of the border.[23] This is because, in the diplomatic realm where negotiations occurred, the influence of power relationships typically limits the focus of discussions to the allocation of the water and not on the interests of the water users, including the environment.

---

[19] Zeitoun, *supra* note 11, at 7.
[20] Zeitoun, *supra* note 11, at 9.
[21] Meredith Giordano and Aaron Wolf, *Incorporating equity into international water agreements*. 14 SOC. JUST. RES., no. 4, 349, (Dec. 2001).
[22] Convention for the Equitable Distribution of the Waters of the Rio Grande for Irrigation Purposes, U.S.-Mexico, May 21, 1906, 34 Stat. 2953, [hereinafter 1906 Convention].
[23] Kathy Alexander Martin, Boundary water agreements, *in* WATER POLICY IN TEXAS: RESPONDING TO THE RISE OF SCARCITY, (Ronald Griffin, ed. 2010).

The Role of Ambiguities

Negotiated agreements between participants with unequal power tend to include deliberate ambiguities.[24] Of particular relevance to the Rio Grande are ambiguities where issues are either not addressed or are not defined. In the Rio Grande, ambiguity in negotiated agreements can be either positive or negative. On the positive side of the ledger, ambiguity allowed the International Boundary and Water Commission (IBWC) to address issues that are not strictly allocative, such as salinity. However with respect to drought management, ambiguity has been less effective.

The 1944 water allocation Treaty (1944 Treaty)[25] between the United States and Mexico allows circumvention of allocation procedures during extraordinary drought. Mexico is allowed to make up deficiencies in deliveries incurred during one accounting cycle during the next five year cycle.[26] Drought conditions were well known at the time the treaty was negotiated. Indeed, recurring drought related shortages precipitated the negotiations that eventually led to the treaty.[27] However, the treaty does not define extraordinary drought. Incorporating ambiguity into the treaty by not defining this term created implementation problems later on, as evidenced by the water debt crisis. Failure to define extraordinary drought, and therefore leaving this issue open to varying interpretations inhibits progress towards sustainable management of the river by creating

[24] Itay Fischhendler, *Ambiguity in transboundary environmental dispute resolution*, 45 J. PEACE RES., no. 1, 91, (2008).
[25] Treaty Between the United States of America and Mexico, February 3, 1944, U.S.-Mex. 59 Stat. 1219 [hereinafter 1944 Treaty or Treaty).
[26] Alexander Martin, *supra* note 23. *See also* Joe G. Moore, Jr, Walter Rast, and Warren Pulich, 2002, *Proposal for an integrated management plan for the Rio Grande/Rio Bravo*, *in* FIRST INTERNATIONAL SYMPOSIUM ON TRANSBOUNDARY WATERS MANAGEMENT, AVANCES EN HIDRAULICA 10, XVII MEXICAN HYDRAULICS CONGRESS, MONTERREY, MEXICO, 189-204, (A. Aldama, et al., eds. 2002).
[27] Norris Hundley, Jr., *Dividing the waters: A century of controversy between the United States and Mexico*, (1966).

discord and uncertainty about available water among users in both countries.[28] Because responses to this recurring issue are dealt with in the diplomatic realm, bounded by the treaty and focused on conflict avoidance, an enduring resolution is less likely. Even if the two countries could agree on a definition of extraordinary drought, additional implementation issues were not addressed in the treaty, further exacerbating ambiguity problems. Specifically, the problem of what should occur when onset of a drought occurs in the middle of a five year accounting cycle and extends beyond the end of the next cycle was not addressed in the treaty. This ambiguity may have been unintentional, there is little to no evidence indicating that such a scenario was contemplated during the treaty negotiations because the negotiations focused on rights under historical conditions with no consideration for potential alternate future scenarios. The 1944 Treaty was also negotiated before a severe drought in the 1950s so the implications of a supra seasonal drought did not inform the negotiations. The treaty does not include flexibility to deal with such a situation, thus solutions are left to the type of conflict resolution method, i.e. diplomatic negotiations, that created the problems in the first place.

Best Alternative to a Negotiated Agreement

A fundamental question is how to handle power differentials between groups within a multi level hierarchy.[29] One method to resolve the inherent power issues in a more traditional ADR type of model is to include a tiered framework in the process, for example: negotiation, mediation, arbitration, and finally adjudication. This checks the ambitions of the more powerful parties by providing a BATNA (best alternative to a

---

[28] Alexander Martin, *supra* note 23.
[29] Fikret Berkes, *Community based conservation in a globalized world*, 104 PROC. NAT'L. ACADEMY SCI., no. 39, 15188, (Sept. 25, 2007).

negotiated agreement) for the less powerful. A BATNA can encourage those involved to remain at the table when impasses occur.

Determination of whether a BATNA truly exists requires consideration of social and political factors. For example, in many Latin American countries, the ineffectiveness of the judiciary system and lack of equal access may produce situations where there is no BATNA for the less powerful members of society.[30] In the case of the United States, environmental interests are in a less powerful position than those with an economic interest in the river's water. Within the United States territorial boundaries, this imbalance in power is mitigated because environmental interests do have a BATNA in matters concerning endangered species in the form of litigation under the Endangered Species Act (ESA).[31] In addition, regarding construction projects within the United States, the National Environmental Policy Act (NEPA) [32] provides some limited environmental protection.

The purpose of NEPA is:

> [T]o declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the nation…[33]

The applicability of the NEPA to actions of the USIBWC is clear, as shown in efforts to include environmental considerations in the Rio Grande canalization project.[34] However,

---

[30] Mariana Hernandez Crespo, *A Systemic perspective of ADR in Latin America: Enhancing the shadow of the law through citizen participation*, 10 CARDOZO J. CONFLICT RESOL, 91, (2008).
[31] Endangered Species Act [hereinafter ESA], Pub. L. No. 93-205, 81 Stat. 884, (Dec. 28, 1973).
[32] National Environmental Policy Act of 1969 [hereinafter NEPA], Pub. L. 91-190, 42 U.S.C. 4321-4347, Jan. 1, 1970.
[33] 42 U.S.C. 4321(2006) at Sec.2 Purpose
[34] International Boundary and Water Commission (IBWC), *Hydraulic model of the Rio Grande and floodways within the Lower Rio Grande Flood Control Project*, (June 2003), http://www.ibwc.state.gov/Files/LRGFCPHydModRpt.pdf. *See also* William Wilcox, *Western flood*

that project is wholly within the boundaries of the United States. In addition, NEPA is not applicable to whole river restoration type activities, only to specific projects. NEPA actions also typically do not address historical evolution of the watershed management decisions which create a specific degraded condition, nor does NEPA allow consideration of an entire affected ecosystem unless the boundaries of the ecosystem coincide with the jurisdictional boundaries of the federal agency proposing an action.[35] Thus, NEPA likely has little applicability to the day to day binational water management decisions that contribute to species decline.

The other legal instrument, which directly addresses species concerns, is the Endangered Species Act (ESA). If there is no recourse to international systems of justice, as discussed above, and NEPA does not provide protection, would the legal instrument specifically applicable to species concerns provide protection for species in the binational river? The ESA is one of the most enduring statutes for species protection in the western hemisphere. But does it provide a BATNA for those concerned about protecting endangered and threatened species in binational reaches of the Rio Grande?

The ESA is intended to conserve endangered and threatened species and their habitats. This law applies to United States government entities.[36] Governmental entities are required to protect listed species by ensuring that their actions do not jeopardize the continued existence of these species.[37] Congress passed the Endangered Species Act of 1973 (ESA or the Act) to

---

management in the 21st Century: A Tightrope between competing values. W. WATER L. & POL'Y REP., 153, (Mar. 2000).

[35] Laura Smith and Alexander Fernald, *The ineffectiveness of using the National Environmental Policy Act of 1969 to implement environmental enhancement in the Rio Grande Canalization Project*, 14 REV. FISHERIES SCI., 139 (2006).

[36] 16 U.S.C. § 1532 (13) (2006).

[37] 16 U.S.C. § 1536.

> [P]rovide a means whereby the ecosystems upon which endangered species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes and treaties set forth in subsection (a) of this section".[38]

Congress further determined that national policy would be "that all federal departments and agencies shall seek to conserve endangered species and shall utilize their authorities in furtherance of the purposes of this Act",[39] and that "federal agencies shall cooperate with state and local agencies to resolve water resource issues in concert with conservation of endangered species".[40] In a landmark decision, the United States Supreme Court stated:

> It is clear from the Act's legislative history that Congress intended to halt and reverse the trend toward species extinction- **whatever the cost** (emphasis added). The pointed omission of the type of qualified language previously included in endangered species legislation reveals a conscious congressional design to give endangered species priority over the "primary missions" of federal agencies. Congress, moreover, foresaw that §7 would on occasion require agencies to alter ongoing projects in order to fulfill the Act's goals.[41]

Despite the passage of the Act and guidance from the Supreme Court as to the intent of the Act, the trend toward degradation of riverine habitat resulting from water management practices in the Western United States continues. This is particularly evident in the Upper portion of the Rio Grande Basin within the United States, where changes in fish assemblages and extirpation of a number of species from their historic ranges are a direct result of federally initiated water development projects.[42]

---

[38] 16 U.S.C. § 1531(b) (2006).).
[39] 16 U.S.C. §1531 (c) (1) (2006).
[40] 16 U.S.C. §1531 (c) (2) (2006).
[41] *Tennessee Valley Authority v. Hill et al*., 437 U.S. 153 (1978).
[42] Robert J. Edwards and Salvador Contreras-Balderas, *Historical changes in the icthyofauna of the Rio Grande (Rio Bravo Del Norte), Texas and Mexico*, 36 SW. NATURALIST, no. 2, 201-212. *See also* Robert Rush Miller, *Man and the changing fish fauna of the American Southwest*, Papers of the Michigan Academy of Science, Arts and Letters, Vol. XLVI, 1961 (1960 Meeting).

The role of the ESA as it relates to river systems is fundamentally different from the way in which the ESA is applied in other settings. There are three reasons for this: [43]

i. The ESA has a wider reach in a riverine system due to hydrologic factors such as the size of some major drainage basins and the contributions of tributary streams to overall basin hydrology and ecology;

ii. Because many large river systems are controlled in one form or another by federal agencies, Section 7, which requires consultation on major federal actions, is often most widely applied. This is in contrast to application of the ESA in other contexts such as forest management and land development where the operative provision is usually Section 10[44]; and

iii. Species recovery in a river basin setting is different because restoration efforts often involve returning a degraded environment to an approximation of its natural state. In other settings the ESA usually involves protecting the "natural" condition from further harm.

The most important provisions of the ESA, as it relates to inland river systems, are those contained in Section 7. Section 7 requires federal agencies to consult with the Secretary and to "utilize their authorities in furtherance of the purposes of the Act".[45] Section 7 also requires federal agencies to insure that their actions do not jeopardize the continued existence of an endangered or threatened species or adversely affect a species' critical habitat.[46] This prohibition also extends to species that are proposed for listing and

---

[43] Mary Christina Wood, *Reclaiming the natural rivers: The Endangered Species Act as applied to endangered river ecosystems*, 40 ARIZ. L. REV. 197, 200, (1998).
[44] 16 U.S.C. §1539 (2006) (permitting requirements for incidental taking of endangered species).
[45] 16 U.S.C. §1536 (a) (1) (2006).
[46] 16 U.S.C. §1536 (a) (2) (2006).

to the proposed critical habitat for that species.[47] One of the more controversial provisions of the Act, and they are all controversial in one context of another, is the provision that requires the Secretary, after consultation with the federal agency to issue a Biological Opinion, described as follows:

> Provide to the federal agency and the applicant, if any, a written statement setting forth the Secretaries opinion, and a summary of the information on which the opinion is based, detailing how the agency action affects the species or its critical habitat. If jeopardy or adverse modification is found, the Secretary shall suggest those reasonable and prudent alternatives which he believes would not violate subsection (a)(2)[48]

Determining the reasonable and prudent alternative creates the most conflict in Western river systems because the reasonable and prudent alternative can, and often does, require augmentation of streamflow. This creates a serious challenge for water managers in over allocated systems, given that most of the water is already allocated to other uses, leaving none for the species. Water marketing is often the only option, although marketing assumes that water will be priced based on its highest use, which is defined by human needs for water. This can often make this option cost-prohibitive in terms of securing water for the environment.[49]

Section 9 of the ESA relates to taking of endangered species. Taking is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."[50] Taking an endangered species is prohibited under Section 9.[51] It should be noted that there are provisions for incidental taking of species

---

[47] 16 U.S.C. §1536 (a) (4) (2006).
[48] 16 U.S.C. §1536 (b) (3) (A) (2006).
[49] An exception in the Rio Grande is an initiative by the Trans Pecos Water Trust to purchase or lease existing irrigation rights in Texas and convert them to instream uses, http://www.transpecoswatertrust.com/projects.html.
[50] 16 U.S.C. §1532 (19) (2006).
[51] 16 U.S.C. §1538 (a)(1) (2006) (relates to endangered species of fish and wildlife).

subject to a permit issued by United States Fish and Wildlife Service (USFWS).[52] Should a federal agency implement, or propose to implement, an action that results in a taking of an endangered species, consultation under section 7 would be required.[53] This does not mean that the agency necessarily must comply with the opinions of the USFWS as regards the impact of federal actions; it merely means they must consult. An example of the application of this provision in the Rio Grande is the re-introduction of the Rio Grande silvery minnow into the international reach of the river.[54]

ESA and the Courts

There have been no court decisions to date clarifying how ESA provisions would apply specifically to actions of the USIBCW in the binational reach of the river. However, there are court precedents which could shed light on the extent to which litigation under the ESA could be considered a BATNA for environmental interests in any type of negotiation or mediation regarding ecosystem protection in the binational river. A series of lawsuits over implementation of the ESA in the Middle Rio Grande in New Mexico resulted in the initiation of discussions and some cooperation among water users with a goal of moving toward more sustainable river management. Congressional intervention in the form of a rider to an energy bill has since raised questions as to whether Congressional intent of 30 years ago with regards to Endangered Species protection has entered a new era, by raising the specter of legislatively determined biological opinions.[55]

[52] 16 U.S.C. §1539 (2006) (permitting requirements for incidental taking of endangered species).
[53] *supra* notes 46 and 47.
[54] United States Fish and Wildlife Service (USFWS), 500,000 Rio Grande silvery minnows released into river at Big Bend National Park, (2009), http://www.fws.gov/southwest.
[55] Energy and Water Development Appropriations Act, Pub. L. No. 108-137, § 208, 117 Stat. 1827, 1849-50 (2003). *See also* Consolidated Appropriations Act, 2005, Pub. L. No. 108-477, § 205, 118 Stat. 2809,

This situation is not uncommon in river basins across the Western United States. A crisis in water management as a result of ESA litigation opened the door to challenges to the Act because its implementation may mean changes to the way the Law of the River operates in any given system.[56] This type of fundamental change in legal instruments that allocate rights to all of the water in a given system leads to conflict between entrenched water uses and new uses for the environment. These conflicts, within the territorial boundaries of the United States, are more frequently being resolved through litigation involving the "meaning" of the ESA or the "intent of Congress" in passing the legislation.

Even in situations where the ESA clearly applies, the results are mixed. For example, implementation of the ESA in the Columbia and Upper Colorado River Basins did not result in protection of endangered species.[57] In fact, the opposite occurred because of the unwillingness of federal agencies, including the USFWS, to meet their statutory obligations. Additionally, politics played a large role, often greater than that of science, in ESA implementation in those basins. One suggested remedy is an enhanced role for the Courts which could include judicial review of agency determinations under Section 7 and assumption of a more activist role in required relief.[58] However, at the binational level in the Rio Grande, what court would have jurisdiction, particularly when there is no treaty relating to conservation of species or protection of ecosystems? Even if one assumes that the 1944 Treaty provisions are flexible enough to cover species

---

2949 (2004) and Energy and Water Development Appropriations Act, 26, Pub. L. No. 109-103, § 121(b), 119 Stat. 2247, 2256 (2005).

[56] The Law of the River includes the body of law governing water management in an individual river system, including prior appropriation in the Western states, Interstate Compacts and Treaties.

[57] Wood, *supra* note 44.

[58] *Id.*

concerns, or could be through amendment via the Minute system, there are no provisions in this treaty for judicial oversight of any kind.

The question of whether the ESA provides a BATNA that is adequate to protect species in the binational Rio Grande is complex. On the one hand, Section 7 requires consultation when an agency has discretion in an action. This section could also apply when that discretion is not expressly prohibited. In the case of the USIBWC, the binational character of the river and the United States' obligations under the 1944 Treaty limit the agency's discretion. The USIBWC has little flexibility for independent action given that the 1944 Treaty controls management of the river. This means that the United States probably could not unilaterally dedicate instream flows to species needs and expect Mexico to honor this commitment, especially when such as action could harm Mexican water allocations and uses that are protected by the Treaty. Because of this, the ESA probably does not provide a BATNA for United States environmental interests in the context of negotiations over United States water operations in the international reaches of the river.

Another legal hurdle is whether a United States federal agency can consider extraterritorial issues, although both discretion and extraterritoriality are closely intertwined in the binational Rio Grande. In *Defenders of Wildlife v. Norton* the U.S. District Court ruled that the U.S. Bureau of Reclamation's (USBR) duty to consult over operations affecting the Colorado River Delta did not extend to operations affecting "extra territorial" species downstream from river flows over which the Bureau had no discretionary control.[59] USBR argued successfully that it had no control over water deliveries to and within Mexico and therefore only needed to consider actions within its

[59] *Defenders of Wildlife v. Norton,* 257 F.Supp.2d 53, (2003)

area of discretion in the United States. The Court agreed noting that every drop of water had already been accounted for by users on both sides of the border through the 1944 Treaty allocations. In this case the spatial relationship between the two countries was upstream/downstream. In the binational Rio Grande, the two countries are side-by-side. Thus options for flow augmentation to protect species and their habitat are severely limited unless the action is a joint binational endeavor.

One solution to the judicial impasse over ESA litigation is to create collaborative processes to avoid litigation. However, these types of processes have had limited success. In the Middle Rio Grande in New Mexico, the collaborative process for protection of the endangered silvery minnow is ongoing.[60] Many water users participated in this process because of concern regarding the effect of ESA Section 7 consultations on water available from USBR contracts.[61] If USBR contracts, such as those with the Middle Rio Grande Conservancy District (MRGCD) are no longer subject to Section 7, and environmental advocates must rely on Section 9 alone, the potential exists for the water users to distance themselves from the process. This could lead to dire consequences for endangered aquatic species in this reach of the Rio Grande in the future.

The treatment of endangered species in the Colorado River Delta also provides insight into how collaborative processes may affect outcomes for environmental needs in the context of a binational river basin.[62] In this case, the international character of the Colorado River precluded application of the statutory national level protections of either

---

[60] More information about this program is available at www.middleriogrande.com.
[61] Reed D. Benson, *Dams, duties and discretion: Bureau of Reclamation water project operations and the Endangered Species Act*, 33 COLUMB. J. ENVTL. LAW, no. 1, at 53-56, (2008).
[62] Bret C. Birdsong, *Séances, ciéngas and slop: Can collaboration save the delta*, 8 NEV. L. J., 853, 866, (2008).

country and a collaborative process was initiated in the United States. Environmental groups were initially given a seat at the table; however, the concerns of these groups were given short shrift because the existing collaborative structure favored the more powerful interests of the water users.[63] In effect, there was no recourse for the environmental groups outside the collaborative process, and thus, for them, no BATNA except for participation in the collaborative process. This experience clearly illustrates that the legal framework for ecosystem protection should be binational in order to be effective. After all, nature does not "know" or "respect" humanly constructed boundaries.

A Vision for the River?

