



AN ABSTRACT OF THE DISSERTATION OF

Nathan T. Eidem for the degree of Doctor of Philosophy in Geography  
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Title: Enhancing Social-Ecological Resilience in the Colorado River Basin

Abstract approved:

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Aaron T. Wolf

This research presents the Colorado River basin as a social-ecological system. Utilizing event data on cooperative and conflictive interactions over fresh water, the system is decomposed to look for evidence of outcomes of resilience enhancement. The Animas-La Plata Project in the upper San Juan basin is presented as a case study, and qualitative methods are used to analyze interactions that led to its construction in order to assess social-ecological outcomes.

In the upper San Juan basin, cooperative interactions over fresh water outnumbered conflictive ones. Interactions over water rights and infrastructure were most common, and the most cooperative interactions focused on these issue types. Many of these interactions focused on the Animas-La Plata Project compromise, which ultimately enhances social-ecological resilience in the Colorado River basin.

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Enhancing Social-Ecological Resilience in the Colorado River Basin

by  
Nathan T. Eidem

A DISSERTATION

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degree of

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March 8, 2012.

APPROVED:

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Nathan T. Eidem, Author

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## TABLE OF CONTENTS

	<u>Page</u>
CHAPTER 1: INTRODUCTION .....	1
Contributions to the Literature .....	3
Background .....	5
Research Problem and Objective.....	11
Methods .....	13
Focus and Overview of the Dissertation .....	34
CHAPTER 2: SOCIAL-ECOLOGICAL RESILIENCE - A PRIMER.....	37
Resilience in Social-Ecological Systems .....	37
The Colorado River Basin: An Exemplary Social-Ecological System .....	47
Studying Social-Ecological Systems .....	75
CHAPTER 3: DECOMPOSING A SOCIAL-ECOLOGICAL SYSTEM: INTERACTIONS OVER FRESH WATER IN THE UPPER COLORADO RIVER BASIN .....	78
Interactions over Water Resources in the USBR UC Region.....	83
Upper Colorado Decomposition.....	86
Water Resources in the Upper Colorado River Basin .....	86
Resilience in the Study Area .....	90
Interactions over Fresh Water in the Upper San Juan Basin .....	91
CHAPTER 4: ANIMAS-LA PLATA: ENHANCING SOCIAL- ECOLOGICAL RESILIENCE IN A RUBE GOLDBERG WORLD .....	96
Animas-La Plata .....	97
Outcome: Enhanced Social-Ecological Resilience .....	104
Summary .....	108
CHAPTER 5: CONCLUSIONS.....	110

## TABLE OF CONTENTS (Continued)

	<u>Page</u>
BIBLIOGRAPHY .....	122
APPENDICES .....	135
Appendix I .....	135
Appendix II .....	143
Appendix III.....	158
Appendix IV.....	162



## LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
Figure 1.1: Model of Institutional Robustness in Transboundary Resource Settings.....	12
Figure 1.2: Conceptualization of Methods.....	15
Figure 1.3: A Multitier Framework for Analyzing a Social-Ecological System .....	16
Figure 1.4: Colorado River Basin Study Areas.....	17
Figure 1.5: Schematic of the Dissertation.....	36
Figure 2.1: Conceptualization of a social-ecological system .....	39
Figure 2.2: Conceptualization of the Colorado River basin social-ecological system.....	48
Figure 2.3: The Colorado River Basin.....	50
Figure 2.4: Colorado River Basin Average Annual Runoff.....	51
Figure 2.5: Colorado River Basin Ecoregions .....	55
Figure 2.6: Colorado River Basin Land Cover.....	56
Figure 2.7: Colorado River Basin Plumbing .....	58
Figure 3.1: Upper Colorado Basin USGS Watersheds.....	82

## LIST OF FIGURES (Continued)

<u>Figure</u>	<u>Page</u>
Figure 3.2: Event Intensity in the Upper Colorado Region.....	84
Figure 3.3: USBR-WWIS Data Coverage Compared to the Colorado River Basin .....	87
Figure 3.4: Upper San Juan Weighted Average Event Intensity .....	94

## LIST OF TABLES

<u>Table</u>	<u>Page</u>
Table 1.1: Examples of Coded Events.....	21
Table 1.2: Generic Keywords used to collect news articles .....	25
Table 1.3: News sources used to construct the UC Event Database....	26
Table 1.4: Overview of interview subjects .....	31
Table 3.1: Major Components of the Law of the Colorado River Relating to this Research .....	88
Table 3.2: The number of interstate compacts governing each watershed in the Upper Colorado River Basin .....	92
Table 3.3: Interstate compacts governing the Upper San Juan Basin..	92
Table 3.4: Events coded to the Upper San Juan watershed by issue type, conflict, and cooperation .....	93

This work is dedicated to the memory of Lloyd M. Eidem, D.V.M.

# Enhancing Social-Ecological Resilience in the Colorado River Basin

## CHAPTER 1: INTRODUCTION<sup>1</sup>

*"Water is the natural subject for study in geography - one of the few disciplines broad enough in its outlook to bridge the gaps between the physical, social, human, and cultural worlds. If we sometimes feel that our various disciplines are becoming too fragmented - too many subdisciplines are being created by narrower and narrower specialists - we can look with pleasure on the field of water resources where we must seek those interrelations between the physical, the human, and the cultural if we are to achieve a worthwhile grasp of the subject. Water is an ideal subject with which to unite the broad discipline of geography." – John Mather*

In order to improve understanding of social-ecological resilience, this dissertation focuses on interactions over fresh water on an intranational and interstate scale. A qualitative mixed-methods approach is used in this research. Integrating an event database approach with a framework for studying complex social-ecological systems, stakeholder group interactions are analyzed across space and time in order to find evidence of outcomes of resilience enhancement (e.g. Institutional capacity building, conflict resolution,

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<sup>1</sup> Portions of this chapter appear in 1) Eidem, N. 2008. The WWIS-WWIN Collaboration: An Analysis of the Social, Economic, and Biophysical Environments Supportive of and the Historic Trends in Conflict and Cooperation in the Bureau of Reclamation's Upper Colorado Region 1970-2005. Western Water Institutional Solutions Project Report. U.S. Bureau of Reclamation. and 2) Eidem, N.T, K.J. Fesler, and A.T. Wolf. 2012. Intranational Cooperation and Conflict over Freshwater: Examples from the Western United States. *Journal of Contemporary Water Research and Education*. In Press.

improved ecological conditions, etc.). The opposite outcome would be reduced resilience, which theoretically could be identified by conflictive behavior, the dissolution of institutions, or declining ecological conditions. One of the West's most important sources of water, the upper basin of the Colorado River basin, is the focus of this project.

The upper Colorado (UC) River basin encompasses portions of five states, and is the source of fresh water for some of the largest and fastest growing cities in the U.S. These cities include Denver, Colorado, Las Vegas, Nevada, Los Angeles, California, and Phoenix, Arizona, none of which is within the UC Basin (NRC 2007). As populations and demand for fresh water grow, water resources managers will have to deal with competing uses and potentially conflictive situations over available water more frequently. Further, two major factors, one institutional and one bio-physical, make the situation more pressing. First, the Colorado River Compact was based on "grossly inaccurate stream-flow estimates..." (Hundley, Jr. 1975: 322). Second, "there is broad consensus among climate models that [the Southwest] will dry in the 21<sup>st</sup> century and that the transition to a more arid climate should already be under way" (Seager et al. 2007: 1181).

Understanding how stakeholder groups enhance resilience could help

water resources planners and managers to adapt to changing conditions. This could, in-turn, breed more resilient systems through cooperative institutional capacity building, thus reducing the potential for future conflict. The primary objective of this project is to gain a greater understanding of social-ecological resilience from a water resources perspective in order to provide examples of how stakeholder groups enhance resilience.

### **Contributions to the Literature**

This dissertation builds on an analysis of conflict and cooperation over water resources in the U.S. Bureau of Reclamation (USBR) UC Region (Eidem 2008). Employing the methods developed by the Transboundary Freshwater Dispute Database at Oregon State University (Wolf et al. 2003; Fesler 2007) on the UC Region provides data and insight into conflict and cooperation over fresh water at a new scale of analysis. This paper also merges an event database analysis with resilience theory at the intranational-interstate scale.

The following chapters use a framework for analyzing a social-ecological system (Ostrom 2007) to decompose the upper Colorado River basin, which is within the USBR UC Region. While Ostrom proposes the framework, she leaves implementation for future work (Ostrom 2007; Ostrom

and Cox 2010). To the author's knowledge, this framework has not been employed. This dissertation incorporates an event database into the framework in order to better understand social-ecological resilience in the Colorado River Basin. This is a unique combination, and provides a method for others interested in studying interactions between resource users and associated outcomes using Ostrom's framework. While the UC Basin provides the broad scale of analysis, the Animas-La Plata Project is analyzed in a case study.

The Animas-La Plata project has been thoroughly analyzed in the literature (Ingram 1990; Gosnell 2001; Hayes 2001; Pollack and McElroy 2001; Higgins 2007; Ellison 2009; and Ellison and Newmark 2010), but not from a social-ecological systems perspective. Surrounded by contention from the beginning, ALP provides an example of the type of cooperation that is going to be necessary to live sustainably in the Southwest.

Understanding how stakeholder groups enhance resilience in an over allocated river system that is facing a future of increased aridity could provide benefits beyond the Southwest. This dissertation provides insight into stakeholder group interactions in a social-ecological system experiencing stress, with additional stress projected in the future. While the specifics may



differ, water is shared worldwide. Shedding light on stakeholder group interactions under these conditions might help to increase resilience, and ultimately, sustainability in social-ecological systems around the globe, regardless of the amount of fresh water available.

## **Background**

The 21st century could see global temperature increases of 1 °C to 5 °C (Mohenshi et al. 2003; Stern 2007). Climate change has the potential to influence the timing and amount of surface runoff, evapotranspiration rates, groundwater recharge, and could ultimately increase consumptive use (Miller et al. 1997). Considering the increasing uses of water by growing human populations, climate change could add a new level of complexity to water supply and allocation. Declining water levels would lead to a decrease in available instream flow for fish and could influence vegetation in river basins. These changes can reduce the resilience of ecological communities (Rahel et al. 1996; Wootton et al. 1996; Walther et al. 2002; Root et al. 2003). Ecological resilience has been described as "a measure of the ability of...systems to absorb changes of state variables, driving variables, and parameters, and still persist" (Holling 1973: 17), or how rapidly an ecological system can recover

following a disturbance (Adger 2000: 350). Essentially, ecosystems are resilient when they can absorb an external perturbation without experiencing a change in existing ecological processes and relationships. Non-resilient systems experience a new path of ecological succession, a "sequence of changes initiated by disturbance" (Ricklefs 2001: 422), resulting in a new association of species. Changes to the biosphere resulting from climate change could have significant effects on biological diversity. Many ecologists argue "that resilience is the key to biodiversity conservation and that diversity itself enhances resilience, stability, and ecosystem functioning" (Adger 2000: 349). Changes affecting ecosystem health could be problematic for human society, as it depends on ecosystem services to function. Fresh water provision, food production, waste filtration, coastal protection, and recreation are some of the major services provided by ecosystems (Costanza et al. 1997).

Although we depend on these systems to survive, we impact their functionality with our daily activities and resource management practices, which can lead to the breakdown of natural systems (Falkenmark 2001). This is a "wicked problem" (Lazarus 2009: 1159), because of the interdependencies between society and nature, and the difficulty in finding a solution without creating conflict between stakeholder groups. Solving one problem could

create an equally disruptive problem in another part of the "earth system" (Young and Steffen 2009).