Consideration of both environmental and water user interests would require a paradigm shift to a collective vision for the river, which does not exist at this time. For example, the current vision for the river from the perspective of the USIBWC is to "preserve the international boundary and improve the quality, conservation, and utilization of transboundary water resources in the border region".[64] The vision of CILA (Comisión Internacional de Límites y Aguas), the USIBWC's Mexican counterpart, is to provide leadership in handling boundary and water issues in a framework of respect and institutional cooperation and to responsibly and efficiently handle financial and natural resources to establish better living conditions in the border region.[65]

There is some disconnect between these visions. On the Mexican side of the border, the vision ties resource use to human benefits. On the United States side, the focus is simply on use of the resource, which reinforces a rights based perspective. However, neither vision includes broader concepts such as providing linkages to the

---

[63] *Id.* at 866.
[64] http://www.ibwc.state.gov/Files/FY06_Strategic_Plan.pdf.
[65] http://www.sre.gob.mx/cila/.

ecosystem goods and services the river provides. Absent such linkages, a movement beyond rights to interests, including those of the environment is unlikely.

Interest based approaches can reduce dispute resolution time frames and they also have the added benefit of flexibility to address shifting priorities. The United States has certainly entered into these types of negotiated agreements on its northern border.[66] Aside from legal and institutional concerns, shifting from rights to interests does create some dilemmas. Initially, a shift towards creating a context for an interest based focus can exacerbate existing problems because policy time lags are often the result of interest-based negotiations.[67] In other words, response to rapidly evolving problems may be hindered.

In addition to policy time lags, the ability to move from rights to interests can be affected by the way an issues is framed. A frame is the way an individual or group looks at a particular situation. Frames can either help to resolve conflict or prevent its resolution.[68] In the case of the Mexican water debt crisis in the Rio Grande, the conflict was presented as an either-or dispute. Mexico claimed an inability to comply with treaty requirements because of extraordinary drought. The United States position was simply that the U.S. had an entitlement claim to the water. Both sides used characterization frames in the press to foster support for their positions.[69] The frames in this case are a direct result of the methods used to resolve the dispute. Diplomatic negotiation is used

---

[66] Wolf, *supra* note 14, at 251.
[67] Wolf, *supra* note 14, at 249.
[68] Thomas Shriver and Charles Peaden, *Frame disputes in a natural resource controversy: The case of the Arbuckle-Simpson Aquifer in South-Central Oklahoma*, 22 SOC'Y & NAT. RESOURCES, no. 2, 143, 146, (2009). *See also* Boris Brummans, Linda Putnam, Barbara Gray, Ralph Hanke, Roy Lewicki, and Carolyn Wiethoff, *Making sense of intractable multiparty conflict: A Study of framing in four environmental disputes*, 75 COMM. MONOGRAPHS, no. 1, 25, (Mar. 2008).
[69] Alexander Martin, *supra* note 23.

to settle disputes; therefore the issue is framed in terms of each nation's respective rights to the water.

The result of the divergent issue frames was that no action occurred to resolve the underlying issue of defining extraordinary drought. In fact, in this case, the issue is still unresolved. This type of policy time lag reduces the likelihood of equitable and durable resolutions.[70] This is because the greater the differences between positions, the greater the likelihood of an intractable conflict.[71] One option could be to reframe the issue within the context of "sustainability", which would also precipitate a shift to an interest based framework. But, can such a reframing occur within the current conflict management paradigm? And, if not, what needs to change?

Process Design

A traditional analysis of water conflicts would classify those in the binational Rio Grande as "resolved" and classify the relationship between the parties as "cooperation".[72] However, the research agenda for dispute resolution in transboundary watersheds tends to focus on whether or not an agreement is reached, i.e. a treaty or protocol is signed.[73] Classifying conflicts in this way may distort the extent to which the relationships between the parties to a dispute are actually cooperative. For example, there were various interim agreements between the United States and Mexico during the conflict over the water debt between 2000 and 2005. These interim agreements were renegotiated several times due to Mexico's inability to supply the requisite water. An analysis based solely on whether an agreement was reached would likely consider this as a cooperative outcome. This

---

[70] Wolf, *supra* note 14, at 248.
[71] Shriver, *supra* note 69, at 146.
[72] Wolf, *supra* note 14.
[73] Oregon State University, Basins at Risk Project, http://www.transboundarywaters.orst.edu/research/basins_at_risk/index.html

would lead to a conclusion that there are a large number of cooperative outcomes; despite the repeated renegotiation of the issue of insufficient water deliveries and the heated nature of this conflict at state and local levels.[74]

As with most attributes of a complex system, the reality is not that simple. If a conflict is deemed resolved because an agreement is reached, only to continue to occur when similar situations arise in the future, change is needed in the standard method used to resolve disputes. If diplomatic negotiation is ineffective in the long term, and traditional ADR methods are not adequate because there is no BATNA, an adaptive governance framework based on collaborative processes may be the only solution for a sustainable future.

Moving from rights to interests requires a movement away from nationalistic interests and a shift in focus towards more integrated management of the river for the benefit of the river basin and its inhabitants, including aquatic species. In the Rio Grande this shift may be slowly beginning with the signing of Minute 308 and the incorporation of wording about sustainable use into the dialogue regarding water management.[75] However, no concrete overarching agreements for sustainable basin management have been signed to date, although discrete initiatives to protect water quality and improve on-farm efficiency are ongoing.[76] This indicates the possibility that interest based management could be accomplished within the current legal and institutional structure, if the United States and Mexico have the political will to move forward jointly.

There are many principles of dispute resolution system design that need to be considered in developing a collaborative process on a very large scale, including

---

[74] Alexander Martin, *supra* note 23.
[75] 1944 Treaty, supra note 25, at Minute 308.
[76] http://riogrande.tamu.edu/, See also http://www.ibwc.state.gov/CRP/Index.htm.

leadership support, conflict prevention rather than conflict management, and a mechanism that facilitates progress from conflict resolution to monitored management initiatives. Transforming a system towards adaptive governance requires, among other things, a movement away from polarization to shared visions, flexible processes that are discourse oriented, and an acknowledgement that although conflict is inevitable, a communication forum should be maintained.[77] Trends in adaptive management emphasize not only experimentation but also linkages between multiple governance levels and are converging to a new paradigm; adaptive co-management.[78] ADR, with its focus on resolving conflicts as they occur, focuses on shorter term solutions and not on long term decisions and policies.[79]

Shariff proposes a set of principles for institutions designed to manage conflict, which may be applicable to process design in the Rio Grande:

i. Inclusiveness: all stakeholders affected by the institution's work;
ii. Broad coverage of related issues;
iii. Depth of jurisdiction on individual issues;
iv. Centralized data sources and data gathering;
v. Decentralization and multiple forums;
vi. Control over decisions should be vested in those affected by the decisions; and

[77] Per Olsson, Lance Gunderson, Steve R. Carpenter, Paul Ryan, Louis Lebel, Carl Folke, and C.S. Holling. *Shooting the rapids: Navigating transitions to adaptive governance of social-ecological systems*. 11 ECOLOGY & SOC'Y, no. 1, 18 (2006).
[78] Dave Huitema, Eric Mostert, Wouter Egas, Sabine Moellenkamp, Claudia Pahl-Wostl, and Resul Yalcin, *Adaptive water governance: assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda*. 14 ECOLOGY & SOC'Y , no. 1, 26, (2009).
[79] Robin Gregory, Tim McDaniel and Daryl Fields, *Decision aiding not dispute resolution: Creating insights through structured environmental decisions*, 20 J. POL'Y ANALYSIS & MGMT., no. 3, 415, (2001).

vii. Opportunities for regular review of processes to allow adaptation to changing circumstances.[80]

The most important of these, and the most difficult, from the perspective of application to the Rio Grande are inclusiveness, decentralization, and control. This is because these particular principles are not currently operationalized in the basin's institutional framework. For a transboundary watershed, another principle should be that decision making efforts need to be binational in scope to be effective. The experience of the Colorado River Delta illustrates this principle. This collaborative process broke down over questions of jurisdictional scope, when some United States participants advocated for consideration of the affected environment in Mexico, although Mexico was not included in the process.[81]

Structurally, a design such as that proposed by Sharif would seem, on its face, to be an adequate starting point for constructing a dispute resolution process in the Rio Grande. Unfortunately, all factors on the above list are not created equal. A fundamental stumbling block to successful implementation may be the differing goals of socially based dispute resolution and scientifically based inquiry.[82] The goal of the dispute resolution process is some sort of finality, while scientifically based processes are searches for answers in a process that involves constant reassessment. Incorporating an adaptive management framework into basin water management would be one method for managing this disconnect. Historically, the reluctance of the United States and Mexico to reopen allocation issues in the 1944 Treaty, or to address issues such as drought that may

[80] Khalil Z. Shariff, *Designing institutions to manage conflict: Principles for the problem solving organization*, 8 HARV. NEGOT. L. REV., 133, (2003).
[81] Birdsong, *supra* note 63.
[82] Barbara Cosens, *Resolving conflict in non-ideal complex systems: Solutions for the law-science breakdown in environmental and natural resource law*, 48 NAT. RESOURCES J., 257, 264, (2008).

be directly related to allocation frameworks, may limit the effectiveness of a dispute resolution process that does not definitively solve a given problem.

A cautionary note is in order. In order for collaborative environmental decision making to work within the context of transboundary water relations between the United States and Mexico, the legal framework must specifically allow for the protection of environmental attributes. If it does not, then collaborative decision making, or any other form of inclusive dispute resolution process, may not result in net benefits to the environment. With respect to a re-structured dispute resolution process, the 1944 Treaty suffers from many of the same issues faced in conflicts where science plays an important role.[83] There is no neutral scientific advice, the Treaty is written unclearly largely as a result of efforts to ensure its passage, the data needed to address basin issues related to aquatic resources is spotty at best, and there is a considerable lack of transparency in decision making by the IBWC.[84]

Consensus based processes are often touted as a method for resolution of complex environmental issues. There are noteworthy issues with this approach. Those most frequently listed are:

i. consensus based processes tend to focus on problems that are easiest to resolve and are therefore often the least important;

ii. consensus based processes tend towards a goal of reaching agreement instead of reaching a quality agreement;

iii. there is an inherent bias in participant selection because those who participate are those more likely to benefit from the agreement;

---

[83] *Id.* at 287.
[84] Robert J. McCarthy, *Executive authority, adaptive treaty interpretation, and the International Boundary and Water Commission, U.S.—Mexico*, 14 U. DENV. WATER L. REV., 197, (2011).

iv. Marginalization of disadvantaged groups because the gap between citizen and elite knowledge skews power towards the elites; and

v. There is no agreement as to what the problem actually is.[85]

An alternative is a deliberation based paradigm. Participants discuss opinions and viewpoints, consider all of the arguments and develop linkages between positions. This type of process would allow more discourse on the exact nature of the problem under consideration. To be effective, a deliberative process would need to be inclusive of multiple stakeholders, which raises another set of issues related to binational water management in the Rio Grande.

<u>Public Participation</u>

Participatory processes should also not be viewed as a panacea for incorporating other viewpoints into a dialogue and deliberation type process. Some view improperly designed participatory processes as contributing to power inequalities because of the timing of these processes in policy development and the lack of inclusion of deliberative results in policy implementation.[86] Another issue is what to do with disempowered groups.

Disempowered groups are defined various ways; for example as those excluded from policy making because they have no administrative standing, or those who traditionally have less influence because of lack of ability to lobby, organize or secure legal representation.[87] Disempowerment is not solely a function of social attributes of a

---

[85] Marleen van de Kirkhoff, *Making a difference: On the constraints of consensus building and the relevance of deliberation in stakeholder dialogues*, 39 POL'Y SCI., no. 3, 279, 282, (2006). *See also* Christopher F. Karpowitz, Chad Raphael, and Allen Hammond, *Deliberative democracy and inequality: Two cheers for enclave deliberation among the disempowered*, 37 POL. & SOC'Y, no. 4, 576, (2009).
[86] Lorrae van Kerkhoff and Louis Lebel, *Linking knowledge and action for sustainable development*, 31 ANN. REV. ENVTL. RES., 445, 461, (2006).
[87] Karpowitz, *supra* note 86 at 579.

particular group; groups can be disempowered in relation to specific issues.[88] For example, in the case of disputes over the Mexican water debt, irrigation interests in the United States, who previously wielded considerable power and influence with respect to allocation issues, were excluded from the decision making process with respect to negotiation and resolution of the water debt crisis.[89] With respect to power relationships, particularly as these may impact linkages between research and action, issues such as funding, oversight, and appropriateness can contribute to exclusion of particular discourses.[90]

Cultural Considerations

In addition to power relationships, differences in national cultures should be considered in design of an appropriate public deliberative process. For example, Enserink et al.[91] examined cultural factors and public participation in four European countries using Hofstede's[92] dimensions of national cultures. These authors hypothesize a relationship between Hofstede's dimensions and public participation in river basin management.

Hofstede's dimensions include power distance (degree of equality), individualism/collectivism, uncertainty avoidance (tolerance for ambiguity) and masculinity. Higher rankings for power distance correlate more closely with top-down management regimes, individualism is not a determining factor, and collectivism (higher individualism) improves the likelihood of public participation in more formal settings if power distance is low. High masculinity scores are not likely to produce public

---

[88] *Id.* at 579.
[89] Alexander Martin, *supra* note 23
[90] van Kerkhoff, *supra* note 87 at 473.
[91] Bert Enserink, Mita Patel, Nicole Kranz, and Josefina Maestu, *Cultural factors as co-determinants of participation in river basin management*, 12 ECOLOGY & SOC'Y , no. 2, 24, (2007).
[92] http://www.geert-hofstede.com

participation, and high uncertainty coupled with high power distance is more supportive of top-down control. Table 5.1 lists the Hofstede country dimension scores for the United States and Mexico.[93]

Table 5.1 Hofstede Country Dimension Indices

Country	Power Distance Index	Individualism	Uncertainty Avoidance	Masculinity
Mexico	81	30	69	82
United States	40	91	62	46

Although the relationship between country dimension scores and public participation is hypothetical, these scores could be used to identify potential barriers to implementation of an inclusive process and actions which could mitigate those barriers. High individualism scores indicate a tendency to be unconcerned about how a negotiation is going for others so long as it is going okay for oneself.[94] This factor coupled with asymmetric power suggests a need to ensure that any process design is protective of disempowered groups. The disparate power distance scores for the two countries, which is a measure of whether a society is hierarchical or egalitarian, supports the need for design attributes that allow less powerful groups to formulate their positions and interests without interference from more powerful groups. The tendency in hierarchical societies such as Mexico is deference to those in higher positions, which, in this case, might tend to allow governmental authorities to control the nature of any discourse.[95] Additionally, differences in individualism scores between the two countries may also influence

[93] *Id.*
[94] Jeanne Brett, *Culture and negotiation*, 35 INT'L J. PSYCHOL, no. 2, 97, (2000).
[95] *Id.* at 100.

behavior during the process as well as the participant's view of the process itself.[96] These differences could translate into differing views of the nature of conflict, i.e. whether conflict is embraced or avoided, whether participant interaction is formal or informal, and whether discussions are either direct and task oriented or occur more holistically.[97]

A Path Forward

Do the appropriate conditions exist in the Rio Grande for transformative change? First, in order to address issues related to disempowerment, enclave deliberation may need to be a component of a broader process. Enclave deliberation allows the voice of marginalized and excluded groups to be heard by providing those groups an opportunity for internal development of positions within a more homogeneous group prior to incorporating those positions into broader policy discussions.[98] Enclave groups can be structured around views, structural location and identity.[99] In the case of the Rio Grande, enclave groups could be based around either structural location (the members' relationship to the issue) or views (a group's position). If the goal is to move the discussion from rights to interests, structural location would seem to be the best way to include consideration of the environment.

The USIBWC does make some efforts towards public participation through Citizens Forums. Currently, the USIBWC organizes these forums on the basis of river basin (Colorado or Rio Grande) and location in the river basin.[100] However, these forums are designed to inform citizens about agency initiatives and not to promote citizen input into policy issues. Grouping by geography has the benefit of focusing participants on

---

[96] Walter Wright, *Cultural issues in mediation: Individualist and collectivist paradigms*, (Jan. 2000), http://www.mediate.com/articles/wright.cfm.
[97] *Id.*
[98] Karpowitz, *supra* note 86, at 582.
[99] *Id.* at 583.
[100] http://www.ibwc.state.gov

particular issues; however, the current structure does little if anything to promote diverse viewpoints from heretofore excluded groups and hence would not be effective as a surrogate for public inclusion in a deliberative process.

Traditionally, adaptive management is viewed within the context of re-evaluation of scientific decisions through monitoring and experimentation. However, adaptive management concepts can and should be applied to social decisions such as institutional design elements. Creating a process for a very large group of stakeholders from two countries where there is a lack of experience in incorporating stakeholder concerns would necessitate re-evaluation of design elements at appropriate intervals. In addition, changing conditions in the system could also influence design elements and require their re-evaluation in response to rapidly developing social and ecological changes in the system. Within the context of developing a framework for adaptive governance, the final design element for the deliberative process outlined above would be adjustment mechanisms to account for potential problems resulting from implementation of theoretical design frameworks in social situations.

Experiences from Europe point to the need for design of participatory processes for water resource management to include legal and financial support as well as a clear mandate.[101] This ensures that results and recommendations from stakeholders are incorporated into the decision making process. On the United States side of the border additional restrictions could apply to an effort to create a stakeholder entity with advisory capacity. The Federal Advisory Committee Act[102] might apply to a stakeholder

---

[101] Ilke Borowski, Jean-Pierre Le Bourhis, Claudia Pahl-Wostl, Bernhard Barraqué, *Spatial misfit in participatory river basin management: Effects on social learning, a comparative analysis of French and German case studies*, 13 ECOLOGY & SOC'Y, no. 1, 7, (2008).

[102] Federal Advisory Committee Act, Pub. L. 92-463, 86, Stat. 770, (1972).

committee developed to provide input to the USIBWC. Some exemptions to the act apply, for example a stakeholder advisory group would probably be exempt if chartered by the state of Texas or by both Texas and New Mexico. It is also unclear what the status of the committee would be if it were established in the binational setting and whether it could provide advice to the USIBWC, and expect that advice to play a significant role in decision making, given that disputes are currently resolved by diplomacy.

Assuming that legal and institutional barriers could be overcome, this section presents a pathway for transformative change in the management of water resource conflicts in the Rio Grande. First, diplomatic negotiation certainly must continue to have a role because of the foreign relations component of transboundary water management. However, this type of dispute resolution should be the final stage in a process where what is to be decided and the projected outcome is guided by a broad spectrum of interests. Furthermore, the process should be multi-staged, beginning with engagement at the local level, proceeding through a deliberative stakeholder process which includes joint fact finding and concluding with a meaningful role in joint decision making.

The first order of business would need to be development of a shared vision for the Rio Grande. The process for developing a shared vision should begin from the bottom up and include stakeholders and the public from both sides of the border. Vision development could start with an enclave deliberation process, in the form of Civic Forums.[103] The forums referred to here would be community based, using outside independent facilitators, with agency and governmental representatives involved solely to provide information and data specifically requested by the community. In this way the

[103] The nomenclature adopted here is a lexical convenience and does not imply or advocate that these Forums would or should build on those currently operated by the USIBWC.

concerns of the community could be elicited in a format that facilitates discussion and encourages dialogue. This does not mean that the USIBWC or other agencies could not participate in the role of a convener, or by contributing funding, but that this or other agencies should not be "in charge" of the process.

Focusing the public dialogue on problems, goals, and issues would generate input for subsequent stakeholder discussions with a foundation in community values. In addition, the public dialogue process would help ensure that decision making effectively considers and delivers public benefits, as the public defines them, via feedback between the stakeholders and the public. Public views would be represented and stakeholders and decision makers would then be accountable to the public interest. The Citizens Forums would also provide input on the composition of the stakeholder groups to ensure that they were representative of all interests.

The next stage would be consideration and deliberation by a stakeholder group that includes all interests. Moore et al. propose a framework for stakeholder participation in the Rio Grande, which could represent a starting point for process design.[104] These authors suggest a structure, geared towards planning, that includes a technical advisory group composed of federal level agencies from both countries as well as a representative of each affected state. At the state level, each state representative to the binational group would have a technical advisory group representing state level interests. Structuring this initiative in the form of a technical advisory group runs the risk of perpetuating the same type of command and control approach that resulted in current systemic problems. Even something as seemingly insignificant as the name of the group could have implications for participation by some sectors. Framing the groups as stakeholder groups in the

[104] Moore, *supra* note 26.

context of sustainable use might mitigate the participation issue and allow ecosystem needs to be considered in the process. Ultimately, the Citizens Forums would also weigh in on the composition of the stakeholder groups. The final stage of the process would be development of specific mechanisms for incorporation of stakeholder input into decision making. The role of stakeholders should be beyond that of a merely advisory body for any deliberative process to be meaningful.

Conclusion

The current conflict management system in the Rio Grande basin is not resilient because system adaptability is limited. Current conflict resolution practices do not result in sustainable outcomes and should not be considered to be effective. Examining dispute resolution outcomes by focusing on the methods that created those outcomes rather than the outcomes themselves provides insight into a pathway for transformative change in the system. The most promising framework for such change is a dialogue and deliberation based process. This is one of the few options available for meaningful incorporation of environmental concerns into policy and decision making. A preliminary framework is proposed but the actual implementation of such a framework should be based on input from those most affected by water management in the binational river.

CHAPTER VI

COMPARATIVE ANALYSIS OF INTERNATIONAL WATER RESOURCE INSTITUTIONAL REGIMES

Institutions created for the management of transboundary water resources vary based on internal factors, such as the participating nations and water management issues, and external factors, in particular global economic policies and the influence of international donors. These factors are in addition to the normal suite of river basin management issues in watersheds that are wholly within one country. The international aspect of these basins adds another level of complexity for water resource management because it may require the subordination of national interests to the public good of the entire watershed and its inhabitants.

The Rio Grande drains two countries, the United States and Mexico, and eight states within the two countries: Texas, New Mexico, Colorado, Chihuahua, Coahuila, Durango, Nuevo Leon and Tamaulipas. In addition to being a major boundary between the two countries, it is the fifth longest river in North America, flowing over 1,885 miles from its headwaters in Colorado to its outlet at the Gulf of Mexico. The drainage area of the basin is approximately 355,000 square miles, of which 176,000 square miles contributes flow to the river. The basin covers 11% of the continental United States, and 44% of the land area in Mexico. The climate is arid to semi-arid, with precipitation ranging from less than 8 inches per year in the San Luis Valley of Colorado, to 10 inches per year near Ciudad Juarez/El Paso, to approximately 24 inches per year at Brownsville/Matamoros.

Historically, attaining adequate water supplies for agricultural use and the water needs of rapidly-growing human populations has been the predominant management focus, generating varying degrees of conflict at the local, state and international level. As an example, current water supply management paradigms in the Rio Grande Basin identify water needs for human consumptive uses, but typically do not identify flows to sustain riverine ecosystems. Unfortunately, the institutional structure in the basin does not include or foster mechanisms to resolve conflicts in ways that result in sustainable use of the river for all purposes, including sustaining riverine ecosystems. Extraordinary drought and growing populations have strained the existing agreements and institutional structure, and they have thus far proven ineffective for resolving the more complex issues associated with achieving the sustainable use of the river and its resources. Failing to deal with these problems may further strain an institutional structure essentially lacking the ability to deal with such issues.

In addition to water allocation issues for both humans and the environment, relevant basin problems include: (i) habitat loss; (ii) lack of a unified cross-sectoral, cross-jurisdictional forum to address ecosystem management; (iii) reliance on litigation pursuant to the Endangered Species Act to protect the growing numbers of species at risk in reaches of the river subject to the jurisdiction of the United States; (iv) legal and financial issues related to listing and evaluation of risk to listed species in Mexico; (v) population growth and associated social and economic issues; and (vi) water quality concerns. Numerous individual programs address these issues, however, fragmented authority at all governmental levels, and a reluctance to address water allocation frameworks codified in existing treaties and interstate compacts, make sustainable management of water resources within this basin a daunting challenge.

Sustainable management of transboundary rivers requires consideration of a multitude of issues, ranging across the ecological and social spectrum, and many methods have been proposed to deal with these types of issues. This study examines transboundary water resource institutional regimes existing in countries around the world to determine how the management regime in the Rio Grande compares to that in other basins and to identify institutional structures that may be transferrable to the specific case of the Rio Grande. The questions to be addressed include how, and to what extent, the institutional regime exhibited in the Rio Grande compares to those evidenced across a range of international regimes and whether such a comparison can identify pathways and processes that could lead to a more resilient and effective institutional structure for the Rio Grande.

A methodology for cross-basin comparison must first be established. Theoretical frameworks developed for both small scale and large scale institutional regimes are evaluated in this chapter, beginning with an assessment of issues of scale as it relates to analysis methods. Common Pool Resource (CPR) design principles, a local scale method, and simple diagnostics, a global scale method, are evaluated for their applicability to an international river basin setting. Issues with using CPR design principles in a cross basin analysis are identified and discussed. Simple diagnostics is selected for a comparative analysis across a range of international river basin institutions around the world. International initiatives, both legal and financial, and the roles these factors may play in the structure of existing international water management regimes, are discussed within the context of path dependency and the issues it creates for cross basin case study comparisons.

The comparative analysis is based on a structured focused comparison approach. This approach is used to apply diagnostic factors to institutional regimes in the Rio Grande and other international river basins to determine similarities and differences among the regimes. The selected basins vary based on the number of nations involved, climatic conditions, economic status of the participants, and consideration of cultural attributes that could impact the design of management regimes. The basins are then ranked on the basis of the results of the comparative analysis. This paper concludes with an assessment of the rankings and identifies strengths and weaknesses of the Rio Grande institutional regime relative to other international water management regimes.

Scaling Issues and Analysis Methods

There are a number of methods for analyzing institutional designs for water resource management. However, most were designed to examine resource issues at particular scales. For example, institutional design can be investigated using design principles derived from research into smaller scale systems or Common Pool Resources (CPR). It also can be considered on the basis of factors derived from research at the larger international or global level. This inevitably leads to questions as to whether or not findings based on local level analyses can be scaled up, or whether those based on global level analyses can be scaled down (Brondizio et al. 2009).

The focus of research on CPRs has traditionally been governance units at a local scale. CPRs are identified by two properties. First, they are nonexcludable, in that it is impossible to prevent all members of a user group from availing themselves of their benefits. Second, they are rival, in that use of the CPR by some members reduces the supply or use available to other members. Hooper indicates that river basins should be considered as CPRs, suggesting principles of river basin management to "overcome the tragedy of the river basin commons" (2005, 232). Brown (2003) maintains that the regional water resources of the Middle Rio Grande can be considered a complex CPR problem. However, Young notes '[C]reating a management regime to protect… an ecosystem requires members of the relevant group to join forces to supply a public good, whereas the tragedy of the commons arises from actions of a group of users that deplete or destroy a good supplied by nature" (2002, 147). In a managed river basin, the management of the system is often based on laws and treaties which, in turn, govern the extent to which the 'good,' water in this case, is actually supplied to human users.

In evaluating whether or not a transboundary river basin could be considered as a CPR, the issues of excludability and rivalness must be addressed. These issues pose some particular conceptual problems. For example, in the Rio Grande/Rio Bravo and its subwatersheds, excludability is manifested in the form of prior appropriation at the state level within the United States, and also in the form of water allocation paradigms embodied in a 1944 Treaty that allocates the water between the United States and Mexico (1944 Treaty). However, water allocation regimes are socially constructed; therefore, they are not intrinsic properties of the natural system. These socially constructed management regimes are the primary determinant in whether the 'good' (water) supplied by nature is available for particular users, including the environment.

Another issue related to identification of a river basin with a large geographic extent as a CPR is uncertainty. Local users are more likely to have a sense of the physical systems that immediately surround them. At a river basin scale, as complexity increases, there is increasing uncertainty with respect to attributes of ecosystems and the interactions of those attributes. This can lead to issues associated with the interplay of science and policy, which results in implementation issues for CPR design principles.

There is no single approach for resolving complex resource problems (Ostrom 2005). Ecological, social and political realities are always changing, meaning that a particular set of rules will not necessarily result in the same allocation of benefits among users over time. Ostrom (2005) also notes the hazards inherent in solutions proposed by academics and other policy analysts "outside" the problem. Young (2002b) suggests that attempts to apply local processes at larger scales should proceed with caution. Applicability of the "lens" of CPRs to water resource issues in transboundary basins is thus complicated.

After a comparative analysis of local management schemes in Tanzania, Quinn et al. (2007) concluded that the design principles should not be imposed on resource regimes, but can instead be used as a framework for analysis. Although this approach would solve some of the issues associated with applying the CPR design principles in an analysis of a transboundary river basin, it does not address the issue of which design principles should be used for the analysis. The number of design principles varies according to author, and most of the design principles are directed to local level institutional structures (Agrawal 2001). Agrawal further comments that issues of boundaries and stationarity could result in re-categorization of some attributes of CPRs from context to elements of an analysis, as these relate to specifications of design principles.

Young (2002) identifies problems with use of CPR design principles in an international or global setting. Small-scale CPRs are a relatively homogenous class. Environmental issues at larger scales, such as regionally or globally, are heterogeneous. This difference may hinder attempts to scale CPR design principles up from the local level to the global level. In addition, CPR design principles may not adequately account for the influence of externalities, either acting upon a CPR system, or where the CPR is itself the source of externalities with respect to those outside the CPR.

Brondizo et al. (2009) note that there is no single spatial or temporal level applicable to effective governance of resource management regimes. Functional interdependencies and connectivity contribute to multilevel issues in any regime. These authors point out that most CPR research is conducted at small scales, while a concurrent research agenda examines governance issues at a global scale. There is little research on the appropriate scale for analyzing institutional systems design for international river basins because they are essentially a regional problem with an international component. Because of scaling issues related to use of the CPR design principles, and what may be limited applicability at larger scales, institutional diagnostics, which focuses on specific attributes of an institutional regime, is a more appropriate vehicle for a cross-comparisons between international river basins.

Young (2002) suggests institutional diagnostics as a method for evaluating the effectiveness of institutions. This approach acknowledges that environmental problems should be viewed on a case-by-case basis and that recommendations be tailored to account for particular combinations of social and ecological conditions. There are two types of institutional diagnostics: simple and complex. Simple diagnostics include: (i) identification of social and ecological conditions; (ii) design implications associated with those conditions; and (iii) application to specific cases. Simple diagnostics acknowledges chaotic behaviors in complex systems, and addresses problem duration and uncertainty regarding the nature of ecosystem properties. However, simple diagnostics evaluates problems individually for institutional design implications, and assumes that individual problems and their design implications do not interact. Complex diagnostics adds the dimension of interaction between system elements. It is often necessary to use a combination of both simple and complex diagnostics in evaluating institutional regimes (Young 2002).

Clearly any suite of diagnostic conditions would exhibit substantial interrelatedness in a complex and dynamic system. For example, early warning systems involve some sort of monitoring procedures, such as gaging stations, water quality monitoring or biomonitoring. Economic and developmental disparities often exist among individual nations within a river basin; however, those nations with more resources can be involved in collaborative arrangements to provide technical or financial assistance to less developed countries. This would be considered a technology transfer within a diagnostic framework. Pahl-Wostl et al. (2007) highlight the interdependency of social learning and uncertainty, which are issues inextricably linked to equity and fairness.

Social learning is also related to capacity building and technology transfers wherein mechanisms such as workshops or facilitated discussions allow for integration of new or divergent scientific viewpoints. Young (2002) suggests that these interactions should not be glossed over in many cases. The purpose of the cross-case comparison described below, however, is merely to determine whether broad-scale generalizations may be applicable to individual cases. Therefore, this analysis only considers the simple case wherein diagnostic conditions are not interrelated.

International Influences and the Problem of Path Dependency

International Law and Practices

A major development of current international water law were the 1966 Helsinki Rules on the Use of International Rivers (Rules), which encompassed issues related to reasonable and equitable use. Although these Rules were not adopted, they were practiced to the extent that the Rules reflected what most states were already doing (Dellapenna and Gupta, 2008). The 1997 U.N. Convention on the Law of Non-Navigational Uses of International Watercourses was adopted by the U.N. General Assembly, but does not replace previous agreements unless negotiating parties choose to do so. It also does not address ecological issues. Nevertheless, this convention underlies Integrated Water Resource Management (IWRM) in many international river basins. (Dellapenna and Gupta 2008 and Pahl-Wostl et al. 2008).

The Berlin Rules on Water Resources, adopted by the International Law Association in 2004, extend the international water law framework beyond allocation issues by encompassing related ecosystem issues, groundwater, and public participation (Dellapenna and Gupta, 2008). Transferability of this legal framework across all international river basins may be a challenge. Many water resource issues are context dependant. Therefore, this more comprehensive global legal framework may not adequately consider the cross-scale interaction between local, state and national legal frameworks. Careful application is required when imposing these generalized principles on an individual complex social-ecological system.

The desire to “help” developing countries through the export of science-based river basin management began in the mid-twentieth century with U.S. attempts to encourage application of the Tennessee Valley Authority (TVA) model. The TVA model advocated large scale development of the river, but also addressed economic issues, poverty in particular, through a series of linked initiatives. The attempts to export the TVA model were rooted in a belief that its successes could be replicated in other river basins (Molle, 2006). In fact, the TVA model was a major factor in development of river basin commissions in river basins in Mexico, in the Danube and Mekong basin countries, Senegal and other countries. The most frequently-cited management approach at the present time is IWRM.

As with the adoption of the TVA model in developing river basins, use of IWRM in international river basins is becoming more widely practiced, effectively globalizing this management paradigm. Global institutions such as the World Bank require environmental impact assessments (World Bank 1993) and prior notification to co-riparians as pre-requisites for funding (Pochat, 2006). In addition, the World Bank is involved in ongoing efforts to incorporate environmental flow issues into existing projects (Hirji and Panella, 2003). As part of the process for incorporating environmental flows, the World Bank encourages client countries to incorporate environmental flows into domestic water policy (World Bank 2009). This also has implications for public participation, because those most dependent on environmental flows in the river, such as indigenous peoples or recreational users are often those least likely to participate in water resources decision making. This is because these interests are typically outside the power hierarchy. Accordingly, the World Bank now requires consultation with local indigenous people in all water resources projects.

Policies of the World Bank are also influenced by the Global Environmental Facility (GEF) because the Bank is an implementing agency for the GEF, as are the United Nations Environment Program (UNEP) and the United Nations Development Program (UNDP) (Anderson and Hey 2005, Matz 2005). The GEF, an international financial organization whose International Waters Programme addresses cooperation on transboundary water management by encouraging institutional reforms, is regarded as a primary impetus behind adoption of international law, river basin action plans and environmental programs (GEF 2006). In addition to requiring elements of IWRM in funded projects, the GEF has also established a more informal forum, IW:LEARN, where knowledge gained through experiences in particular river basins can be communicated to practitioners in other river basins (Sklarew et al. 2001).

At a level lying between being international and global in scope, the European Water Framework Directive (European Union 2009) and the South African Development Community Protocol on Shared Watercourses (SADC 2009) provide requirements for water development projects undertaken by member states. Development of such supra-national and supra-basin organizations simplify managing for externalities such as climate change, shifting markets and population mobility issues. The current global governance of water is a shifting, diffuse network that includes top-down, bottom-up and side-by side networks (Pahl-Wostl et al. 2008). The U.N. recently created an umbrella mechanism (UN-Water) to coordinate efforts aimed at implementing agreements related to sustainable development, as well as facilitating cooperation and collaboration. The move towards coordination of different sectors (food, education, health and environment) has also played out in the shifting structures of international arrangements for river basin management.

Path Dependency and its Implications for Analysis

National and international laws governing water resources, which reflect existing practices, are giving way to an emergent global water law that is shaping water resources management (Dellapenna and Gupta 2008). However, this trend towards uniformity in the legal arena results in the unintended consequence of uniformity in implementation. Uniformity in implementation results in a one size fits all approach which lessens the likelihood of innovation based on emerging properties within individual river systems. This can result in inadequate institutional design in individual systems.

From a theoretical perspective, the implementation of a "global toolbox" also has the potential to create path dependencies, which can hamper the ability to infer generalized principles in analyses of international river basins. For example, trends in international laws and promulgation of requirements for funding from international agencies such as the World Bank, which often require adherence to international laws and conventions, can lead to institutional uniformity across international management regimes (Molle 2005). The principles espoused by the international institutions, i.e. IWRM, are certainly laudable; however, reliance solely on the "global toolbox" can lead to a loss of resilience in the affected systems. This loss in resilience is a result of institutionalized limitations on the ability of the social-ecological system to transform itself (Anderies et al. 2006).

Path dependency results when management regimes, the creation of which initially involves choices, become static in the sense that strategies are developed to fit the regime's institutional pattern, and are not continually evolving social/ecological system features (Thelen 1999). This is not to say that international management regimes do not evolve, they do. However, the evolution of these systems may be constrained by the selected institutional development pathway (Andresen and Hey 2005). This can lead to rigidity traps (Holling et al. 2002). A rigidity trap occurs when innovations and emerging system properties are not incorporated into the management regime because a mandated development pathway is strongly entrenched in the existing management structure.

Path dependency and resulting rigidity traps are certainly considerations in a comparative study. Although a determination that system designs are comparable may be true at a superficial level, any comparison would be spurious if the system design was mandated to comply with international funding requirements. Individual treaty requirements can mitigate for this situation because these types of individualized legal instruments do impose some constraints on wholesale application of standardized institutional designs. This factor allows for a comparison between systems, such as that proposed herein.

Case Study Methods

For purposes of this study, a case is defined as an instance of a class of events, wherein the event is the type of institutional regime created to manage transboundary water resource issues (George and Bennett 2005). This study uses a structured focused comparison approach for a small number of cases. As George and Bennett (2005, 67) describe it:

> The method is "structured" in that the researcher writes general questions that reflect the research objective and that these questions are asked of each case under study to guide and standardize data collection, thereby making systematic comparison and cumulation of the findings of the cases possible. The method is "focused" in that it deals only with aspects of the historical cases examined.

George and Bennett (2005) also outline requirements for a case study using this approach. Specifically, the selected cases should represent instances of a particular phenomenon. In this study, the broad category of cases is institutional regimes for water resource management in transboundary river basins. The selected cases are guided by the research objective. The United Nations Environment Programme (UNEP) identifies 263 international river basins (2002). Of these, 106 have water institutions of some type, with less than 20% of the agreements being multilateral. From within the larger class of international river basins, this study was limited to basins in which multilateral agreements are in effect. From this smaller subset, ten basins representing a range of conditions were selected for further analysis.

Finally, case studies should "employ variables of theoretical interest for purposes of explanation…[t]hat provide some leverage for policymakers to enable them to influence outcomes" (George and Bennett 2005, 69). As these authors point out, this is somewhat of a positivist approach. However, use of the diagnostic approach applied in this study, which evaluates factors associated with complex systems such as the chaotic nature of these systems and uncertainty, overlays the positivist approach with a more interpretive framework.

Application of Simple Diagnostics: Case Selection

Simple diagnostics is applied to ten international river basins, including the Rio Grande, to determine how the water management regime in the Rio Grande compares to other international regimes. The basins selected for this analysis are the Amazon, Danube, Great Lakes Border Region, La Plata, Mekong, Ganges, Orange-Senqu, Okavango, Nile and the Rio Grande. These selected basins encompass a broad range of spatial, climatic, and social variability. Their international spatial distribution is illustrated in Figure 6.1. Management regimes may also differ, depending on climatic variability. The selected basins also include those in both dryer and wetter areas as shown in Figure 6.2.