Solving these types of problems has become a priority for public policy makers and analysts. Historically, these efforts have been overly simplistic, which limits "the ability of scientists and analysts to explain and learn from these problems and diverse responses [to them]. We term this the panacea problem. The panacea problem occurs whenever a single presumed solution is applied to a wide range of problems" (Ostrom and Cox 2010: 452-53). Instead of blueprint management strategies, flexible approaches promoting collaboration, coordination, and adaptation are better suited for managing complex social-ecological systems for sustainability (Kofinas 2009).

Conservation and sustainability are essential concepts in nature-society geography. In this tradition, the following research seeks to better understand the relationship between humans, other living organisms, and the non-living world in order to foster sustainable resource management, which in turn could help to create a sustainable society. The fundamental link of this interrelationship between biotic and abiotic components is fresh water. The molecule is essential to all forms of life, a powerful erosional agent, not always predictable, and the universal solvent. Beyond its biological and physical

properties, we utilize water in every aspect of our lives: to irrigate our crops, to power our technology, both in terms of hydroelectric power generation and hydrothermal cooling, to manufacture goods, to clean our possessions, to create art, and to recreate in. These characteristics put water resources at the center of social-ecological research.

Social-ecological systems research combines the studies of ecological systems and social systems. Though part of the naturally occurring earth system, humans have manipulated nature to build societies, thus creating complex coupled social-ecological systems (Fiege 1999). A co-dependency was created where humans still depend on natural systems, but now naturally occurring ecological systems depend on social systems because of human control. For example, at a minimum, humans require water to drink. This implies fresh water of sufficient quality, so as not to impact human health. Plants and microorganisms in the ecological system filter waste out of the water, which helps to maintain good water quality. As civilization developed, and human settlements grew, water impoundment became common to provide a reliable supply. By altering natural flows, downstream plants and animals experienced a non-natural disturbance in their water supply. Some species went extinct, or were pushed to the brink of extinction, while new,

invasive species filled the void, making the ecological system less resilient.

Ecological resilience is not the only concern in social-ecological systems. Continuing with the example of water impoundment and the previous discussion of human uses of water, competing societal demands are incorporated. Humans use water, a limited resource, for a variety of purposes. When the natural system introduces a decrease in available water, the social system becomes vulnerable to this change. Social resilience refers to “the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change” (Adger 2000: 1). When a social system experiences a water shortage, it must prioritize uses (e.g. domestic, agricultural, and industrial) in order to prevent a societal collapse.

From this point, the concept of social-ecological resilience becomes important. This refers to the ability of this complex coupled system to respond and adapt to change. Because humans have exerted a certain amount of control over the natural system on which they depend for a reliable supply of good quality water, and natural systems have become dependent on humans, water for the natural system became a use to be considered when prioritizing limited supplies. Humans altered water management practices in

an effort to minimize their impacts, thus making downstream species dependent on human society. By making natural flows a priority, humans increased social-ecological resilience in the system. The ecological system is able to maintain its functions, which helps to create a supply of clean water for society. Even though this is a simple example of one natural resource, it gets complex quickly. In reality, there are many additional factors to consider when studying social-ecological resilience. Understanding these complex systems requires studies of component sub-systems, which can be linked together in order to gain insight into the larger picture. In order to contribute to this understanding, this project looks at social-ecological resilience from a water resources geography perspective.

Geography is the ideal disciplinary lens through which to study all of the complexities of social-ecological systems. Such coupled human-environment systems fit perfectly into the nature-society realm of geography. The broadness of geography has always been its strength as a discipline. It has been called *the mother of all sciences* for its ability to borrow from and contribute to all other disciplines. This study incorporates literature by scholars in a range of disciplines, including ecology, environmental studies, geography, history, political science, sociology, and sustainability science. This

speaks to the inter-disciplinary nature of water resources, and the realization that scholars must work across traditional discipline divides to address complex social-ecological issues. This makes sense pragmatically, as stakeholders directly involved in the day-to-day interactions over water resources come from a range of disciplinary backgrounds.

### **Research Problem and Objective**

As humans exerted a large amount of control over Western rivers through engineering wonders and institutional arrangements, the natural hydrologic systems in the West were turned into “complicated socio-ecological system[s]...” (Worster 1985: 227). As is evident by the name, a social-ecological system (SES) has two main components, a social system and an ecological system. Social systems are networks comprised of laws, institutions, stakeholder groups, and relationships between them. Ecological systems are comprised of earth's living and non-living parts. Social-ecological systems vary in scale, and like regions, are user defined. Whatever the scale, these complex systems are subject to stress, and must adapt to changes or perturbations. The ability of a system to adapt to these changes is its resilience. It has been suggested that conflict ensues when institutional

capacity is insufficient to deal with a perturbation, whether biophysical, socioeconomic, or geopolitical (Wolf et al. 2003) (Figure 1.1).

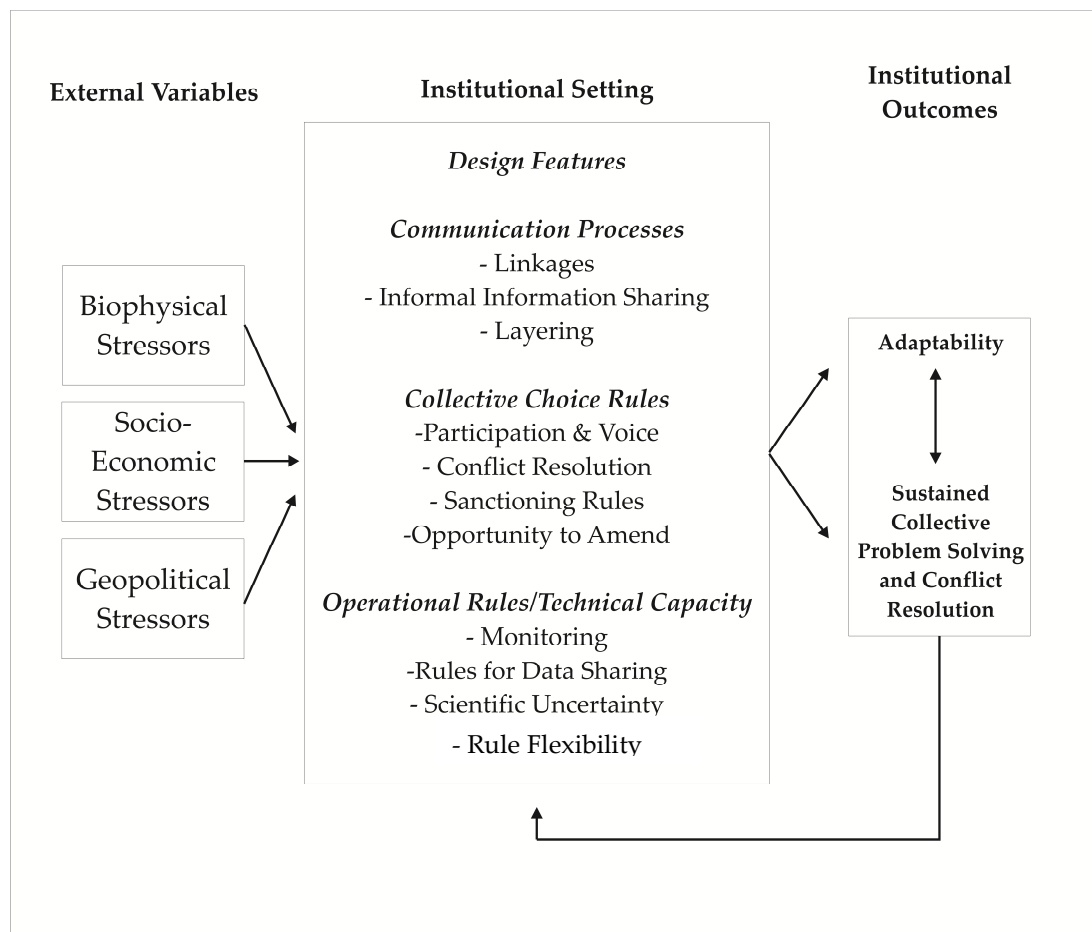


Figure 1.1: A Model of Institutional Robustness in Transboundary Resource Settings. Source: Wolf 2010

Institutional capacity to deal with changes makes a system more resilient, thus, conflict occurs where resilience is lacking. Further, it has been suggested that conflict reduces a system's resilience by inhibiting social



learning and adaptation to change (Galaz 2005). This means that a system's resilience is in flux, and influenced by stakeholder interactions. A system lacking resilience is prone to conflictive interactions, which further decrease the resilience of the system. On the other hand, institutional capacity is created through cooperation (e.g. signing of treaties and the formation of collaborative governmental organizations), which increases system resilience.

As competition between water users and water use sectors increases, the potential for conflict increases. However, research has shown that cooperation is more prevalent than conflict in international river basins (Wolf 1998; Yoffe 2001). On the other hand, as the demand for water approaches or meets available supply, intranational conflicts may increase (Postel and Wolf 2001). It has been shown that on an intranational scale, as in international river basins, cooperation is more common than conflict (Fesler 2007; Eidem 2008). The objective of this dissertation is to provide insight into the relationship between human interactions over water resources and social-ecological resilience.

## **Methods**

To achieve this objective, a qualitative mixed-method geographic

analysis is employed (Figure 1.2). Drawing from the literature on social-ecological systems and common-pool resources, this research focuses on interactions over fresh water in order to shed light on how stakeholder groups enhance resilience within the Colorado River Basin. This study area was selected because it is in a region projected to be influenced by climate change (Seager et al. 2007), water is the general link between nature and society here (Sauer 1945), and it is an easily demonstrated social-ecological system. Ostrom's (2007) conceptual framework for decomposing social-ecological systems guides this paper (Figure 1.4). Limiting analysis to second-tier variables from this framework, interactions and outcomes, is the first step in the decomposition.

Event data from the USBR Western Water Institutional Solutions (WWIS) Project provide stakeholder interactions for analysis. The WWIS project studied interactions in the USBR UC Region, which leads to the second step in the decomposition, reducing the study area to the UC basin. The third step further reduced the geographic region of analysis to the upper San Juan basin (Figure 1.4), based on an analysis of interstate compacts governing water resources in the UC basin. The final step in the decomposition was based on