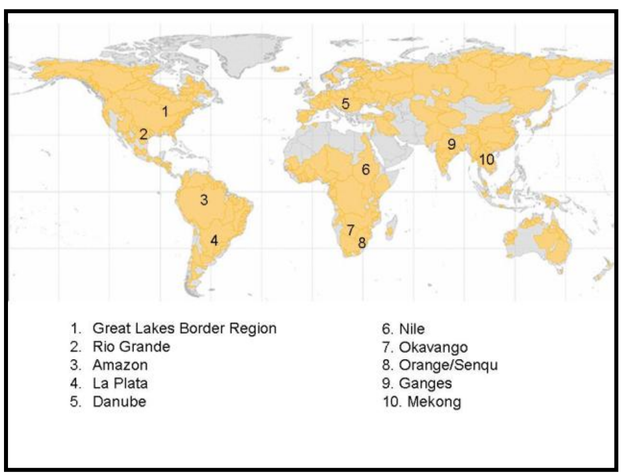

Figure 6.1 Spatial Distribution of River Basins (adapted from Global Runoff Data Centre (2007): Major River Basins of the World/Global Runoff Data Centre: Koblenz, Federal Institute of Hydrology (BfG), 2007.

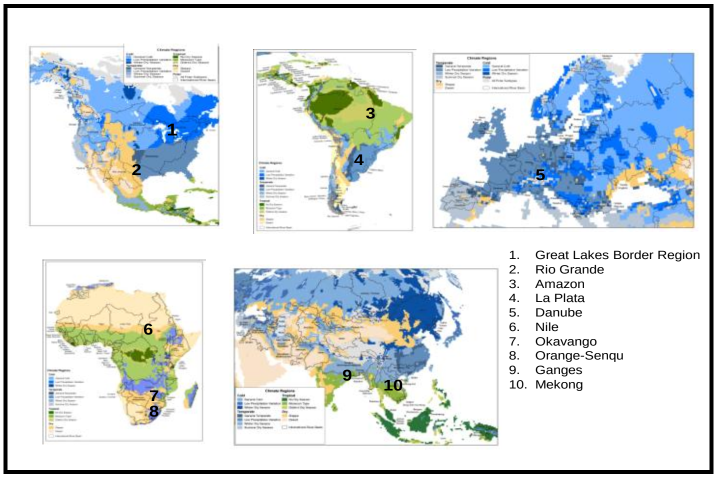

Figure 6.2. Climatic Variability for Selected River Basins (from Transboundary Freshwater Dispute Database. 2009.)

Administrative boundaries typically do not coincide with natural resource boundaries (Alexander Martin 2010). On a global scale, social data is typically collected for countries, which makes transformation of this data to international river basins (i.e., basin comprising multiple countries) particularly difficult. However, consideration of economic and social factors is an important element for consideration in selecting cases for a cross-comparison of institutional regimes. The Gross Domestic Product Per Capita (GDP), for example, is a measure of the average amount of money added to a nation's economy as the result of the production of goods and services; in other words, this indicator measures average national income, being used in this chapter as a surrogate for economic factors.

Figure 6.3 is a measure of economic development in the selected river basins, illustrating the range of economic conditions in the selected basins. The 2001 GDP per capita for each country, in each basin, was averaged across the basin to create a specific value for each river basin. Although arguably coarse, because economic conditions can vary on a regional basis within individual countries, this measure does provide some indication of available economic resources for nations in these river basins, as well as being a measure for comparison.

Figure 6.4 is a relative measure of the social system in each country. This figure includes both the Human Development Index (HDI) and the Gender Empowerment Measure (GEM). The HDI is a composite index of a countries health, knowledge and standard of living. This measure was created using the 2006 HDI for each country in each river basin, averaged across the basin (FAO 2009). The HDI is not an indicator of the extent to which gender inequality exists, which is an important consideration in design of public participation processes in an international river basin

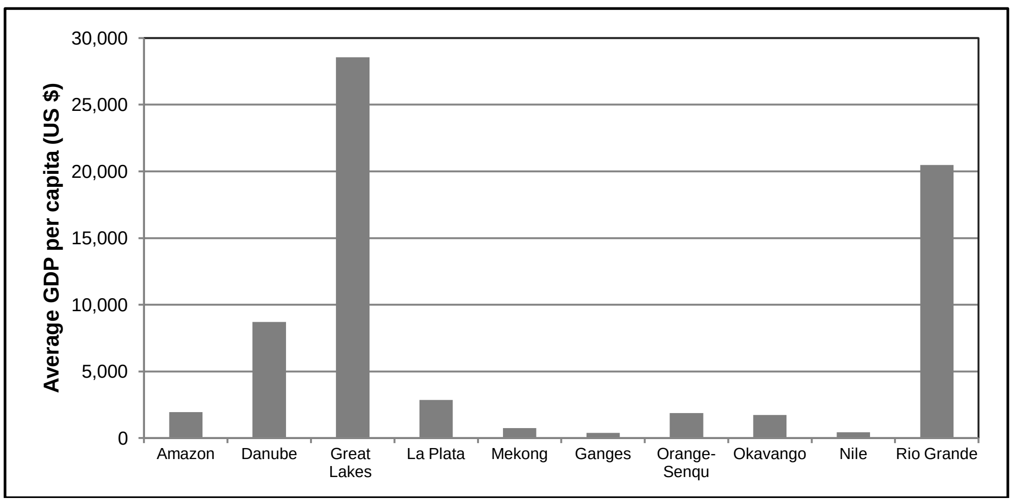

Figure 6.3 Economic Development in Selected River Basins (Gross Domestic Product per Capita (U.N. 2003))

management regime. To demonstrate how this social attribute varies among the cases, the Gender Empowerment Index (GEM) in Figure 6.4 was created on the basis of the GEM for each country averaged across the basins. The GEM measures the presence of women in political and professional life, and also considers the income ratio between men and women (UNDP 2009).

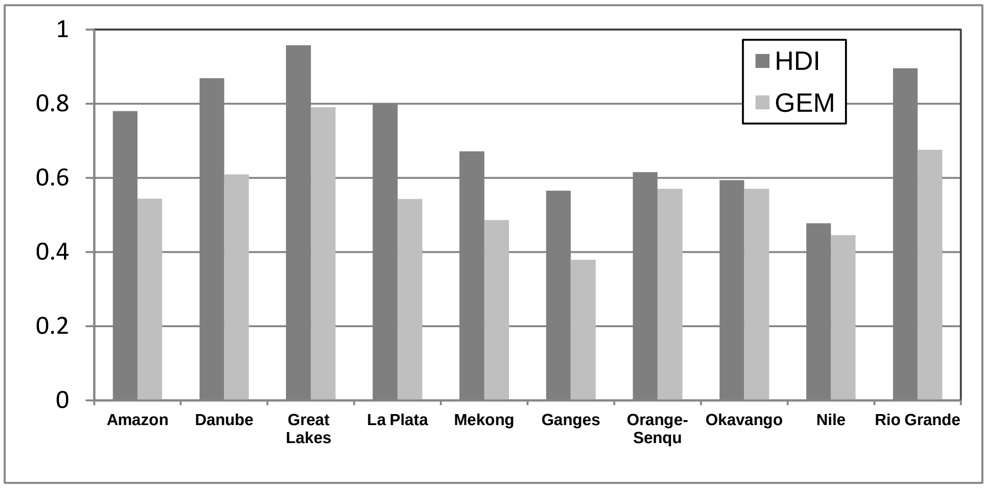

Figure 6.4 Social Development in Selected River Basins (Human Development Index (FAO 2009) and Gender Empowerment Index (UNDP 2009))

Application of Simple Diagnostics: The Approach

The application of simple diagnostics to the selected study basins is based on the structured, focused comparison approach, as discussed previously. A standardized set of criteria was examined for each international river basin institutional regime. The criteria were Young's (2002) suggested categories for simple diagnostics. Simple diagnostics is based on three types of diagnostic conditions; namely, (i) ecosystem properties; (ii) actor attributes; and (iii) implementation issues, and subtypes of each of these types. Application of the diagnostic conditions is consistent with a complex adaptive systems approach. Simple diagnostics considers the impact of ecosystems on people (ecosystem properties), people on ecosystems (actor attributes), and how the frequently conflicting needs of each are dealt with from an organizational perspective (implementation issues). Each basin is treated as an individual case, which provides insight into the determination of whether or not the attributes of individual cases are similar. At the same time, applying the criteria across a range of cases allows generalizations and contrasts across the cases. Thus, application of simple diagnostics involves assessment of properties of social-ecological systems and diagnostic conditions related to those features. The basins and the reference sources for each are listed in Appendix IV.

<u>Ecosystem Properties</u>

Young defines ecosystem properties, in the context of simple diagnostics, as "features of the relevant biogeophysical systems (and of our knowledge about them) that have consequences for institutional design" (2002, 177). The subset of diagnostic conditions related to ecosystem properties are (Young, 2002:178):

a. Nonlinear or chaotic systems, surprises;

b. Problem Duration;

c. Functional Interplay; and

d. Uncertainty, imperfect knowledge.

Nonlinear systems are characterized by sudden changes. As such, management institutions should include the capability to respond when unexpected situations arise. For example, early warning systems for flooding, drought, or potentially catastrophic shifts in ecosystems provide information that can trigger changes in management practices that allow a rapid response to these types of sudden shifts. Forecasting systems, to include not only measurements of environmental parameters such as streamflow, but also action plans to address problems related to drought, floods and ecosystem decline, were the factors examined for each basin for this category.

Problem duration is an indicator that considers the structure of institutional management regimes. Where problems persist over time, institutional structural attributes such as dispute resolution mechanisms, administrative arrangements and funding mechanisms can contribute to effective institutional responses. Young's suggested diagnostic condition includes dispute resolution mechanisms as part of administrative arrangements. Giordano and Wolf (2003) also identify dispute resolution mechanisms as a key factor in resilient institutions. Giordano et al. (2005) note that changes in the environmental attributes of a system, as seen in complex and dynamic systems, are troublesome, unless mechanisms exist to deal with rapid onset problems. Because of the important role played by conflict and conflict resolution mechanisms, the type of dispute resolution mechanism in each regime is considered separately. For this factor, therefore, application of simple diagnostics departs from Young's suggested categories. Thus, the two criteria for this category are: (i) the presence of an international institution(s) with authority to manage long term issues such as water allocations and long term environmental problems; and (ii) the type of dispute resolution mechanism, which is a primary factor in the ability of management institutions to respond to sudden changes.

Functional interplay is the extent to which basin institutions are linked or exhibit coordination in managing water resource issues. Treaties, available literature and programmatic plans were examined for indications of the level of coordination across functions and programs. Uncertainty and imperfect knowledge reflects the fact that our knowledge about complex ecosystems remains inadequate. This category is defined by whether or not basin institutions established a precautionary approach to attempt to avoid harm to the river basin social/ecological system. In addition, public participation efforts were considered as a surrogate for the social learning aspect of this category. Information on the broad category of ecosystem properties and the assessment of the diagnostic conditions for each river basin is provided in Appendix I.

<u>Actor Attributes</u>

Actor attributes are a class of diagnostic conditions related to "characteristics of the set of actors whose behavior gives rise to environmental problems" (Young 2002, 177). The diagnostic conditions associated with actor attributes are (Young 2002, 178):

a. Variability of political and socioeconomic systems;

b. Heterogeneity of member interests;

c. Asymmetries in causal responsibilities; and

d. Asymmetries in capacity.

Variability of political and socioeconomic systems is a function of the extent to which policies at the international level, and those at the national or local levels. are similar or dissimilar. This attribute is characterized by flexibility in water resource management. Flexibility includes indications that the management system for a particular basin includes mechanism(s) that mitigate against path dependency problems.

Heterogeneity of member interests is a measure of the extent to which the concerns of states in an international river basin setting are aligned. In other words, do national interests outweigh the interests of the river basin as a whole, and to what degree are less important national interests set aside in the interest of solving common problems at the international scale? Issue linkages are used as a measure of heterogeneity. In other words, are there attributes of the management structure which link transcending issues such as poverty, development, or maintenance of biodiversity on a basin wide scale, to management of water resources?

Asymmetry in causal responsibilities is a measure of power relations between basin countries, and the extent to which countries undertake unilateral actions that threaten the social/ecological system of the river basin. This is primarily an equity issue, with the river basins being evaluated in this study in regard to the extent to which management regimes emphasized equity. Equity issues include how water is shared in allocative regimes and public participation mechanisms which ensure that any decision making includes all stakeholders.

Asymmetry in capacity, like asymmetry in causal responsibility is also fundamentally a question of equity, and is related to power relationships between the countries in an international basin. This diagnostic condition is a measure of the extent to which technology, and other types of assistance and cooperation between basin states, leads to exchanges of data and scientific knowledge in an effort to resolve environmental issues in the basin. Information on the broad category of actor attributes can be found in Appendix II.

Implementation Issues

The set of diagnostic conditions associated with implementation issues are closely related to institutional performance, as opposed to either ecological (ecosystem properties) or social (actor attributes) issues. These issues are particularly important in light of the fact that institutions may collapse in the case of serious violations. The diagnostic conditions related to implementation are (Young 2002, 178):

a. Violation tolerance;

b. Incentives to cheat; and

c. Lack of transparency.

Violation tolerance is a function of whether or not, and to what extent, participants in an institutional regime follow the 'rules.' Rules can include such things as compliance with treaty requirements, for instance providing a specific amount of flow to a co-riparian country. Infractions can be major or minor, depending on the institutional structure, while rules to prohibit violations may or may not be included in a management regime. Rules to prohibit overuse are more common in regimes that are driven by allocative issues. In some international regimes, rules that distribute benefits are often found in underlying bilateral arrangements between parties to a multilateral agreement. For this diagnostic condition, implementation review systems were examined to determine whether or not benefit sharing rules exist and, if so, to what extent are those rules included in the multilateral agreements? At this point, international regimes in purportedly water-rich areas, such as the Amazon Basin, do not include allocative rules. However, given uncertainties associated with climate change and resource shifts, these types of rules may have a more important role in the future.

If a management regime includes rules, are there incentives to cheat? The clearest incentive occurs when there are no sanctions to punish violators. The existence of either violation sanctions or deterrence is examined as a diagnostic condition for incentives to cheat. Even if rules exist to distribute benefits, and the management regime includes sanctions for violations, the extent of compliance is unknown unless monitoring procedures are in place. The final diagnostic condition is the extent to which the management regime includes a monitoring network and the breadth and scope of that network. Information on the broad category of implementation issues can be found in Appendix III.

Comparative Analysis and Basin Rankings

Homogeneity of international regimes can result from path dependencies created as a result of the influence of international laws and requirements of donor agencies. However, review of the information contained in Appendices I, II, and III suggests that, although the overarching goals such as sustainable development or integrated river basin management may be similar, the institutional structures created to achieve the goals can be, and often are, context dependent. This does not necessarily mean that management ‘lessons learned’ are not transferable. What the analysis suggests is that, across the range of river basins comprising this analysis, the institutional regimes are at various stages of progression toward achieving the goals.

For example, with respect to diagnostic conditions associated with Ecosystem Properties (Appendix I), the analysis indicates that basins such as the Amazon, Danube, Great Lakes Border Region and La Plata have coordinated and interconnected management structures that address multiple issues. Basins such as the Ganges have a main agreement with a single focus on allocation. The Danube and Great Lakes Border Region have robust dispute resolution mechanisms including arbitration and referral to the International Court of Justice (Danube) and consensus based on joint fact finding and arbitration mechanisms (Great Lakes Border Region). At the opposite end of the spectrum, the Amazon, La Plata, Nile, and Rio Grande rely on various configurations of diplomatic negotiation to settle disputes.

With respect to diagnostic conditions related to Actor Attributes (Appendix II), management structures in the Amazon, Danube, Great Lakes Border Region, and La Plata exhibit structural flexibility by incorporating multiple layers, master planning, watershed initiatives and science based decision making, and consolidation and coordination of projects. In the Ganges, Okavango, and Nile, flexibility is limited because national interests take precedence over basin-wide interests. The Danube, Great Lakes Border Region, and Rio Grande have the capacity for financial and technical support, primarily because riparian countries in these basins include more developed countries. Most other basins are limited in this category because of lack of funding mechanisms.

Finally, with respect to diagnostic conditions related to Implementation (Appendix III), basins such as the Amazon, La Plata, and Okavango lack benefit sharing rules for allocations of water, while the Danube and Rio Grande institutional structures incorporate specific allocative mechanisms which are agreed upon by the basin countries. The Danube, Great Lakes Border Region, and Rio Grande have a variety of monitoring networks for water quantity and water quality and the riparian countries routinely share data. The Amazon, Okavango, and Nile Basins currently lack comprehensive data collection systems while the La Plata, Mekong, Ganges, and Orange-Senqu have some systems in place.

Accordingly, an additional analysis is performed to determine a hierarchy among the river basins in this study. A simple ranking approach is used whereby, for each diagnostic factor, the river basins are assigned a number of 1, 2 or 3, with the larger number indicating the most fully developed diagnostic factor being considered. For basins for which a factor is not present at all because of context, an example being implementation systems in the Amazon River Basin, a value of zero is assigned. The ranking criteria, based on the diagnostic analysis, are as follows:

- 1- the institutional regime does not exhibit this element, or the element is exhibited minimally;
- 2- the institutional regime exhibits this element, but the element is not fully developed; and
- 3- the institutional regime exhibits this element in a more or less fully developed fashion.

Based on this comparative analysis of the ranking factors, the comparative ranking of the river basin regimes is summarized in Table 6.1.

Table 6.1 Comparative Ranking Based on Diagnostic Factors

Basin	Ecosystem Properties					Actor Attributes				Implementation			Rank
	1*	2	3	4	5	6	7	8	9	10	11	12	
Amazon	2	3	1	2	3	3	3	1	1			1	20
Danube	3	3	3	2	3	3	2	3	3	3	3	3	34
Great Lakes Border Region	2	3	3	3	3	3	3	3	3	2	2	3	33
La Plata	2	3	1	2	3	3	3	1	1			2	21
Mekong	2	2	2	1	2	2	2	1	1	2	1	2	20
Ganges	1	1	2	1	1	1	1	1	1	2	1	2	15
Orange-Senqu	2	2	2	2	2	2	2	1	1	2	1	2	21
Okavango	1	2	2	1	1	1	2	1	1			1	13
Nile	1	2	1	2	2	1	2	1	2	1	1	1	17
Rio Grande	2	2	1	2	1	2	1	1	3	3	2	3	23

* The diagnostic factors are numbered sequentially in the order they appear in Appendices I-III. For example: 1 = Early Warning Devices/Rapid Response Capability, 2 = Management Structures, 3 = Dispute Resolution Mechanisms, 4 = Coordination Mechanisms, 5 = Social Learning/Adaptability/Precautionary Approach, 6 = Flexibility, 7 = Issue Linkages, 8 = Emphasis on Equity, 9 = Capacity Building and Technology Transfers, 10 = Implementation Review Systems, 11 = Sanctions/Deterrence, and 12 = Monitoring Procedures.

Discussion of River Basin Rankings

Based on the rankings presented in Table 6.1, the river basins fall into a hierarchy of three groups. Group 1 Basins, including the Okavango, Nile and Ganges, typically exhibit less-developed institutional regimes. This is not surprising given their relatively low rankings on the economic and social factors identified in Figures 6.3 and 6.4, compared to the other basins in this study. This reality highlights the need for careful consideration of the structure of the institutional regimes for these river basins, particularly as specific structural aspects are tied to options for continuing financing of institutions, and the challenges of inclusiveness at lower levels of a management hierarchy. Nevertheless, these low rankings do not necessarily mean that the experiences for these basins are not instructive in regard to institutional design and effectiveness. As an example, although OKACOM (Okavango Basin) is relatively new, it is ranked higher in the categories of Management Structures and Dispute Resolution Methods than basins with existing management regimes, such as the Rio Grande. Efforts underway via the Nile Basin Initiative (NBI) to codify existing cooperative practices into a legal framework may ameliorate the low rankings of this basin in some of the diagnostic categories. In addition, the NBI framework indicates a pathway for basins where negotiations typically occur over a long period of years. Via the NBI, cooperative mechanisms were developed and established, while legal negotiations are ongoing. This pathway created a space wherein consideration of issues on a collaborative basis could occur without a strict legal protocol, thus lessening policy lags that often are the hallmark of regime creation mechanisms within which little can be achieved until the needed legal framework is in place. Radar diagrams are used to display the quantitative rankings in each diagnostic category starting from the same point to facilitate comparisons between the basins by indicating similarities and clustering of points. Figure 6.5 presents the rankings for each of the Group 1 Basins across the diagnostic categories.

Some of the Group 2 Basins (Amazon, La Plata, Mekong, Orange-Senqu) typically exhibit higher rankings for diagnostic conditions related to incorporation of environmental issues, issue linkages and flexibility. This is not the case for the Rio Grande for which its ranking is driven, in part, by capacity building/technology transfers and monitoring. The United States is a riparian country in this basin, and has the ability to provide financial and technical support for initiatives in these categories. The Rio Grande also is ranked highly in regard to implementation due to the strict allocation requirements, although these allocation requirements could lead to collapse of the institutional structure in the long term unless modifications occur (see Alexander Martin 2010 for a discussion of the Mexican water debt).

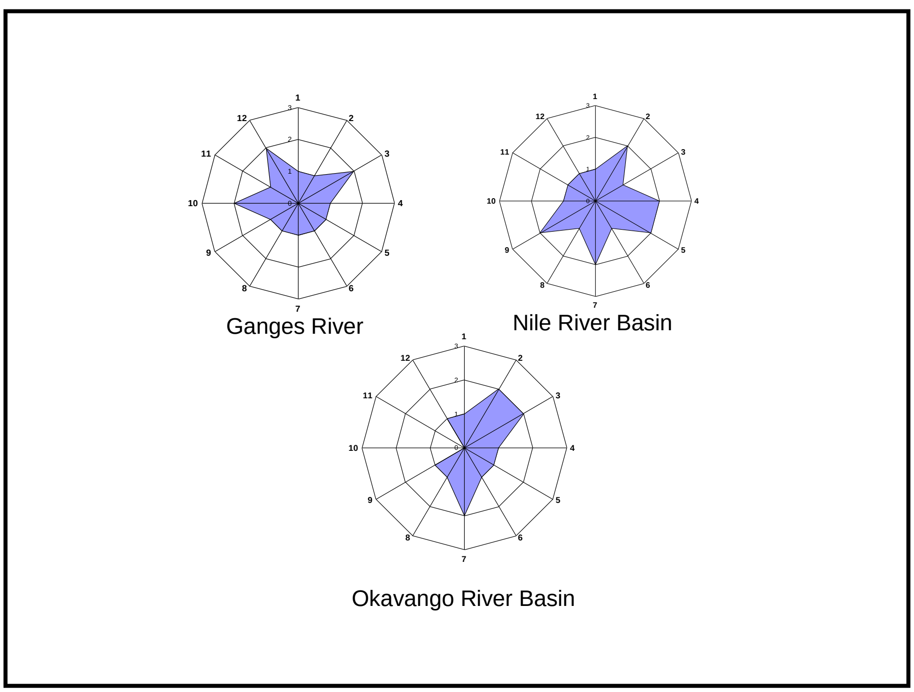

Figure 6.5 Rankings of Group 1 Basins Across Diagnostic Categories

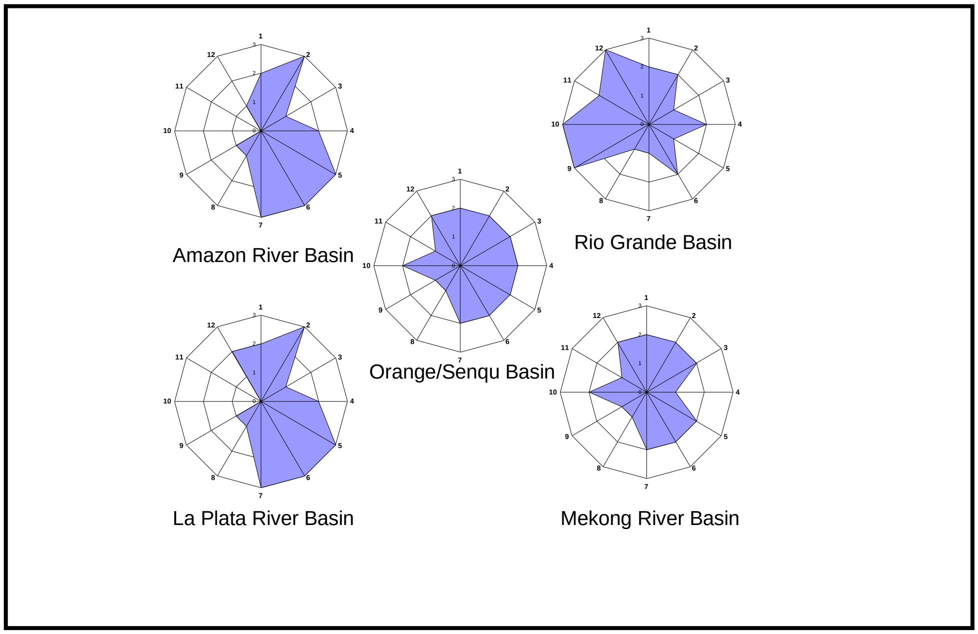

Figure 6.6 Rankings of Group 2 Basins Across Diagnostic Categories

A surprising result of this analysis is the relatively low ranking of the Rio Grande (Group 2), compared to the Group 3 Basins (Danube, Great Lakes Border Region) (Figure 6.7). Based on economic and social indicators, and given the economic and political power of the United States, one of the Rio Grande riparian nations, one would expect this basin to rank more consistently with the rank of the Great Lakes Border Region on the U.S. northern border. However, actions of the United States government on a broad range of environmental issues, such as climate change and biodiversity, may indicate reluctance on the part of the national government to engage in multi-lateral actions (Schruers 2005), unless other agreements require it. In the Great Lakes Border Region, impetus for multi-lateral problem solving is fostered by an institutional structure supportive of such measures. As the results in Table 6.1 indicate, the institutional structure of the Rio Grande is clearly lacking in the areas of dispute resolution mechanisms, social learning, issue linkages and an emphasis on equity.

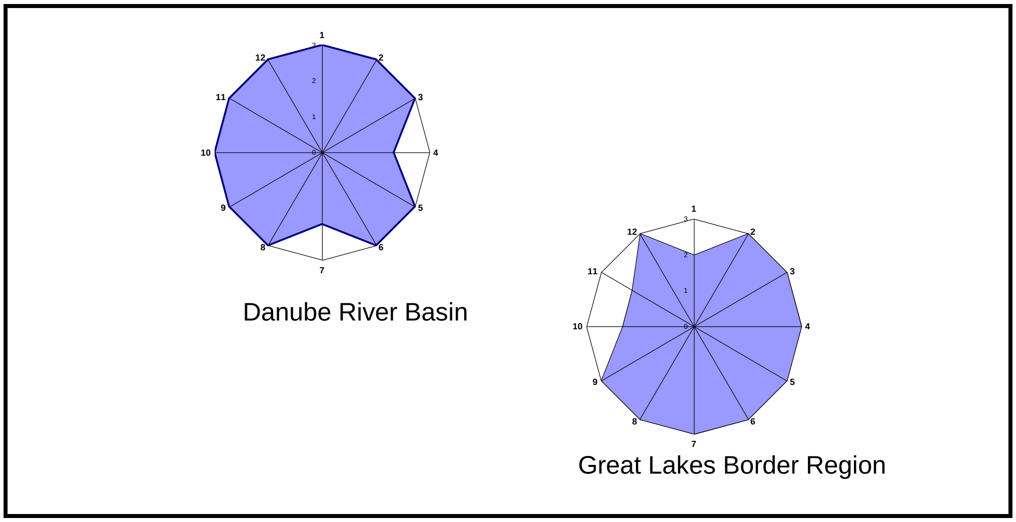

Figure 6.7 Rankings of Group 3 Basins Across Diagnostic Categories

Conclusion

Information from the cross-case comparison indicates that, with respect to other institutional regimes, the Rio Grande regime is lacking in factors that: (i) promote incorporation of environmental concerns; and (ii) the participation of civil society in determining the future direction for the basin. Although it is possible that this conclusion could have been reached without a cross-case comparison, the comparative analysis framework resolves issues related to use of individual case study methods by allowing standardized analysis methods thereby facilitating comparison across the river basins. In addition, the comparison provides information in support of the hypothesis that, in the global context, the institutional regime of the Rio Grande is inadequate in important respects. The comparison also illustrates that, in the context of effective international regimes, factors identified as lacking in the Rio Grande institutional structure, do contribute to effective management of other transboundary waters. Further, the cross-scale comparison identified other basins do exhibit institutional attributes not currently present in the Rio Grande, but which might be able to be incorporated into the water management institutional structure of the Rio Grande Basin. The issue of transferability is not addressed here, although there may be lessons that can be learned from institutional regimes in other transboundary river basins that exhibit characteristics that the Rio Grande institutional regime does not possess. In order to further elaborate on issues related to transferability, a more detailed case study of the Rio Grande institutional regime is needed to determine if the diagnostic results presented herein have applicability to the Rio Grande as a singular case.

Appendix I Diagnostic Conditions Associated with Ecosystem Properties

Basin	Early Warning Devices/Rapid Response Capability	Management Structures	Dispute Resolution Mechanism	Coordination Mechanisms	Social Learning, Adaptability, Precautionary Approach
Amazon	• Current hydrometeorological networks are inadequate due to resource constraints, limited spatial coverage and obsolete technology, • Strong biodiversity initiatives but no forecasting mechanism	• Amazon Cooperation Treaty Organization (ACTO) includes a Meeting of Ministers of Foreign Affairs, a Permanent Secretariat, seven special commissions for various issues, the Amazon Cooperation Council and National Commissions, • Bilateral and multilateral agreements among ACTO signatories	• Diplomatic means	• Framework for cross-sectoral coordination in place but fragile and in its infancy, under ACTO protocol,	• Institutional focus on sustainable use of resources to assist member countries, local knowledge is viewed as indispensable, also recognition of indigenous knowledge
Danube	• Hazardous spill warning system, • ICDPR Flood Action Programme, • Identified hydromorphologically altered segments are a factor in new project approvals and design of mitigation measures	• International Commission for the Protection of the Danube (ICDPR) includes country delegations, can appoint permanent or ad hoc experts, includes a steering group • European Water Framework Directive (EWFD) • Bilateral and multilateral agreements among DRPC (Danube River Protection Convention) signatories	• Consensus voting by 4/5 vote • Negotiation • Arbitration • International Court of Justice	• ICDPR, cross ministerial lines, includes expert groups and observers	• Danube environmental forum, environmental assessments, precautionary principle explicitly included

Appendix I Diagnostic Conditions Associated with Ecosystem Properties

Basin	Early Warning Devices/Rapid Response Capability	Management Structures	Dispute Resolution Mechanism	Coordination Mechanisms	Social Learning, Adaptability, Precautionary Approach
Great Lakes Border Region	• Great Lakes Water Quality agreement includes monitoring but may not include provisions to respond to the current generation of water quality and ecosystem problems, although the agreements include joint actions to address point and non-point pollution sources • No ecosystem change forecasting ability, although the International Joint Commission (IJC) can alert the two nations to emerging issues • Limited drought response mechanisms (drought is not currently acknowledged as a pervasive problem although increased water withdrawals are seen as a problem), • International Flood Mitigation Initiative in the Red and Souris Basins	• International Joint Commission (IJC) • Great Lakes Water Quality Agreement, • Transboundary watershed boards, • International St.Lawrence/Lake Ontario study board, • Ongoing efforts to move toward nested linked management entities at multiple levels	• Consensus decisions based on joint fact-finding and public consultation • Arbitration based on a reference from one of the signatory nations, although both nations must agree to submit to arbitration • Diplomacy	• Much coordination at international, federal, and state levels but little inclusion of local governments, cooperative horizontal federalism in the St. Lawrence shows promise, but no one entity coordinates all	• Reference mechanism allows investigation of problems outside treaty jurisdiction, provisions for recommendations from outside scientists via the science team, international watersheds initiative to identify new issues as they arise

Appendix I Diagnostic Conditions Associated with Ecosystem Properties

Basin	Early Warning Devices/Rapid Response Capability	Management Structures	Dispute Resolution Mechanism	Coordination Mechanisms	Social Learning, Adaptability, Precautionary Approach
La Plata	• Under the Intergovernmental Coordinating Committee (CIC), exchange of hydrologic data and early warning system for extreme events, • Ongoing efforts to address flood warning and mitigation, • No common system for water quality assessment or information exchange, • Implementation of RIGA (La Plata River Basin Environmental and Management Network).	• Conference of Foreign Affairs Ministers, • Intergovernmental Coordinating Committee (CIC), • Regional Technical Committees, Administrative Commission for the Rio de La Plata (Argentina and Uruguay), • Binational Technical Commission for the Maritime Front • RIGA	• Decisions of the CIC are made on a unanimous basis • No true basin wide system, management through bilateral and trilateral partial coalition agreements among various states	• CIC but no supra national organization, • RIGA developed to strengthen stakeholder processes, • Current GEF project to coordinate existing initiatives into a consolidated framework	• Precautionary Approach included in the Strategic Action Programme for the Rio de La Plata and its Maritime Front, Strategic Action Programme for the La Plata Basin includes adaptation planning to account for the impacts of climate change

Appendix I Diagnostic Conditions Associated with Ecosystem Properties

Basin	Early Warning Devices/Rapid Response Capability	Management Structures	Dispute Resolution Mechanism	Coordination Mechanisms	Social Learning, Adaptability, Precautionary Approach
Mekong	• Some water quality monitoring but not comparable among signatory nations. • Drought and flood management capacity is limited.	• Mekong River Commission (MRC) with Ministerial Council, Joint Committee, Secretariat and National Committees	• Unanimous for the MRC • Mekong River Committee is governed by the signatory states instead of the MRC acting as a governance body • Council can resolve issues and the Joint Committee has some authority when the Council is not in session • Parties can request mediation	• MRC only includes 4 of the basin countries; China and Myanmar only participate in an observer status, • Programs are linked to donors and not among countries, • Asian Development Bank providing impetus for governance changes such as creation of national ministries for natural resources	• MRC adopted conceptual public participation policy in 1999 but little progress towards implementation. Public participation occurs at state and local levels to varying degrees in the different countries for example water user groups

Appendix I Diagnostic Conditions Associated with Ecosystem Properties

Basin	Early Warning Devices/Rapid Response Capability	Management Structures	Dispute Resolution Mechanism	Coordination Mechanisms	Social Learning, Adaptability, Precautionary Approach
Ganges	• Limited flood forecasting and early warning systems in progress under the purview of the Joint River Commission, • No institutional structure for addressing ecosystem issues or water quality	• Indo-Bangladesh Joint Rivers Commission mainly for enforcing allocations under the Treaty for Sharing of the Ganges/Ganga	• Disputes over water sharing are fist dealt with by the Joint Committee • If the Joint Committee cannot resolve the dispute, it is sent to the Indo-Bangladesh Joint Rivers Commission • If still not resolved, the dispute is sent to the governments for political/diplomatic resolution	• None, India unilaterally is going forward with the "River-Linking" project over the opposition of downstream Bangladesh, • National level integration is fragmented	• No provisions for inclusion of outside groups or scientists • No explicit recognition of impacts of proposed actions
Orange-Senqu	• No concrete drought rules. • River Health Programme includes bio monitoring and ecosystem assessment. • South African Development Community (SADC) protocols provide for monitoring	• Orange-Senqu River Commission (ORESCOM), which is composed of a Council, Secretariat and Task Teams • Several bilateral agreements	• Consultation • Referral to the SADC Tribunal	• More coordinated efforts due to SADC Shared Watercourse Protocol and influence and financial clout of South Africa	• Elements of the precautionary principle included implicitly through requirements to cause no harm to resources or other users and notification requirements

Appendix I Diagnostic Conditions Associated with Ecosystem Properties

Basin	Early Warning Devices/Rapid Response Capability	Management Structures	Dispute Resolution Mechanism	Coordination Mechanisms	Social Learning, Adaptability, Precautionary Approach
Okavango	• Although the Okavango Delta is a designated RAMSAR site, there are no coordinated mechanisms for hydrologic or environmental assessments • Information on hydrology and biological factors exists but is fragmented, there are a limited number of data collection stations but none in Angola although six are planned	• Permanent Okavango River Basin Water Commission (OKACOM): permanent commission, technical arm and steering committee, secretariat established in 2007 pursuant to South African Development Community (SADC) Shared Watercourses Protocol, basin wide forum	• Dialog and negotiation via OKACOM to reach consensus • Referral to the SADC Tribunal	• River basin commissions within each subbasin but effectiveness is limited, lack of coordination at the national level	• Recognition that actions may have consequences for other users

Appendix I Diagnostic Conditions Associated with Ecosystem Properties

Basin	Early Warning Devices/Rapid Response Capability	Management Structures	Dispute Resolution Mechanism	Coordination Mechanisms	Social Learning, Adaptability, Precautionary Approach
Nile	• Bilateral agreement between Egypt and Sudan allows for reductions due to drought for Egypt and Sudan. • No basin wide flood or drought forecasting, no environmental monitoring	• Council of Ministers of Water Affairs for Nile Basin countries (Nile COM), technical advisory committee (Nile TAC) and a secretariat (Nile SEC) • Nile Basin Initiative (NBI) is a transnational cooperation mechanism but was not created via a treaty or convention • Negotiations for a Cooperative Framework Agreement underway since 1997	• Dialog and negotiation via NILE-COM	• Nile Basin Initiative , • Eastern Nile Subsidiary Action Program (ENSAP) and Eastern Nile Council of Ministers (ENCOM) between Egypt, Sudan and Ethiopia, • Domestic factors and poverty in the Nile Basin countries hinder international coordination because they deflect national attention away from Nile Basin water issues	• Shared Vision Programme includes provisions for future stakeholder involvement and applied training for water professionals

Appendix I Diagnostic Conditions Associated with Ecosystem Properties

Basin	Early Warning Devices/Rapid Response Capability	Management Structures	Dispute Resolution Mechanism	Coordination Mechanisms	Social Learning, Adaptability, Precautionary Approach
Rio Grande	• International Boundary and Water Commission/Comision Internacional de Limites y Aguas (IBWC/CILA) coordinate on flood management in the binational river, • 1906 Convention addresses specific drought reductions, vague language regarding drought reductions in the 1944 Treaty. • Binational initiatives address water quality, • No coordinated effort to address ecosystem issues	• IBWC/CILA with a national section for each country headed by an Engineer-Commissioner, as well as principal engineers for subsections • Border XXI, but this is coordinated by United States Environmental Protection Agency (EPA) • North American Development Bank (NADBank) entities, Commission on Environmental Cooperation (CEC) and Border Environmental Cooperation Commission (BECC)	• Minute system which provides recommendations to the respective national governments • Diplomatic means	• Coordination in the form of some joint projects, water quality, flood control and dam operation and maintenance. None related to ecosystems • Joint supervision of water allocations between the two countries • No mechanism for coordination across a broad range of issues and projects	• Supra basin scale (Colorado and Rio Grande) limits adaptability and flexibility • No specific inclusion of precautionary principle or explicit recognition of environmental consequences of proposed actions