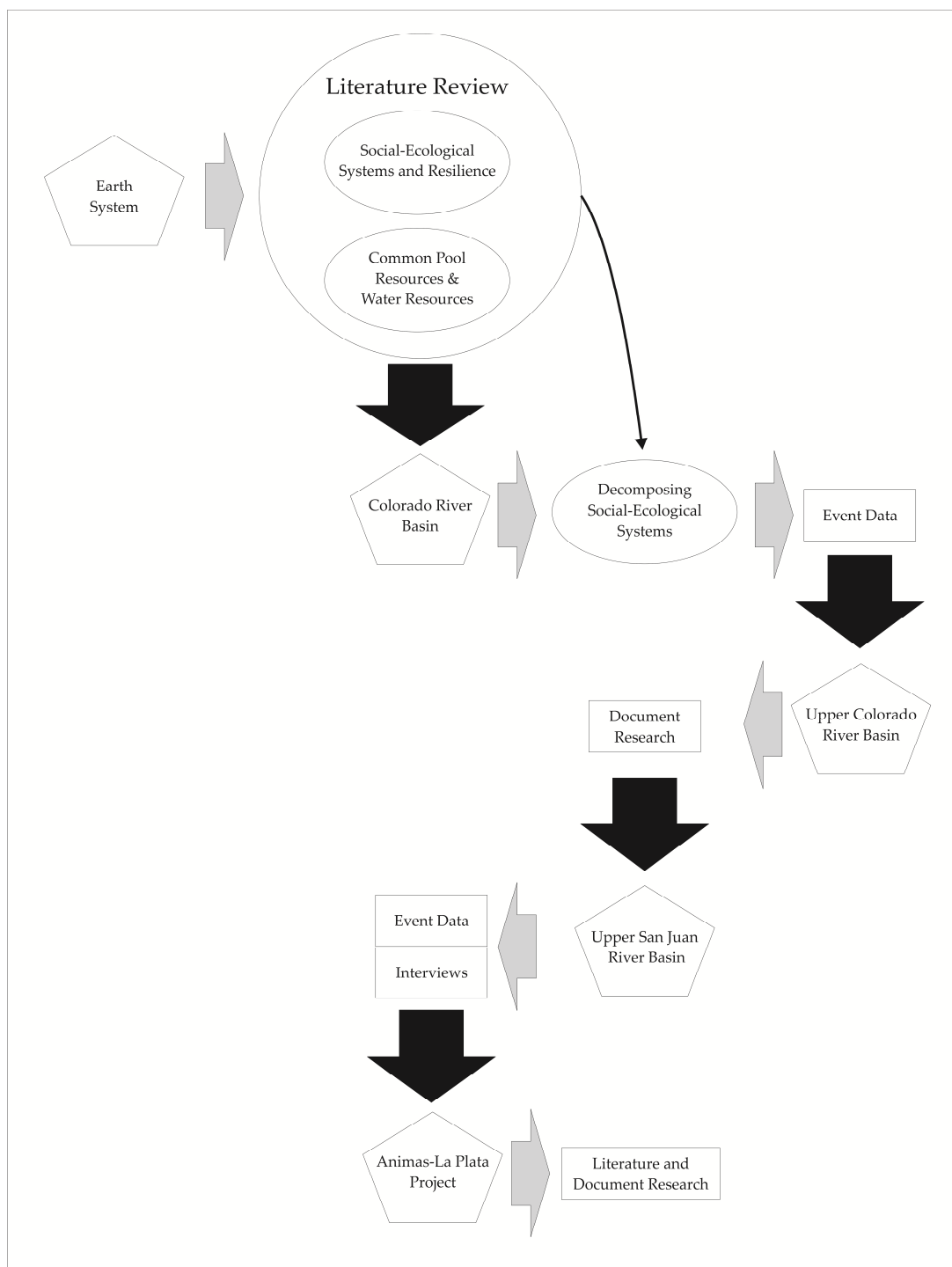


Figure 1.2: Diagram conceptualizing the methods used to decompose the Colorado River Basin SES.

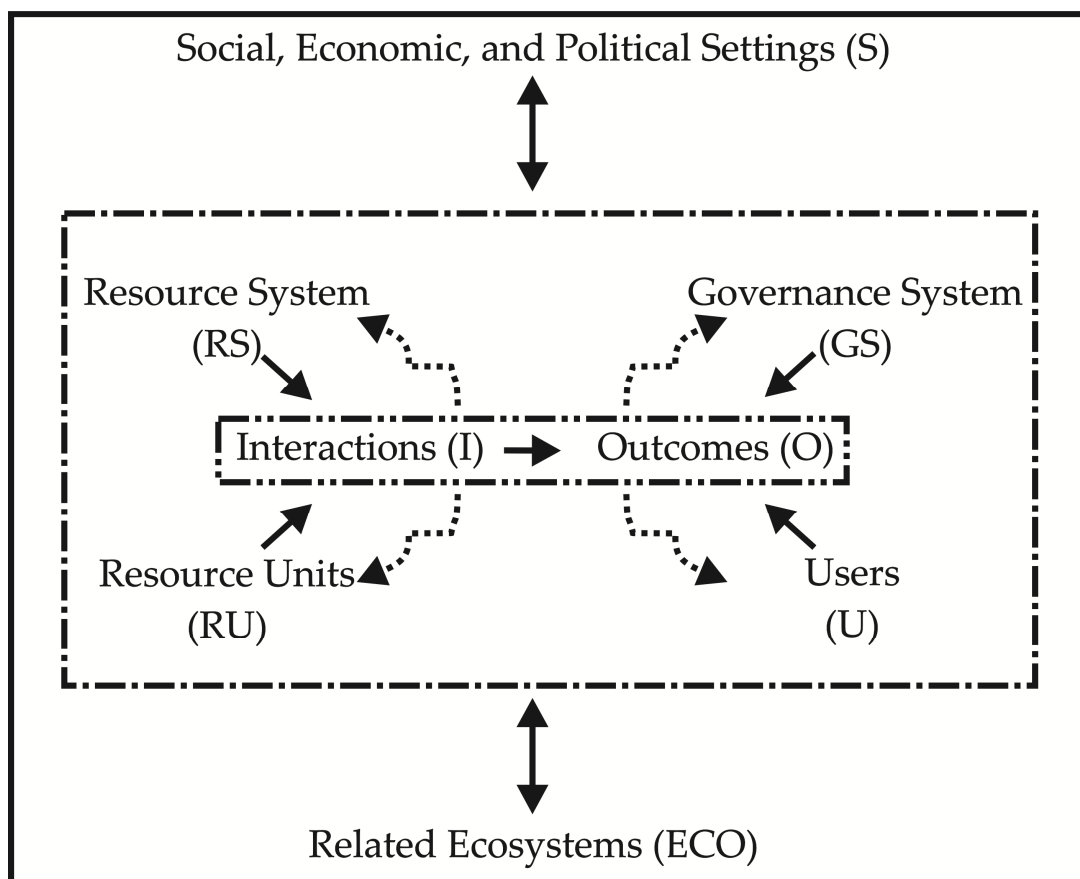


Figure 1.3: A Multitier Framework for Analyzing a Social-Ecological System (Straight arrows represent direct causal links; curved arrows represent feedbacks) Source: Ostrom 2007



Figure 1.4: Map showing the locations of sub-basins of the Colorado River social-ecological system that serve as the primary study areas for this research.

an analysis of interactions in the upper San Juan basin and interviews with key stakeholders. These pointed to a case study of the newest, and perhaps last of the large federal water projects in the region, Animas-La Plata. The following sections provide details of the methods employed in this dissertation.

#### *Event Data*

Event data are important to this research, as they provide the interactions for analysis. An event is any interaction between parties that is action-defined, recorded, and made available to the public. To be an event relevant to this research, an action must be driven by some aspect or dimension of fresh water resources (water as a scarce or consumable resource, or as a quantity to be managed), and occur within the study area, the USBR UC Region. For development of the event databases, teams of trained coders conduct searches of media databases (e.g. Lexis-Nexis), and code events to a scale ranging from intense conflict (negative values) to intense cooperation (positive values). The more negative or positive a number is, the more intense the interaction between stakeholders. Event intensity corresponds to what action actually occurred, from a verbal argument, to the signing of an

interstate compact. This ranking gives a measure of the intensity of interactions between and among stakeholders, and provides a method to show behavioral changes over time (Shellman 2004). It is not a measurement of the attitudes expressed implicitly or explicitly in the media stories (Smith et al. 2001; Fesler 2007; Eidem 2008).

While political scientists have been analyzing event data, natural resource scientists and managers have not utilized this resource mainly because these event databases focus on diplomatic and militaristic behaviors, and have not been well suited to environmental issues (Schrodt 1994; Fesler 2007). The Transboundary Freshwater Dispute Database (TFDD) is so suited. The TFDD classification scheme was created by modifying the Conflict and Peace Database (Azar 1980) ranking system to adjust for water resource management issues and concerns at the international level (Wolf et al. 2003). Further modifications were made to adapt this classification scheme to the intranational scale. The Intranational Political Interactions (Moore and Lindstrom 1996) was used to describe local political actions in each intensity level, and additional intranational cooperative actions were modified from The Struggle Spectrum (Keltner 1994; Fesler 2007; Eidem 2008). After considering these factors, scales were constructed in which the conflict-

cooperation intensities for this research range between 5 (most cooperative) and -5 (most conflictive) intranationally. Neutral events are ranked zero (Appendix I). See Table 1.1 for examples.

Events are also coded to issue type categories (Appendix I). The “issue types” became a part of the hydropolitical database and included: water quality, invasive species, conservation, drought, flood, ground water depletion, infrastructure issues, fish passage, instream water rights, water rights more generally, intergovernmental issues, water transfers, and navigation. All the issue types can be generalized into water supply events (e.g. quality, conservation, flooding) or water allocation events (e.g. intergovernmental, water rights, instream uses). Categories were originally developed for the international scale (Wolf et al. 2003), and subsequently modified for the intranational scales which do not focus on trans-national issues (Fesler 2007; Eidem 2008). Regardless of scale, each event can be classified as only one issue type. Endangered species-related concerns could be filed under several different issue types. For instance, if temperature standards are not being met, the issue would be water quality. If flows are in dispute, then the issue is instream water rights. If a dam is blocking fish migration, then the issue is fish passage. Coding events in this manner



maintains research focus on water management, not fish management.

Table 1.1: Examples of coded events from the WWIS event database

<b>Event Date</b>	<b>Basin</b>	<b>Issue Type</b>	<b>Intensity Value</b>	<b>Event Summary</b>
1988	Upper San Juan	Water Rights	5	Congress passed the Colorado Ute Indian Water Rights Settlement Act of 1988.
1992	Upper San Juan	Infrastructure	-4	A lawsuit halts [Animas-La Plata] project to in order to conduct a supplemental environmental impact study.
1995	Upper San Juan	Water Quality	-2	New Mexico's chief legal official warned federal dam-builders that Animas-La Plata, as currently planned, is likely to cause "virtually continuous water quality violations in New Mexico."

Events within the study area are coded to U.S. Geological Survey (USGS) hydrologic accounting units, which are watersheds. While the Colorado River basin is international, only events of intranational interaction were coded. While this approach provides a useful method for collecting a large number of events for analysis, there are some limitations.

#### *Limitations of Event Data*

The first potential issue relating to event data coded from newspapers is bias. Two types of bias, selection and description, influence events coded from newspaper articles. Not all events occur in the public arena, and not all events that are public are reported in the press. Ultimately, whether an event is reported or not comes down to the priorities of the news agencies. This can be influenced by media fatigue, which occurs when journalists and/or readers become uninterested in a long-lived series of interactions. While it cannot be controlled by researchers using event data, selection bias influences the number and type of events in a database. The effects of source bias can be reduced by collecting articles from a diverse group of newspapers, as each has different editorial standards, and covers a different geographical region (Snyder and Kelly 1977; Schrodtt 2000; Maney and Oliver 2001; Smith et al.

2001; Earl et al. 2004; Fesler 2007).

Description bias, or spin, is the second type of bias affecting newspapers. This relates to how events are portrayed in a news article, which can be attributed to efforts to increase the appeal to readers. Even though an article may be slanted based on social or political views, it still provides a historical record of an event that took place. As discussed previously, event data only reflect interactions that have occurred and not interpretations of the events (Smith et al. 2001; Fesler 2007).