Appendix II Diagnostic Conditions Related to Actor Attributes

Basin	Flexibility	Issue Linkages	Emphasis on Equity	Capacity Building and Technology Transfers
Amazon	• Structurally, the Amazon Cooperation Treaty Organization (ACTO) includes multiple layers • Evolution from Amazon Cooperation Treaty (TCA) in 1978 to ACTO in 1998 due to changed ecological and social conditions and changed goals	• Ecosystems and land use are linked to water resources • Acknowledgement of linkages between water management, biodiversity, environmental management and poverty	• The goal is sustainable development but there is limited participation at more local levels, although this is being addressed through GEF and World Bank Brazil project,	• Ongoing efforts to bring together isolated scientific efforts which are important in terms of specific input but are fragmented in that they are conducted by research centers or countries at the national and subregional levels with little overall coordination or data sharing
Danube	• Creation of Danube River Basin Master Plan • Ongoing efforts to incorporate climate change impacts	• Water quality is linked to quantity though this is just starting, land use is linked to water quality and other ecosystem attributes	• Good public participation due to World Wildlife Fund (WWF) initiatives and requirements of the European Water Framework Directive, • Includes a formal strategy for public participation	• Required by Danube River Protection Convention (DRPC) and European Water Framework Directive (EWD) • Scientific committees study various issues and promote knowledge sharing and include contracting parties and observers

Appendix II Diagnostic Conditions Related to Actor Attributes

Basin	Flexibility	Issue Linkages	Emphasis on Equity	Capacity Building and Technology Transfers
Great Lakes Border Region	• Structure and inclusion of science based decision making allows changing approaches over time, • New structures such as watershed initiatives created as issues arose	• Ecosystem approach in 1978, for the Red and St. Croix quantity and quality were joined into ecosystem approach, science report looks at all aspects for Great Lakes	• Creation of watershed boards included interactions with stakeholders, not all watershed boards established due to jurisdictional problems but interim approaches taken in those cases	• Great Lakes Science Advisory Board, science team advances science based decision making
La Plata	• Creation of (La Plata River Basin Environmental and Management Network (RIGA) • Movement towards consolidation and coordination of projects under the purview of GEF climate change investigations	• Incorporate environment into development, linkages of processes such as sedimentation issues in the Bermejo but no action • Includes consideration of animal and plant life, education, disease control, infrastructure and economic issues	• Public participation is encouraged but difficult to implement (Bermejo), public participation is not fully adopted in operation of the Intergovernmental Coordinating Committee (CIC) or the treaty	• Upgrade existing institutions (Bermejo), shared GIS in the Bermejo, Transboundary Diagnostic Analysis (TDA) will work on fragmented capacity at regional level
Mekong	• Changes have occurred and the regime has evolved over time but some of this is due to external pressures from the financial communities	• Mekong River Commission (MRC) started move toward consideration of development and ecosystems, basin development plan is encompassing linked issues with the current plan focusing on poverty alleviation	• Has a public participation policy document but no real public policy, no linkage to civil society or NGOs or even to other ministries not directly related to the MRC	• Long strategic approaches but funding is still based on outside donors, much is driven by Asian Development Bank

Appendix II Diagnostic Conditions Related to Actor Attributes

Basin	Flexibility	Issue Linkages	Emphasis on Equity	Capacity Building and Technology Transfers
Ganges	• Limited due to national interests and distrust, • The water sharing treaty has a thirty year life span which could be considered flexible, except that 5 year reviews have not occurred	• Aquatic ecosystems and coastal mangroves are ignored because water is allocated to human uses. Fisheries collapses resulted	• India refuses to consult with Bangladesh on the River linking project • Little stakeholder involvement in either country • The treaty is based on equitable sharing and the treaty uses the word equity in reference to various provisions	• Refusal by India to share Environmental Impact Statement (EIS) data
Orange-Senqu	• Treaty has changed and evolved over time, due to changing circumstances	• River Programme considers quantity, quality and environmental concerns	• Lesotho Highlands Treaty in 1986 recognizes equitable sharing • Public participation is included in South African Development Community (SADC) Protocol but is problematic in some countries and new methods are needed to include local stakeholders	• Ongoing studies to determine allocations and Orange-Senqu River Commission (ORESCOM) granted authority to advise the countries • SADC Protocol includes sharing of data and technology for monitoring purposes
Okavango	• Limited due to national interests recent changes to Permanent Okavango River Basin Water Commission (OKACOM) could improve this	• Cross-sectoral and cross disciplinary collaboration not effective, relationship of flows and ecological sustainability of the Okavango Delta	• Commitment to stakeholder participation but major issues related to language and economic level, international Non-Governmental Organizations (NGOs), Okavango river delta plan limited by lack of stakeholder involvement, basin wide forum consisting of 10 local community reps from each country	• Many studies need to be conducted, institutions strengthened

Appendix II Diagnostic Conditions Related to Actor Attributes

Basin	Flexibility	Issue Linkages	Emphasis on Equity	Capacity Building and Technology Transfers
Nile	• Much emphasis on national interests as opposed to basin wide interests, civil war in Sudan threatens long term water sharing agreement between Egypt and Sudan	• Nile Basin Initiative (NBI) links issues but emphasis is on development, links shared vision program links socio-economic development and environment, much emphasis on the links between poverty and water resources development	• Equitable utilization for all countries is not resolved • Involvement of civil society is extremely limited, decisions are made by governments	• Shared water resources diploma to train water professionals from other basin countries, • Egypt financing groundwater development in Kenya Rift Valley to preserve surface waters for use downstream
Rio Grande	• Flexibility evidenced by water sharing in dire circumstances in Tijuana, little to none in water allocations in the Rio Grande, supra basin scale limits adaptability • Minute system allows modifications of or additions to the Treaty	• Little linkage to ecosystems; water quality and water quantity are handled separately	• Some movement towards stakeholder participation in the US section; the US recognizes Mexico as a stakeholder	• Good, especially in the area of water quality, sanitation and dam operations

Appendix III Diagnostic Conditions Associated with Implementation

Basin	Implementation Review Systems	Sanctions/Deterrence	Monitoring Procedures
Amazon	• At present there is none	• None	• Limited, current Amazon Cooperation Treaty Organization/Global Environment Facility (ACTO/GEF project is moving towards coordinated technical exchanges which could ultimately lead to a coordinate monitoring framework • No basin wide integrated system
Danube	• Reporting via requirements of European Water Framework Directive	• Penalties if European Water Framework Directive (EWD) goals not achieved	• Water quality monitoring in place and improving • Starting to include biological monitoring • International Commission for the Protection of the Danube (ICDPR) identification of hydromorphologically altered streams and action plan to mitigate impacts
Great Lakes Border Region	• Accountability is an issue in the Great Lakes Water Quality Agreement • Decisions at the international, federal and state levels are often top-down without input from local governments in design	• Science team recommends accountability be included in the annex	• International Watersheds Initiative (IWI) worked to reconcile data and maps and supports joint data collection in hydrology biology and water quality
La Plata	• At present there is none	• None	• Exchange of hydrologic data through Intergovernmental Coordinating Committee (CIC), an oil spill brought water quality issues to the forefront, field testing of sediment control regimes in the Bermejo

Appendix III Diagnostic Conditions Associated with Implementation

Basin	Implementation Review Systems	Sanctions/Deterrence	Monitoring Procedures
Mekong	• Rules for water sharing and environmental flows, basin plans are developed but not implemented, sometimes the "basin" is redefined to leave out tributaries so these projects can go ahead despite impacts to the transboundary watershed • Notification is required for intra- and inter-basin use	• Limited, particularly with China's non-membership and unilateral development in upstream reaches • Rules for cooperation in maintaining instream flows, however lack of participation and unilateral actions by China on upstream tributaries impacts downstream aquatic environment.	• Water quality monitoring and hydrologic monitoring stations throughout the basin
Ganges	• Treaty reduces diversions in times of drought • Formula for water sharing implemented by Joint Rivers Commission	• No specific sanctions, however if requirements are not met, the governments will enter into consultation for emergency adjustments • Consultation in 1997 did not result in additional water for Bangladesh or guarantee that treaty requirements would be met	• Ganges Treaty includes monitoring procedures and observation and recording of daily flows • India does not regularly share other data, in particular upstream water use data • In Bangladesh, use of groundwater is politically determined because of potential effects on future negotiations for surface waters
Orange-Senqu	• Rules for water sharing but not on a basin wide scale, for instance agreements between South Africa and Lesotho that don't include Namibia, which is impacted by the agreements	• Required by South African Development Community (SADC) Protocol but no specific measures	• Limited monitoring available, 10 stations for Namibia, Botswana and Lesotho combined
Okavango	• No data, so no way to monitor compliance	• No equitable water sharing agreement	• No rainfall records, information is fragmented and non-existent for Angola, • Good data on the delta, • Transboundary Diagnostic Analysis (TDA) points out scarcity of imagery and difficulties involved with data in various formats and different scales

Appendix III Diagnostic Conditions Associated with Implementation

Basin	Implementation Review Systems	Sanctions/Deterrence	Monitoring Procedures
Nile	• No central database for Nile Basin Initiative (NBI), data is housed at the national level which limits accessibility • No basin wide rules although efforts are ongoing to produce a cooperative treaty	• Allocations between Egypt and Sudan, no prior notification framework	• Gaging stations maintained to monitor water allocations between Egypt and Sudan, • Other data limited and scattered but ongoing improvements under the NBI
Rio Grande	• Treaty contains requirements for water deliveries and compliance is determined by joint accounting	• If compliance is not achieved, deliveries can be made up in the next accounting period, this issue is highly contentious	• Gages and water quality monitoring, • Annual compact accounting to reconcile data • Some biological monitoring

Appendix IV. Sources by Basin

Basin	Countries	Lierature Sources
Amazon	Brazil, Peru, Bolivia, Columbia, Ecuador, Venezuela, Guyana, Suriname	(Bucher et al., 2000), (GEF, 2003), (ACTO, 2004), (GEF, 2004), (World Bank, 2006), (GEF, 2010), , http://www.otca.org.br/en/
Danube	Romania, Hungary, Austria, Yugoslavia, Germany, Slovakia, Bulgaria, Croatia, Bosnia and Herzegovina, Ukraine, Slovenia, Czech Republic, Italy, Moldova, Poland, Switzerland, Austria	(Danube River Protection Convention, 1994), (European Environment Agency, 2001), (Burchi and Spreij, 2003), (ICDPR, 2004), (ICDPR, 2005), (Malzbender, 2006), (Rieu-Clarke, 2006), (UNDP and GEF, 2006), (European Environment Agency, 2007), (ICPDR et. al, 2007), (UNDP and GEF, 2007), (ICDPR, 2008a), (ICDPR, 2008b), (EEA, 2009), http://www.icpdr.org/icpdr-pages/river_basin_management.htm
Great Lakes Border Region	United States and Canada	(IJC, 2000), (Diaz and Dubner, 2001), (Sproule-Jones, 2002), (Burchi and Spreij, 2003), (Fischhendler and Feitelson, 2005), (IJC, 2005), (Great Lakes Science Advisory Board, 2006), (Hall, 2006), (Fisher, 2006), (IJC, 2006a), (IJC, 2006b), (IJC, 2006c), (Karkkainen, 2006a), (Karkkainen, 2006b), (Loucks, 2006), , (Newton, 2006), (Bielecki, 2007), (Hearne, 2007), (Saeger, 2007), (Valiante, 2007), (Great Lakes Science Advisory Board, 2008), (IJC, 2009), http://www.ijc.org/,
La Plata	Brazil, Argentina, Bolivia, Paraguay, Uruguay	(Binational Commission for the Development of the Upper Bermejo River and Grande de Tarija River Basins et al., 2000a), (Binational Commission for the Development of the Upper Bermejo River and Grande de Tarija River Basins et al., 2000b), (Binational Commission for the Development of the Upper Bermejo River and Grande de Tarija River Basins et al., 2000c), (Gottgens, et al. 2001), (Calcagno, 2002), (Calcagno et al., 2002), (Burchi and Spreij, 2003), (OAS, 2005a), (OAS, 2005b), (UNEP and GEF, 2005), (UNDP et al., 2006), (Vanderbeck et al., 2006), (GEF, 2007), (UNDP et al, 2007), (Gilman et al., 2008), http://cicplata.org/?id=home,

Appendix IV. Sources by Basin

Basin	Countries	Lierature Sources
Mekong	Laos, Thailand, China, Cambodia, Vietnam, Myanmar	(Browder, 2000), (Chenoweth et al., 2001), (Chenoweth, et al., 2002), (Burchi and Spreij, 2003), (Dudgeon, 2003), (Le-Huu and Nguyen-Duc, 2003). (World Bank, 2003), (Lebel et al., 2005), (Molle, 2005), (Davidsen, 2006), (Hirsch, 2006), (MRC, 2006), (MRC, 2007), (Varis et al., 2008), http://www.mrcmekong.org/
Ganges	India, Bangladesh	(Saleth, 1994), (Crow and Singh, 2000), (Brichieri-Colombi and Bradnock, 2003), (Kraska, 2003), (Salman and Uprety, 2003), (Chakraborty, 2004), (Samarakoon, 2004), (Alam, 2007), (Misra et al., 2007), (UNEP and Woodrow Wilson International Center for Scholars, 2007), (UNEP, 2008), (Zeitoun and Mirumachi, 2008), (Rahaman, 2009),
Orange/Senqu	South Africa, Namibia, Botswana, Lesotho	(Earle et al., 2005), (Lautz and Giordano, 2005), (UNEP, 2005), (Lautz and Giordano, 2006), (Heyns et al., 2008), (Kistin and Ashton, 2008), (Krysanova, et al., 2008), (Donkor and Wolde, 2009), (Malzbender and Earle, 2009), (Quibell and Pegram, 2009), http://www.orasecom.org/
Okavango	Botswana, Namibia, Angola, Zimbabwe	(OKACOM, 1998), (UNDP and OKACOM, 1998), (Forrest, 2001), (UNDP and GEF, 2002), (Burchi and Spreij, 2003), (Mbaiwa, 2004), (Bernard and Moetapele, 2005), (Lautz and Giordano, 2005), (UNEP, 2005), (Bethune, 2006), (Kgathi et al., 2006), (Kniveton and Todd, 2006), (Hamandawana et al., 2007), (Hossain and Helao, 2008), (Magole, 2008), (Swatuk and Motsholapheko, 2008), (Donkor and Wolde, 2009), (Malzbender and Earle, 2009), (Mosepele et al., 2009), http://www.sadcwscu.org.ls/programme/hycos/prog_hycos.htm, http://www.okacom.org/index.htm

Appendix IV. Sources by Basin

Basin	Countries	Lierature Sources
Nile	Sudan, Ethiopia, Egypt, Uganda, Tanzania, Kenya, Congo, Rwanda, Burundi, Eritrea	(Dinar and Alemu, 2000), (Brunnee and Toope, 2002), (Burchi and Spreij, 2003), (Kung, 2003), (Nicol, 2003), (Metawie, 2004), (Arsano and Tamrat, 2005), (Conway, 2005), (El-Din Amer et al., 2005), (El-Tom Hamad and El-Battahani, 2005), (Hefny and El-Din Amer, 2005), (Lautz and Giordano, 2005), (Mason, 2005), (UNEP, 2005), (Collins, 2006), (Kagwanja, 2007), (Abdalla, 2008), (Krysanova et al., 2008), (Zeitoun and Mirumachi, 2008), (Donkor and Wolde, 2009), (Malzbender and Earle, 2009), http://www.nilebasin.org/index.php?option=com_frontpage&Itemid=1
Rio Grande	United States and Mexico	(1906 Convention), (1944 Treaty), (Eaton and Anderson, 1987), (Schmandt, 1993), (Mumme, 1999), (Brown and Mumme, 2000), (HARC and ITESM, 2000), (Schmandt, et al., 2000), (CEC, 2001), (National Heritage Institute, 2001), (First International Symposium on Transboundary Waters Management, 2002), (Kelly, 2002), (Texas Center for Policy Studies, 2002), (Moore, et al. 2002), (Burchi and Spreij, 2003), (Schiff, 2003), (CSIS and ITAM, 2003), (Mumme, 2003a),(Mumme, 2003b), (CLE International, 2004), (Environmental Defense and Woodrow Wilson International Center, 2004), (Kelly and Székely, 2004), (Kliot et al., 2004), (IBWC, 2005), (CEC, 2009), (Alexander Martin, 2010)

REFERENCES

Abdalla, K. 2008. Institutional and legal arrangements in the Nile river basin: Suggestions to improve the current situation toward adaptive integrated water resources management. *Water Science and Technology.* 58(10):2031-2040.

Agrawal, Arun. 2001. Common property institutions and sustainable governance of resources. *World Development.* 29(10):1649-1672.

Amazon Cooperation Treaty Organization (ACTO). 2004. Strategic Plan 2004-2012. Available at http://www.otca.org.br/en/plano.php

Amazon Cooperation Treaty Organization (ACTO). Available at http://www.otca.org.br/en/

Alam, Shawkat. 2007. An Examination of the international environmental law governing the proposed Indian river-linking project and an appraisal of its ecological and socio-economic implications for lower riparian countries. *Georgetown International Environmental Law Review.* 19:209.

Alexander Martin, K. 2010. Texas Boundary Water Agreements. In *Water Policy in Texas: Responding to the Rise of Scarcity.* Ed. Ronald Griffin. RFF Press.

Anderies, J., Walker, B. and Kinzig, A. 2006. Fifteen weddings and a funeral: Case studies and resilience-based management. *Ecology and Society.* 11(1):21.

Andresen, S. and E. Hey. 2005. The Effectiveness and legitimacy of international environmental institutions. *International Environmental Agreements.* 5:211-226.

Arsano, Y. and I. Tamrat. 2005. Ethiopia and the eastern Nile Basin. *Aquatic Sciences.* 67:15-27.

Bernard, T. and N. Moetapele. 2007. Dessication of the Gomoti River: Biophysical process and indigenous resource management in Northern Botswana. *Journal of Arid Environments.* 63:256-283.

Bethune, Shirley. 2006. Stakeholder participation in the Okavango River Basin. In *Stakeholder Participation in Transboundary Water Management: Selected Case Studies.* Eds. Anton Earle and Daniel Malzbender. Inwent, Germany. Cape Town: South Africa.

Bielecki, Jessica. 2007. Managing resources with interstate compacts: A perspective from the Great Lakes. *Buffalo Environmental Law Journal*. 14:173.

Binational Commission for the Development of the Upper Bermejo River and the Grande de Tarija River Basins, Global Environment Facility, United Nations Environment Program, Organization of American States. 2000a. *Transboundary Diagnostic Analysis of the Binational Basin of the Bermejo River*.

Binational Commission for the Development of the Upper Bermejo River and the Grande de Tarija River Basins, Global Environment Facility, United Nations Environment Program, Organization of American States. 2000b. *Strategic Action Program for the Binational Basin of the Bermejo River*.

Binational Commission for the Development of the Upper Bermejo River and the Grande de Tarija River Basins, Global Environment Facility, United Nations Environment Program, Organization of American States. 2000c. *Public Participation in the Strategic Action Program for the Binational Basin of the Bermejo River.*

Brichieri-Columbi, S. and R. Bradnock. 2003. Geopolitics, water and development in South Asia: Cooperative development in the Ganges-Brahmaputra delta. *The Geographical Journal*. 169(1):43-64.

Browder, G. 2000. An Analysis of the negotiations for the 1995 Mekong Agreement. *International Negotiation.* 5:237-261.

Brown, J. 2003. "Whiskey's fer drinkin'; Water's fer fighten'!" Is It? Resolving a collective action dilemma in New Mexico. *Natural Resources Journal* 43(1):185. Winter 2003.

Brown, C.S. and S. Mumme. 2000. Applied and theoretical aspects of binational watershed councils (consejos de cuencas) in the US-Mexico borderlands. *Natural Resources Journal*. 40(4):895. Fall 2000.

Brunnee, J. and S. Toope. 2002. The changing Nile Basin regime: Does law matter? *Harvard International Law Journal.* 43:105.

Bucher, E., Bouille, D., Rodriguez, M. and H. Navajas. 2000. Capacity Development Initiative. Country Capacity Development Needs and Priorities. Regional Report for Latin America and the Caribbean. GEF-UNDP Strategic Partnership. September 2000.