In addition to bias, the method used to collect events can influence the quality of the database produced. Three common methods for creating event databases from news articles are: 1) a full-text reading of newspapers on microfilm, 2) a generic keyword search, and 3) an event-based keyword search (Fesler 2007). In a study comparing these methods (Maney and Oliver 2001), it was found that each collected events missed by the other two. Searches conducted using a generic keyword search yielded the highest percentage of events, but missed those in articles not using conventional terminology. The microfilm approach missed events in non-relevant articles. The event-based keyword search is recommended by the authors, but requires a priori knowledge of the region of interest (Maney and Oliver 2001; Fesler 2007).

Although recommended, this approach was not utilized in this study, as the region is too large. The generic keyword search method was employed to collect events from news sources available in the Lexis-Nexis News Database. Based on the results of the previously mentioned comparison of search methods, it is assumed a high percentage of reported events were collected for the USBR UC Region. A variety of search terms were tested in order to get the largest number of returns. Table 1.2 presents the terms and operators used to create the UC Event Database, which produced the highest number of news articles for coding. Utilizing the Lexis-Nexis database introduced another source of potential error. The earliest publication date for available articles was 1970. Most news sources in Lexis-Nexis start in the early 1990s, reflecting the growth of the Internet (Table 1.3).

The final potential source of error in the event database lies in the coders' ability to conform to a standard (accuracy), to consistently classify events (stability), and classify events the same way (reproducibility) (Fesler 2007). Studies have found that well-trained coders have reproducibility rates exceeding 80% (Burgess and Lawton 1972; Schrodtt 1993; Gerner et al. 1994). In terms of coding events as either conflictive or cooperative, coders have been shown to accurately identify events 98% of the time. Further, when coding

events along a continuum of conflict and cooperation, as was done in the UC Event Database, extreme and neutral events are coded more consistently than mid-intensity events (Goldstein 1992).

Table 1.2: Generic keywords used to collect news articles from Lexis-Nexis for the UC Event Database. Source: TFDD

Lexis-Nexis Operators	Generic Keywords
	Rio Grande River and Pecos River and Colorado River and Gunnison River and San Juan River and Sevier River and Green River and Animas River and La Plata River and Great Salt Lake
OR	water OR river! OR dam OR stream OR tributary OR irrigation OR channel OR reservoir AND quality OR flood! OR drought! OR rights
AND	treaty or agree! or negotiat! or partner! or settle! or cooperat! or collaborat! or dispute! or conflict! or disagree! or war or protest!
Guided News Search, News Wires - In: Headline, Lead Paragraphs, Terms	

Table 1.3: News sources used to construct the UC Event Database, and the earliest year for which articles were available in Lexis-Nexis.

Newspaper	Earliest Date
Albuquerque Journal	1995
Albuquerque Tribune	1995
Associated Press Newswire	1977
Denver Post	1994
Deseret Morning News	2003
New York Times	1970
Rocky Mountain News	1994
Salt Lake Tribune	1994
Santa Fe New Mexican	1994
Wyoming Tribune-Eagle	1997

Accuracy can be reduced when coding procedures are complex (Davis et al. 1998), and stability may decrease with boredom, inattentiveness, or lack of motivation (Gerner et al. 1994). The classification scheme used to create the UC Event Database was simplified to increase accuracy, following Fesler's example (Fesler 2007). Further, regular calibrations were conducted with the coding team to increase stability.

The event database approach is a useful method for getting a birds-eye-view of a region, especially when it covers a large area. Further, it is less time consuming than the other methods, as coders do not have to scroll through

reels of microfilm, or conduct interviews or surveys before compiling a database to gain insight into the major issues in the study area. Additionally, event databases can be constructed wherever access to a database of digital news articles is available. Because of the limitations discussed, event data are used in this study to uncover trends, reduce the scale of the study area, and highlight issues and stakeholder groups for more in-depth analysis. The UC Event Database is utilized in Chapters Three and Four of this dissertation. Additional methods were used to gather information to provide insight into the event database

### *Archival Research*

Following the analysis of events in the UC Region, archival research was conducted in the Floyd Dominy Collection at the University of Wyoming's American Heritage Center in January 2008<sup>2</sup>. Each box and folder was searched for documents relating to the Colorado Basin. Ten documents from the collection are referenced in this dissertation, all of them pertaining to conflicts with the Sierra Club in the 1960s. These are discussed in Chapter Two. This research also provided additional background information in

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<sup>2</sup> The author is grateful to Jessica Eidem for her assistance in making copies of pertinent files from the collection.

preparation for interviews conducted in the San Juan Basin.

### *Oral Histories*

In order to put context to the events gleaned from the event database, oral history interviews were conducted in the upper San Juan basin and via telephone in 2008 with 15 individuals from non-randomly and purposively selected key stakeholder groups (Creswell 2003; Sheskin 1985; Yin 1994), based on an analysis of event data in the upper San Juan basin. Interviews targeted key informants for data collection, because they play a unique role in the decision making process, have an intimate knowledge and understanding of the process, and are involved in and offer insight into the process. Targeting key informants allowed for their accumulated knowledge, expectations, and considerations, that are available nowhere else, to be tapped (Feldman 1981; Hooper 2001; Sheskin 1985). These interviews provide insight into the literature, and highlight key interactions between stakeholder groups.

Using the UC WWIS Event Database, stakeholder groups were selected as potential sources for people to interview. Individuals were selected from multiple organizations in order to get a variety of perspective on hydropolitics in the basin. Interviews were conducted with people from four stakeholder



groups: Native Americans, environmentalists, water users, and the federal government. These groups represent the major interests in the upper San Juan basin, and have been involved in conflict and cooperation surrounding major projects. Potential interview subjects were contacted by telephone and/or e-mail, and not all people contacted responded. Interview subjects were given details about the project, and signed consent forms according to the Oregon State University human subjects policy, which protects the confidentiality of individuals.