Burchi, S., and M. Spreij. 2003. Institutions for International Freshwater Management. UNESCO/IHP/WWAP. IHP-VI. Technical Documents in Hydrology. PC→ CP Series. n° 3.

Calcagno, Alberto. 2002. Instilling comprehensive management and technological approaches for the sustainable management of La Plata River Basin water resources. *Ecohydrology and Hydrobiology*. 2(1-4):93-103.

Calcagno, A., Yamashiki, Y. and A. Mugett. 2002. Establishment of a non-governmental regional approach to La Plata River Basin integrated watershed management promoted throughout three international workshops supported by UN and Japanese agencies, led by ILEC. *Hydrologic Processes.* 16:2099-2114.

Chakraborty, Roshni. 2004. Sharing of river waters among India and its neighbors in the 21st Century: War or peace? *Water International.* 29(2):201-208.

Center for Strategic and International Studies (CSIS) and Insituto Tecnológico Autónomo de México (ITAM). 2003. *U.S.-Mexico Transboundary Water Management: The Case of the Rio Grande/Rio Bravo. Recommendations for Policymakers for the Medium and Long Term.* Report of the U.S.-Mexico Binational Council. University of Texas at Austin. January 2003.

Chenoweth, J., Malano, H. and J. Bird. 2001. Integrated river basin management in the multi-jurisdictional river basins: The Case of the Mekong River Basin. *The International Journal of Water Resources Development*. 17(3):365-377.

Chenoweth, J., Ewing, S. and J. Bird. 2002. Procedures for ensuring community involvement in multijurisdictional river basins: A Comparison of the Murray-Darling and Mekong River Basins. *Environmental Management.* 29(4):497-509.

CLE International. 2004. Rio Grande Super Conference. Albuquerque, New Mexico. February 5-6, 2004.

Collins, Robert. 2006. Negotiations and exploitation of the Nile waters at the end of the millennium. *Water International.* 31(1):116-126.

Commission for Environmental Cooperation (CEC). 2001. North American Boundary and Transboundary Inland Water Management Report. North American Environmental Law and Policy Series 7. Available at http://www.cec.org/files/PDF/ECONOMY/NAELP7e.pdf

Commission for Environmental Cooperation (CEC). 2009. Available at http://www.cec.org/home/index.cfm?varlan=english

Conway, Declan. 2005. From headwaters tributaries to international river: Observing and adapting to climate variability and change in the Nile Basin. *Global Environmental Change.* 15:99-114.

Crow, B. and Singh, N. 2000. Impediments and innovation in international rivers: The Waters of South Asia. *World Development.* 28(11):1907-1925.

Davidsen, Pål Arne. 2006. Between rhetoric and reality- A Critical account of stakeholder participation in decision making in the Mekong River Basin. In *Stakeholder Participation in Transboundary Water Management: Selected Case Studies*. Eds. Anton Earle and Daniel Malzbender. Inwent, Germany. Cape Town: South Africa.

Dellapenna, J. and J. Gupta. 2008. Toward global law on water. *Global Governance*. 14: 437-453.

Diaz, L. and B. Dubner. 2001. The Necessity of preventing unilateral responses to water scarcity-The Major threat against mankind this century. *Cardozo Journal of International and Comparative Law*. 9:1.

Dinar, A. and Alemu, S. 2000. The Process of negotiation over international water disputes: The Case of the Nile Basin. *International Negotiation*. 5:331-356.

Donko, S. and Y. Wolde. 2009. *Integrated Water Resources Management in Africa: Issues and Options.* Internet. Available at http://www.ramsar.org/wurc/wurchbk4cs1.doc

Dudgeon, David. 2003. The contribution of scientific information to the conservation and management of freshwater biodiversity in tropical Asia. *Hydrobiologia.* 500:295-314.

Earle, A., Malzbender, D., Turton, A. and E. Manzungu. 2005. *A Preliminary Basin Profile of the Orange/Senqu River.* Inwent Capacity Development Programme: Integrated Water Resources Management in Shared River Basins in the SADC Region. AWIRU, University of Pretoria, South Africa. Cape Town.

Eaton, David J. and John Michael Andersen. 1987. *The State of the Rio Grande/Rio Bravo: A Study of Water Resource Issues Along the Texas/Mexico Border*. Tuscon: The University of Arizona Press.

El-Din Amer, S., Arsano, Y., El-Battahani, A., El-Tom Hamad, O., Hefny, M., and I. Tamrat. 2005. Sustainable development and international cooperation in the Eastern Nile Basin. *Aquatic Sciences.* 67:3-14.

El-Tom Hamad, O. and A. El-Battahani. 2005. Sudan and the Nile Basin. *Aquatic Sciences*. 67:28-41.

Environmental Defense and Woodrow Wilson International Center for Scholars Mexico Institute. 2004. Agricultural Production Trends and the Future of the Trans-boundary Río Grande/Río Bravo Basin. San Antonio, Texas. September 2004.

European Environment Agency. 2001. *Sustainable Water Use in Europe. Part 3: Extreme Hydrological Event: Floods and Droughts.* Environmental Issue Report. No. 21.

European Environment Agency (EEA). 2007. *Climate Change and Water Adaptation Issues*. EEA Technical Report. No. 2/2007.

European Environment Agency (EEA). 2009. *Water Resources Across Europe-Confronting Water Scarcity and Drought.* EEA Report. No. 2/2009.

European Union. 2009. The EU Water Framework Directive-integrated basin management for Europe. Internet. Available at http://ec.europa.eu/environment/water/water-framework/index_en.html

Fischhendler, I. and E. Feitelson. 2005. The formation and viability of a non-basin water management: The US-Canada case. *Geoforum*. 36:792-804.

Fisher, Keith. 2006. Forward: The Great Lakes-St. Lawrence River Basin Compact and Agreement: International law and policy crossroads. *Michigan State Law Review*. Special Issue 2006:1085.

Food and Agricultural Organization of the United Nations (FAO). 2009. Aquastat. Available at http://www.fao.org/nr/water/aquastat/main/index.stm

Forrest, Joshua. 2001. Water policy and environmental sustainability: The Case of post-colonial Namibia. *Public Administration and Development.* 21:393-400.

George, A. and A. Bennett. 2005. *Case Studies and Theory Development in the Social Sciences.* MA: Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University.

Gilman, P., Pochat, V. and A. Dinar. 2008. Whither La Plata? Assessing the state of transboundary resource cooperation in the basin. *Natural Resources Forum.* 32:203-214.

Giordano, M.A. and A. Wolf. 2003. Sharing waters: Post-Rio water management. *Natural Resources Forum.* 27:163-171.

Giordano, M. F., Giordano, M.A. and A. Wolf. 2005. International resource conflict and mitigation. *Journal of Peace Research.* 42(1):47-65.

Global Environment Facility (GEF). 2003. *Concept Document for the Integrated and Sustainable Management of Transboundary Water Resources in the Amazon Basin.*

Global Environment Facility (GEF). 2004. *Integrated and Sustainable Management of Transboundary Water Resources in the Amazon River Basin.* Project Development Preparation-PDF-B. PMS:GF/1010.

Global Environment Facility (GEF). 2006. *International Waters Program Study*. Prepared by Bewers, J. and J. Uitto. GEF Monitoring and Evaluation.

Global Environment Facility (GEF). 2007. *Project Executive Summary*. Request for Council Work Program Inclusion under the GEF Trust Fund. GEFSEC Project ID-2095.

Global Environmental Facility (GEF). 2010. *Projeto GEF Amazonas*. Integrated and Sustainable Management of Transboundary Water Resources in the Amazon River Basin Considering Climate Variability and Change. Available at http://www.otca.org.br/gefam/index.php?idioma=en

Gottgens, J., Perry, J. Fortney, R., Meyer, J. Benedict, M and B. Rood. 2001. The Paraguay-Paraná Hydrovía: Protecting the Pantanal with lessons from the past. *Bioscience.* 51(4):301-308.

Great Lakes Science Advisory Board. 2006. *Consultation on Emerging Issues of the Great Lakes in the 21st Century*. Report of the Great Lakes Science Advisory Board to the International Joint Commission. November, 2006.

Great Lakes Science Advisory Board. 2008. *Priorities 2005-2007. Priorities and Progress under the Great Lakes Water Quality Agreement.* Report to the International Joint Commission. March, 2008.

Hall, Noah. 2006. Toward a new horizontal federalism: Interstate water management in the Great Lakes Region. *University of Colorado Law Review.* 77:405.

Hamandawana, H., Chanda, R. and F. Eckardt. 2007. Hypergame analysis and hydroconflicts in the Okavango Drainage Basin. *Water International*. 32(4):538-557.

Hearne, Robert. 2007. Evolving water management institutions in the Red River Basin. *Environmental Management.* 40:842-852.

Hefny, M. and S. El-Din Amer. 2005. Egypt and the Nile Basin. *Aquatic Sciences.* 67:42-50.

Heyns, P., Patrick, M. and A. Turton. 2008. Transboundary water resource management in Southern Africa: Meeting the challenge of joint planning and management in the Orange Basin. *International Journal of Water Resources Development.* 24(3):371-383.

Hirji, R. and T. Panella. 2003. Evolving policy reforms and experiences for addressing downstream impacts in World Bank water resources projects. *River Research and Applications.* 19:667-681.

Hirsch, Philip. 2006. Water governance reform and catchment management in the Mekong region. *The Journal of Environment and Development.* 15(2):184-201.

Holling, C.S., Gunderson, L. and G. Peterson. 2002. Sustainability and panarchies. In *Panarchy: Understanding Transformations in Human and Natural Systems.* Eds.L. Gunderson and C.S. Holling, 63-102. Washington D.C.: Island Press.

Hooper, Bruce. 2005. *Integrated River Basin Governance: Learning from International Experience*. London, UK: IWA Publishing.

Hossain, F. and T. Helao. 2008. Local governance and water resource management: Experiences from Northern Namibia. *Public Administration and Development.* 28:200-211.

Houston Advanced Research Center (HARC) and Instituto Tecnológico de Estudios Superiores de Monterrey (ITESM). 2000. *Water and Sustainable Development in the Binational Lower Rio Grande/Rio Bravo Basin*. Final Report. EPA Grant No. R 824799-01-0.

International Commission for the Protection of the Danube River (ICPDR), United Nations Development Program (UNDP), Global Environmental Facility (GEF), United Nations Office of Project Services (UNOPS). 2007. *Fifteen Years of Managing the Danube River Basin 1991-2006.* Danube Regional Project.

International Commission for the Protection of the Danube River (ICDPR). 2004. *Danube River Basin District.* River basin characteristics, impact of human activities and economic analysis required under Article 5, Annex II and Annex III, and inventory of protected areas required under Article 6, Annex IV of the EU Water Framework Directive (2000/60/EC). Danube Basin Analysis. WFD Roof Report 2004.

International Commission for the Protection of the Danube River (ICDPR). 2005. *Development of the Danube River Basin District Management Plan-Strategy for Coordination in a Large International River Basin.* River Basin Management Expert Group. Draft-8. DOC-101. November 23, 2005.

International Commission for the Protection of the Danube River (ICDPR). 2008a. *Significant Water Management Issues in the Danube River Basin District.* Document No.: IC 132.

International Commission for the Protection of the Danube River (ICDPR). 2008b. *Danube River Basin Management Plan: Public Participation.* Document No.: ICWD 317.

International Joint Commission (IJC). 2000. *Transboundary Watersheds.* First report to the governments of Canada and the United States under the Reference of November 19, 1998 with respect to international watershed boards. December, 2000.

International Joint Commission (IJC). 2005. *A Discussion Paper on the International Watersheds Initiative.* Second Report to the Governments of Canada and the United States Under the Reference of November 19, 1998 With Respect to International Watershed Boards.

International Joint Commission (IJC). 2006a. *Synthesis of Public Comment on the Forthcoming Review by the Federal Governments of Canada and the United States of The Great Lakes Water Quality Agreement.* A Report to the Governments of the United States and Canada. January, 2006.

International Joint Commission (IJC). 2006b. *Advice to Governments on Their Review of the Great Lakes Water Quality Agreement.* A Special Report to the Governments of the United States. August 2006.

International Joint Commission (IJC). 2006c. *13th Biennial Report on Great Lakes Water Quality.* Prepared pursuant to the Great Lakes Water Quality Agreement of 1978 for submission to the Governments of the United States and Canada and the State and Provincial Governments of the Great Lakes Basin. December, 2006.

International Joint Commission (IJC). 2009. *The International Watersheds Initiative: Implementing a New Paradigm for Transboundary Basins.* Third Report to the Governments on the International Watersheds Initiative. January, 2009.

Kagwanja, Peter. 2007. Calming the waters: The East African community and conflict over Nile resources. *The Journal of East African Studies.* 1(3):321-337.

Karkkainen, Bradley. 2006a. New governance in the Great Lakes: Has its time arrived? *Michigan State Law Review.* Special Issue 2006:1249.

Karkkainen, Bradley. 2006b. Symposium: Transboundary freshwater ecosystem restoration: The role of law, process and lawyers: Managing transboundary aquatic ecosystems: Lessons from the Great Lakes. *Pacific McGeorge Global Business and Development Law Journal.* 19:209.

Kelly, M. 2002. Water management in the binational Texas/Mexico Rio Grande/Rio Bravo Basin. In *Human Population and Freshwater Resources: U.S. Cases and International Perspectives.* Ed. Karin Krchnak. Bulletin Series. Yale School of Forestry and Environmental Studies. Number 107.

Kgathi, D., Kniveton, D. Ringrose, S., Turton, A., Vanderpost, C., Lundqvist, J. and Seely, M. 2006. The Okavango; A River supporting its people, environment and economic development. *Journal of Hydrology.* 331:3-17.

Kistin, E. and P. Ashton. 2008. Adapting to change in transboundary rivers: An Analysis of treaty flexibility on the Orange-Senqu River Basin. *International Journal of water Resources Development.* 24(3):385-400.

Kniveton, D. and M. Todd. 2006. Water resources in regional development: The Okavango River. Editorial. *Journal of Hydrology.* 331:1-2.

Kraska, James. 2003. Sustainable development is security: The role of transboundary river agreements as a confidence building measure (CBM) in South Asia. *Yale Journal of International Law.* 28:465.

Krysanova, V., Buiteyeld, H., Haase, D., Hattermann, F., van Niekerk, K., Roest, K., Martinez-Santos, P. and M. Schlüter. Practices and lessons learned in coping with climatic hazards at the river-basin scale: Floods and droughts. *Ecology and Society.* 13(2):32.

Kung, R. 2003. Addressing the dimensions of transboundary water use: The Nile Basin Initiative. *Mountain Research and Development.* 23(1):4-6.

Lautz, J. and M. Giordano. 2005. Transboundary water law in Africa: Development, nature and geography. *Natural Resources Journal.* 45:1053.

Lautz, J. and M. Giordano. 2006. Equity in transboundary water law: Valuable paradigm or merely semantics. *Colorado Journal of Environmental Law and Policy.* 17:89.

Lebel, L. Garden, P. and M. Imamura. 2005. The politics of scale, position and place in the governance of water resources in the Mekong region. *Ecology and Society.* 10(2):18.

Le-Huu, T. and Nguyen-Duc, L. 2003. Mekong Case Study. UNESCO/IHP/WWAP. IHP-VI. Technical Documents in Hydrology. PC→ CP Series. n˚ 10.

Loucks, Daniel. 2006. Modeling and managing the interactions between hydrology, ecology and economics. *Journal of Hydrology.* 328:408-416.

Magole, L. 2008. The feasibility of implementing an integrated management plan of the Okavango Delta, Botswana. *Physics and Chemistry of the Earth.* 33:906-912.

Malzbender, Daniel. 2006. Public participation under the EU Water Framework Directive. In *Stakeholder Participation in Transboundary Water Management: Selected Case Studies.* Ed. Anton Earle and Daniel Malzbender. Inwent, Germany. Cape Town: South Africa.

Malzbender, D. and A. Earle. 2009. *The Impact and Implications of the Adoption of the 1997 UN Watercourse Convention for countries in Southern Africa.* Commissioned by WWF-Global Freshwater Programme. Internet. Available at http://www.acwr.co.za/pdf_files/WWF_RA_UN%20Convention.pdf

Mason, Simon. 2005. Are we scorpions? The Role of upstream-downstream dialogue in fostering cooperation in the Nile Basin. *Mountain Research and Development.* 25(2):115-120.

Matz, Nele. 2005. Financial institutions between effectiveness and legitimacy – A Legal analysis of the World Bank, Global Environmental Facility and Prototype Carbon Fund. *International Environmental Agreements.* 5:265-302

Mbaiwa, Joseph. 2004. Causes and possible solutions to water resource conflicts in the Okavango River Basin: The Case of Angola, Namibia and Botswana. *Physics and Chemistry of the Earth.* 29:1319-1326.

Mee, Lawrence. 2005. The Role of UNEP and UNDP in multilateral environmental agreements. *International Environmental Agreements.* 5:227-263.

Mekong River Commission (MRC). 2006. *Strategic Plan 2006-2010.* Meeting the Needs, Keeping the Balance.

Mekong River Commission (MRC). 2007. *Report from the International Conference on the Mekong River Commission (MRC).* Hanoi, Vietnam. April 24, 2007.

Metawie, Abdel. 2004. History of co-operation in the Nile Basin. *Water Resources Development.* 20(1):47-63.

Misra, A., Saxena, A., Yaduvanshi, M., Mishra, A., Bhadauriya, Y. and Thakur, A. 2007. Proposed river-linking project of India: a boon or bane to nature. *Environmental Geology.* 51:1361-1376.

Molle, François. 2005. *Irrigation and Water Policies in the Mekong Region: Current Discourses and Practices.* International Water Management Institute. IWMI Comprehensive Assessment and Research Report 95. Columbo:Sri Lanka.

Molle, François. 2006. *Planning and Managing Water Resources at the River Basin Level: Emergence and Evolution of a Concept.* International Water Management Institute. IWMI Comprehensive Assessment and Research Report 16. Columbo:Sri Lanka.

Mosepele, K., Moyle, P., Merron, G. Purkey, D. and B. Mosepele. 2009. Fish, floods, and ecosystem engineers: Aquatic conservation in the Okavango Delta, Botswana. *BioScience.* 59(1):53-64.

Newton, Joshua. 2006. Stakeholder participation in transboundary water management: the North American Great Lakes System. In *Stakeholder Participation in Transboundary Water Management: Selected Case Studies*. Ed. Anton Earle and Daniel Malzbender. Inwent, Germany. Cape Town: South Africa.

Nicol, A. 2003. *The Nile: Moving Beyond Cooperation*. UNESCO/IHP/WWAP. IHP-VI. Technical Documents in Hydrology. PC→ CP Series. n° 16.

Okavango Basin Commission (OKACOM). 1998. *Okavango River Basin Transboundary Diagnostic Analysis.*

Organization of American States (OAS). 2005a. *Pantanal and Upper Paraguay River Basin. Implementation of Integrated Watershed Management Practices for the Pantanal and the Upper Paraguay River Basin.* OAS Office for Sustainable Development and Environment. Water Project Series. Number 3. October, 2005.

Organization of American States (OAS). 2005b. *La Plata River Basin. A Framework for the Sustainable Management of Its Water Resources with Respect to the Hydrological Effects of Climatic Variability and Change.* OAS Office for Sustainable Development and Environment. Water Project Series. Number 6. October, 2005.

Ostrom, Elinor. 2005. *Understanding Institutional Diversity*. Princeton, NJ: Princeton University Press.

Pahl-Wostl, C., Sendzimir, J., Jeffrey, P. Aerts, J., Berkamo, G. and K. Cross. 2007. Managing change towards adaptive water management through social learning. *Ecology and Society.* 12(2):30.

Pahl-Wostl, C., Gupta, J. and D. Petry. 2008. Governance and the global water system: A theoretical exploration. *Global Governance.* 14:419-435.

Pochat, Victor. 2006. *International Policy Concerning Shared River Basins.* United Nations Environmental Program. Dams and Development Project.

Quibell, G. and G. Pegram. 2009. *Strengthening Transboundary Water Management Institutions: The Case of the Orange-Senqu River Commission in Southern Africa.* Internet. Available at http://inweb.gr/twm4/abs/QUIBELL%20Gavin.pdf

Quinn, C., Huby, M., Kiwasila, H. and Lovett, J. 2007. Design principles and common pool resource management: An Institutional approach to evaluating community management in semi-arid Tanzania. *Journal of Environmental Management.* 84:100-113.

Rahaman, Muhammad. 2009. Integrated Ganges basin management: conflict and hope for regional development. *Water Policy*. 11:168-190.

Rieu-Clarke, Alistair. 2006. An Overview of stakeholder participation within the Danube Basin: What current practice and future challenges. In *Stakeholder Participation in Transboundary Water Management: Selected Case Studies.* Ed. Anton Earle and Daniel Malzbender. Inwent, Germany. Cape Town: South Africa.

Saeger, Dana. 2007. Comment: The Great Lakes-St. Lawrence river basin water resources compact: Groundwater, fifth amendment takings and the public trust doctrine. *Great Plains Natural Resources Journal*. 12:114.

Saleth, R. M., 1994. Towards a New Water Institution: Economics, Law and Policy. *Economic and Political Weekly.* 29(39):A147-A155. September 24, 1994.

Salman, M.A.S. and K. Uprety. 2003. Conflict and Cooperation on South Asia's International Rivers- A Legal Perspective. The International Bank for Reconstruction and Development/World Bank. Washington, D.C.

Samarakoon, Jayampathy. 2004. Issues of livelihood, sustainable development, and governance: Bay of Bengal. *Ambio*. 33(1-2):34-44.

Schruers, Miranda. 2005. Global environment threats and a divided northern community. *International Environmental Agreements.* 5:349-376.

Schiff, Damien M. 2003. Rollin', rollin', rollin' on the river: A Story of drought, treaty interpretation, and other Rio Grande problems. *Indiana International & Comparative Law Review* 14:117-171.

Schmandt, J. 1993. *Water and Development: The Rio Grande/Rio Bravo*. Lyndon B. Johnson School of Public Affairs, Austin, TX.

Schmandt, J., Aguilar-Barajas, I., Armstrong, N., Chapas-Aleman, L., Contreras-Balderas, S., Edwards, R., Hazleton, J., de Jesus Navar, J., Mathis, M., Vogel-Martinez, E. and Ward, G. 2000. *Final Report: Water and Sustainable Development in the Binational Lower Rio Grande/Bravo Basin*. United States Environmental Protection Agency. EPA Grant Number: R824799.

Sklarew, D., Annis, S., Mendler, J. and M. Hamid. Forging a global community to address international water crises: The IW:LEARN project. *Water Resources IMPACT.* March 2001.

Sproule-Jones, Mark. 2002. Institutional experiments in the restoration of the North American Great Lakes environment. *Canadian Journal of Political Science.* 35(4):835-857.

Swatuk, L. and M. Motsholapheko. 2008. Communicating integrated water resources management: From global discourse to local practice-Chronicling an experience from the Boteti River sub-basin, Botswana. *Physics and Chemistry of the Earth.* 33:881-888.

Swedish Ministry of Foreign Affairs. 2001. *Transboundary Water Management as an International Public Good*. Prepared for The Ministry for Foreign Affairs, Sweden. Development Financing 2000, Study 2001:1.

Texas Center for Policy Studies. 2002. The Dispute over the Shared Resources of the Rio Grande/Rio Bravo: A Primer. Accessed November 29, 2003. available at www.texascenter.org/borderwater

Thelen, K. 1999. Historical institutionalism in comparative politics. *Annual Review of Political Science.* 2:369-404.

Transboundary Freshwater Dispute Database. 2009. Available at http://www.transboundarywaters.orst.edu/database/transfreshspatdata.html

Treaty between the United States of America and Mexico, February 3, 1944, U.S.-Mex. 59 Stat. 1219 (referred to in the text as the 1944 Treaty).

United Nations (U.N.), (2003). National Accounts Statistics Database. Statistics Division Available at: http://unstats.un.org/unsd/snaama/Introduction.asp

United Nations Development Programme (UNDP) and Okavango Basin Commission (OKACOM). 1998. *Environmental Protection and Sustainable Development of the Okavango River Basin.* Project Brief.

United Nations Development Programme (UNDP) and Global Environment Facility (GEF). 2002. *Environmental Protection and Sustainable Development of the Okavango River Basin.* Project Document. Project of Angola, Botswana and Namibia. Project Number: RAF/00/G33?A/IG/12.

United Nations Development Programme (UNDP) and Global Environment Facility (GEF). 2006. *Strengthening of Inter-Ministerial Coordination Mechanisms for Water Management in the Danube River Basin and the Black Sea Countries.* Current Inter-Ministerial Mechanisms Coordination Report. Danube Regional Project. Draft December 2006.

United Nations Development Programme (UNDP) and Global Environment Facility (GEF). 2007. *Project Output 3.1 "Support for the Institutional Development of NGOs and Community Involvement: Developing the DEF Network:*. Final Report February 2007.

United Nations Development Programme (UNDP), Global Environment Facility (GEF), Administrative Commission for the Río de la Plata (CARP), and Bi-national Technical Commission for the Maritime Front (CTMFM). 2006. *Transboundary Diagnostic Analysis Synthesis for Policymakers.* FREPLATA. UNDP/GEF (RLA/99/G31).

United Nations Development Programme (UNDP), Global Environment Facility (GEF), Administrative Commission for the Río de la Plata (CARP), and Bi-national Technical Commission for the Maritime Front (CTMFM). 2007. *Environmental Protection of the Río de la Plata and its Maritime Front: Pollution Prevention and Control and Habitat Restoration (FREPLATA).* Strategic Action Programme. UNDP-GEF Project (RLA/99/G31).

United Nations Development Programme (UNDP). 2009. Human Development Reports. Composite Indices. Available at http://hdr.undp.org/en/statistics/indices/

United Nations Environment Programme (UNEP). 2002. Atlas of International Freshwater Agreements. In cooperation with Oregon State University and the Food and Agricultural Organization of the United Nations. ISBN:92 807 2232 8.

United Nations Environment Programme (UNEP). 2005. *Hydropolitical Vulnerability and Resilience along International Waters. Africa.*

United Nations Environment Programme (UNEP). 2008. *Freshwater Under Threat: South Asia: Vulnerability of Freshwater Resources to Environmental Change.*

United Nations Environment Programme (UNEP) and Woodrow Wilson International Center for Scholars. 2007. *Environmental Conflict and Cooperation in South Asia: Prospects for Transboundary Dispute Resolution with Shared Water Resources.* Report of the Regional Consultation. June 5-6, 2006. Bangkok, Thailand.

United Nations Environment Programme (UNEP) and Global Environment Facility (GEF). 2005. *Concept Document for Sustainable Water Resources Management in the La Plata River Basin.* A Framework for Sustainable Water Resources Management in the la Plata Basin, with Respect to the Hydrological Effects of Climatic Variability and Change. International Waters OP #9.

Valiante, Marcia. 2007. Symposium the Great Lakes: Reflecting the landscape of environmental law: The role of local governments in Great Lakes environmental governance: A Canadian perspective. *University of Michigan Journal of Law Reform.* 40:1055.

Vanderbeck, I., de Franca, N., and M. Apostolova. 2006. *Lessons Learned Reporting on Stakeholder Involvement: Pantanal and Upper Paraguay*. Experience of the GEF sponsored “Implementation of Integrated Watershed Management Practices for the Pantanal and Upper Paraguay River Basin”. GEF Project ID: 583. International Waters Experience Notes. 2006-005.

Varis, O. Rahaman, M. and Stucki, V. 2008. The Rocky road from integrated plans to implementation: Lessons learned from the Mekong and Senegal River Basins. *International Journal of Water Resources Development.* 24(1):103-121.

World Bank. 1993. *Water Resources Management. A World Bank Policy Paper*. Washington, D.C.

World Bank. 2003. *Water Resources and Environment.* Technical Note C-2. Environmental Flows: Case Studies. Series Editors: Richard Davis and Rafik Hirji.

World Bank. 2006. *Integrated Management of Aquatic Resources in the Amazon (AquaBio)*. Project Information Document (PID) Appraisal Stage. Report No. 35127.

World Bank. 2009. Operational Manual. Internet. Available at http://web.worldbank.org/WBSITE/EXTERNAL/PROJECTS/EXTPOLICIES/EXTOPMANUAL/0,,menuPK:64701637~pagePK:51628525~piPK:64857279~theSitePK:502184,00.html

Young, Oran. 2002. *The Institutional Dimensions of Environmental Change: Fit, Interplay and Scale*. Cambridge, MA: MIT Press.

Zeitoun, M. and N. Mirumachi. 2008. Transboundary water interaction I: Reconsidering conflict and cooperation. *International Environmental Agreements.* 8:297-316.

CHAPTER VII

CONCLUSION

What are the pathways and processes necessary for adaptive institutional solutions that enhance social-ecological resilience in the Rio Grande/Rio Bravo Basin?

Development of water management paradigms within the Rio Grande/Rio Bravo Basin differ on the basis of the geographic and jurisdictional scale of management institutions, as well as the intersection of those scales with temporal changes in the legal and regulatory focus of management strategies, and in the ecosystems that are the focus of management. The premise is that management for single purposes such as water supply, without considering the riverine environment that generates that supply, does not lead to resilient or sustainable systems. In addition, top down command and control based management regimes are usually not able to identify changes that occur slowly over time, nor are they able to respond to rapid change. In the context of this research, institutions that are designed in this manner are not effective. The general objective of this research was to examine the structure and function of institutions governing water supply from a historical perspective that considers both social processes and resulting ecosystem responses. The purpose was to identify opportunities to improve the ability of water resource management institutions to manage the riverine system effectively.

The objective of Chapter II was to evaluate changes in streamflows and fish assemblages resulting from incorporation of legal instruments for environmental protection into the binational framework. The results indicate that incorporation of environmental concerns in the La Paz Agreement did not result in positive changes to aspects of the flow regime and fish communities are continuing to change. This is because riverine environmental concerns were not fully addressed in the Agreement because its focus was limited to water quality. The evaluation in Chapter II did conclude that many of the changes in fish assemblages likely occurred in the early twentieth century. Without significant overhaul of current binational practices, these changes will likely continue to occur. Furthermore, consideration by both countries of drought related issues without concomitant consideration of impacts on aquatic life could increasingly affect fish communities in the future. One identified problem with respect to incorporating concerns related to fish community change into discussions of binational drought management is the lack of data and a forum where these concerns can be addressed.

Analysis of the legal framework in Chapter III identifies specific areas that should be considered should the United States and Mexico consider modifying the 1944 Treaty. For example, data sharing, which contributes to efficiency of water management, must be re-evaluated. From a social-ecological perspective, the ability to respond to changes in the system, and rapid response to those changes if needed, cannot occur if data on water use is not readily available. It would be difficult to determine what types of adjustments would be needed when crises arise, particularly when basic human needs must be taken into account, if there is no data to support decision making or if both sides continue to exhibit reluctance to share this important data. The consequences of keeping this data “hidden” led to deterioration of relations between water users on both sides of the border and contributed to the intractability of the water debt dispute.

Chapter IV examined historical evolution of institutions using a complex adaptive model for social-ecological systems. Creating the historical profile of water management evolution provided both basin specific and theoretical insights. From the current theoretical perspective, these types of analyses should be scale specific. In other words, once a focal scale is identified, the profile should consider scales above the focal scale. In a transboundary watershed, this is not straightforward. There is no focal scale above the international level, defined as the bi- or multi- national scale of the relevant agreements. The next lower level scale, the national scale, is not one discrete scale and, in fact, should be considered as a series of two or more lateral interconnected scales. Scaling issues did not materially affect this analysis. However, they require careful consideration and, in some transboundary systems, possibly modification of the conceptual framework for a complex adaptive systems approach.

Specifically for the Rio Grande, scaling issues were particularly important with respect to the so-called national scale. The relationship between the country scale and sub-country scale exhibits significant plasticity because of water management institutional arrangements between the two countries and in the federal system of the United States. This factor could also limit the utility of the historical profile approach in these types of systems. Of course, in a complex system, relationships are not linear, and, as this research shows, there are not clearly delineated boundary conditions. Chapter IV shows that more research is needed on issues related to application of a complex adaptive system framework to transboundary river systems.

In addition to scaling issues, Chapter IV identifies an anomaly with respect to interactions between time scales in a panarchy. Traditionally, reversion to previous system configurations is thought to occur between contiguous temporal scales. However, as this research indicates, that view may be too simplistic. In the specific case of the Rio Grande, the reversion to previous system configurations occurred between non-contiguous temporal scales. Although identification of an anomaly in this one specific case cannot necessarily be generalized across cases, the issue of interactions across non-contiguous temporal scales should be evaluated in additional systems to determine if modifications to the conceptual framework for resilience analyses are in order.

One practical impact of scaling issues identified in Chapter IV is the applicability of national level legal instruments for species protection in binational water management. Chapter V evaluates current dispute resolution practices in transboundary basins, with a focus on the particular case of the Rio Grande. The shortcomings of reliance on diplomatic negotiation alone are identified and this chapter concludes that incorporating environmental concerns into the binational agenda would be difficult without changes in the way disputes are managed in this basin. After examining the legal basis for the ESA and relevant court decisions for applicability in the binational context, this research concludes that the ESA is not a BATNA and a deliberative process is the most viable option for incorporating environmental concerns.

Chapter V identifies factors, for example power relationships, which limit the utility of a conflict resolution paradigm based solely on diplomatic negotiation. Moving from rights based negotiation to interest based negotiations would require fundamental changes in the way disputes are managed in the binational Rio Grande. However, developing a design for a deliberative process in the binational Rio Grande encounters practical difficulties. First, a legacy of "behind closed doors negotiation" will be difficult to overcome when such changes conflict with the established legal framework, particularly in areas such as inclusiveness, decentralization and control over decisions. Second, ecological, social and political realities are always changing, meaning that a particular set of rules will not necessarily result in the same allocation of benefits among users over time. Chapter V proposes a conceptual framework based on dialog and deliberation that accounts for cultural factors and allows for multiple stages, multiple forums, and stakeholder control over decisions.

Arguably, there are management problems in the Rio Grande. But to what extent are these problems unusual? Are there institutional structures that can mitigate these problems, and, if so, have they been implemented elsewhere. In Chapter VI, institutional diagnostics are used to evaluate ten international river basins. The results of this evaluation indicate that, relative to other international river basins, the institutional regime guiding water management in the binational Rio Grande needs modification. The regime in the Rio Grande falls short in attributes such as dispute resolution, social learning, issue linkages, and equity. Identification of shortcomings across these broader categories allows evaluation of interactions between them when considering system design features.

Identifying a framework for analysis at the scale of an international river basin provides insights and direction for further research. Although recent research efforts in institutional analysis acknowledge disconnects between analytical frameworks for local and global systems, the problem of an analytic framework for regional systems with an international component has yet to be addressed. The international aspect of transboundary basins lends itself more to the globally based frameworks but not without modification. For example, this research identifies an area where the global framework, in this case simple diagnostics, should be modified with respect to international river basins. Specifically, dispute resolution practices and processes should be considered separately from other institutional arrangements. This is because methods to resolve disputes are directly related to the resilience of these systems in that they determine the ability of the social system to respond to change.

Transforming the method used to deal with conflict, and incorporating public participation, would probably involve re-negotiating the 1944 Treaty, and this would be a daunting task. Previous negotiations took many years. Surprisingly, recently created institutional regimes in less politically and economically powerful countries possess some attributes that the Rio Grande regime is lacking. The Nile Basin is particularly interesting in this regard. Given that the process for reforming an institutional regime may be quite lengthy, this basin has adopted an interim collaborative process. This could be particularly relevant to the Rio Grande given that, historically, institutional change does not occur rapidly in this basin. Establishing an interim collaborative process in the Rio Grande would mitigate policy lags that are likely to occur during regime shifts.

Prognosis

Based on the research presented herein, the Rio Grande is a basin in transition and there are three options for this basin. The first is the no action alternative, where the current system remains in place with no modification. The second is to continue under the current regime with some modification. The third is to embark on a journey towards a resilient system, which would require major modification of all areas of binational water management.

The no action alternative certainly has consequences for the Rio Grande social-ecological system. The historical profile and comparative analysis of other transboundary river basins both reveal significant gaps in the institutional structure in the area of ecosystem management. There is no binational entity with clear jurisdiction to consider these issues. There are some positive initiatives, for example Texas' Senate Bill 3 environmental flows process; however, it is uncertain whether this process will improve conditions since it only considers half of the water in the river. Although this process does not apply to existing water rights, it could provide specific target flows for strategies to provide additional instream flows in the river. Consideration of environmental flows in the planning process on the Texas side of the border is limited, particularly in the lower reaches of the binational river, as discussed in Chapter II. Chapter II also concludes that there may be cause for concern with respect to declines in obligate riverine fishes. In addition, the current dispute resolution paradigm is neither efficient nor inclusive. As Chapter IV and V indicate, failure to transform conflict management will not allow a window of opportunity for inclusion of ecosystem concerns and will force the system to continually revert to previous system configurations that would be indicative of a lack of resilience in the social-ecological system.

The second option would be minor modifications to the current system, wholly within the current legal and institutional framework. More recent Minutes to the 1944 Treaty incorporate phrases such as sustainability. In addition, the Minute system could be used to add provisions related to ecosystem needs or a definition of extraordinary drought. Problems with this approach include time lags while diplomatic negotiations occur and the ambiguity that is a hallmark of solutions developed through these types of negotiations. It is certainly possible to work within the current system and move from a rights based paradigm to one based on interests. However, if no changes are made to core processes such as methods to handle conflict or inclusion of the public in the decision making process, it is unlikely that these types of changes would be durable or equitable. In that case, when changes occur in the social-ecological system, and there is no doubt that changes will occur, the system will not be able to effectively adapt. This alternative leads to a system that is slightly more resilient than previous configurations, only because additional issues are addressed. In this option, the system would be transforming, albeit slowly, rather than reverting to previous system configurations which this research indicates are likely not resilient or sustainable.

The final alternative is to completely reconfigure the system. This does not mean immediate wholesale abandonment of current management regimes. Rather, a bifurcated process where the collaborative framework exists in the same space as the current system, while the legal process is revamped, would be most efficient. This type of system change allows for development of a public process to create a vision for the basin without generating the chaos that would occur if the current system was suddenly removed. Optimally, the outcomes of the collaborative process could inform development of a new and more resilient management regime. This alternative would allow creation of a system that is responsive to changes in both the river itself and the inhabitants who depend on the goods and services it provides.

VITA

Kathy Ann Alexander was born in Phoenix, Arizona to Lt. Col. (Ret.) Baird M. Martin (USAF) and Betty J. Martin, currently residing in Houston, Texas. After graduating from Clear Lake High School in Houston, Texas, she attended the University of Texas at Austin where she studied Chemical Engineering and Chemistry. She spent 17 years at the United States Postal Service, retiring in 1995 to become a tree trimmer and landscape designer. She returned to the land of the Longhorns and graduated from the University of Texas with a B.A. in History in 1997. During her time at UT, she discovered the wonderful world of water and entered the Graduate Program in Applied Geography at Southwest Texas State University in 1997. In 1999, she embarked on her career at the Texas Commission on Environmental Quality and completed her thesis, *The Hazards of Place: A Study of Vulnerability to Flood Hazards in Walnut Creek Basin,* in December of 2001. Kathy entered the PhD program in Aquatic Resources at Texas State in 2003. In addition to continuing to work full time while pursuing her doctoral degree, she authored or co-authored several publications on water resource issues. Kathy is a founder and editor of the Texas Water Journal.