The interviews were done in an oral history style. They were conversational in nature, and open-ended to allow the stakeholders to discuss events important to them. Some interviews were not arranged in advance of a trip to the study area, but resulted from other interviews. For example, one interview subject invited the author to an infrastructure planning meeting involving multiple stakeholders representing the targeted groups. Interviews were conducted after the meeting. Further, some subjects recommended other stakeholders to the author, who were contacted during the second round of interviews.

Face-to-face interviews were conducted from February 25 – 29, 2008 in the San Juan Basin. Ten interviews were conducted while in the basin, and

ranged in duration from approximately 30 to 60 minutes (Table 1.4). A second round of telephone interviews was conducted between March and April 2008. Each of the ten phone conversation lasted approximately 20 minutes. Five of the second round interviews were follow-up calls to stakeholders interviewed while on location. The remaining phone interviews were conducted with stakeholders recommended by subjects during the first round.

The first round of interviews was reconnaissance in nature, and was conducted to gain insight into the important issues in the basin at that time. Each interview started with a discussion of the subject's job/role in relation to water resources in the upper San Juan basin. The water resources community is small in the basin. Disclosing these positions could lead to the identification of interview subjects, which would violate the signed confidentiality agreements. Subjects were asked to talk about current water resources issues relating to their job/role. Additionally, preliminary results of the UC Region Study were shared with the subjects to get feedback, and to generate discussion on the topic of conflict and cooperation over water resources. Finally, during the week of interviews in the San Juan Basin, two official meetings were observed. One was a monthly meeting of a water user group, and the other was a meeting between Native Americans and the federal

government to discuss a proposal for infrastructure construction. Following the meeting, a tour of the local domestic water supply system and proposed project location was given. It should be noted that the second meeting and tour related to a project in the Lower San Juan Basin, which is outside of the study area.

Table 1.4: Overview of interview subjects including stakeholder group representation and length of interviews.

Stakeholder Group	Length of Interview (minutes)	Round of Interviews (1st or 2nd)
Environmentalism	50*	1st/2nd
Environmentalism	20	2nd
Environmentalism	20	2nd
Federal Government	50*	1st/2nd
Federal Government	30	1st
Federal Government	30	1st
Federal Government	20	2nd
Native American	50*	1st/2nd
Native American	30	1st
Native American	60	1st
Native American	60	1st
Native American	20	2nd
Water User Group	80*	1st/2nd
Water User Group	50*	1st/2nd
Water User Group	20	2nd
* Total time of 1st and 2nd interviews		

Second round interviews focused on discussions of the Animas-La Plata Project (ALP), which serves as the case study in this paper. Not all subjects interviewed during the first round received follow-up telephone calls, as some discussed ALP sufficiently during the initial interview. The purpose of these calls was to gain a greater understanding of turning points in the history of the project.

The overall purpose of both rounds of interviews was to gain a better understanding of water resources in the upper San Juan basin by learning from those directly involved. Much of the information gleaned from the first round of interviews focused on details beyond the scope of this dissertation. Further, second round interviews produced little new information regarding ALP. They did highlight important turning points in the timeline of events related to the project. While no quantifiable data were collected during the interviews, the conversations helped to identify ALP as the case study for this dissertation, and highlight turning points in its construction. Chapters Three and Four utilize the information collected during the interviews.

### *Case Study*

Based on the analysis of interactions and input from key stakeholders

in the upper San Juan basin, a case study focusing on the top two issue types in the basin, infrastructure and water rights, was selected. The selection process further limited events to those of extreme cooperation (+4 and +5), as it takes a lot of interaction and deliberation to reach a compact or peaceful settlement. These are the types of scenarios that will hypothetically provide insight into the ways in which resilience is enhanced. Limiting events occurring in the upper San Juan watershed to these intensities and issue types, and considering responses from the oral history style interviews, the Animas-La Plata Project was selected as the case to be studied. Following examples from available literature, the case study focused on document analysis and insights gleaned from interviews with key stakeholders (Tang 1991; Ivey et al. 2002; Lopez-Gunn 2003). Newspapers, reports, government documents, and peer-reviewed articles were utilized in this study. Information collected from these sources was integrated to better understand the current state of the basin. Chapter Four presents the case study.

### *Figures*

ArcGIS 9.3 was used to make the maps in this dissertation. Data came from the Transboundary Freshwater Dispute Database, USBR Western Water

Information Network, Environmental Protection Agency, National Land Cover Database, and ESRI. Figures were created using the CorelDRAW X5 Graphics Suite. Lastly, graphs and tables were created using Microsoft Excel 2010.

### **Focus and Overview of the Dissertation**

In order to provide insight into societal sustainability, the central research question of this dissertation is: *How do stakeholder groups enhance resilience in a social-ecological system?* The Colorado River basin is used as an example of a SES, and serves as the study area for answering this question. The basin is decomposed over the course of three chapters. Secondary research questions guide each of these.

The following chapters are essentially self-contained, with each leading directly to the next (Figure 1.5). Following this introduction, Chapter Two provides background on social-ecological systems, resilience, and water resources. In the second part of the chapter, the Colorado River basin is discussed as an example. This is the largest section of literature review in the paper, however later chapters will contain discussions of pertinent literature where necessary.

Chapter Three discusses the results of a geographic analysis used to

decompose a portion of the Colorado River basin SES, the UC Basin. A georeferenced event database is used to spatially analyze cooperative and conflictive interactions between water resources stakeholder groups. The results of this analysis point to a watershed in the upper basin for secondary analysis.

Chapter Four provides a discussion of the results of an environmental history style case study of stakeholders in the Animas-La Plata Project in the upper San Juan River basin. This chapter provides insight into the primary research question in this project, and leads to the final chapter, which offers conclusions and lessons learned from this research.

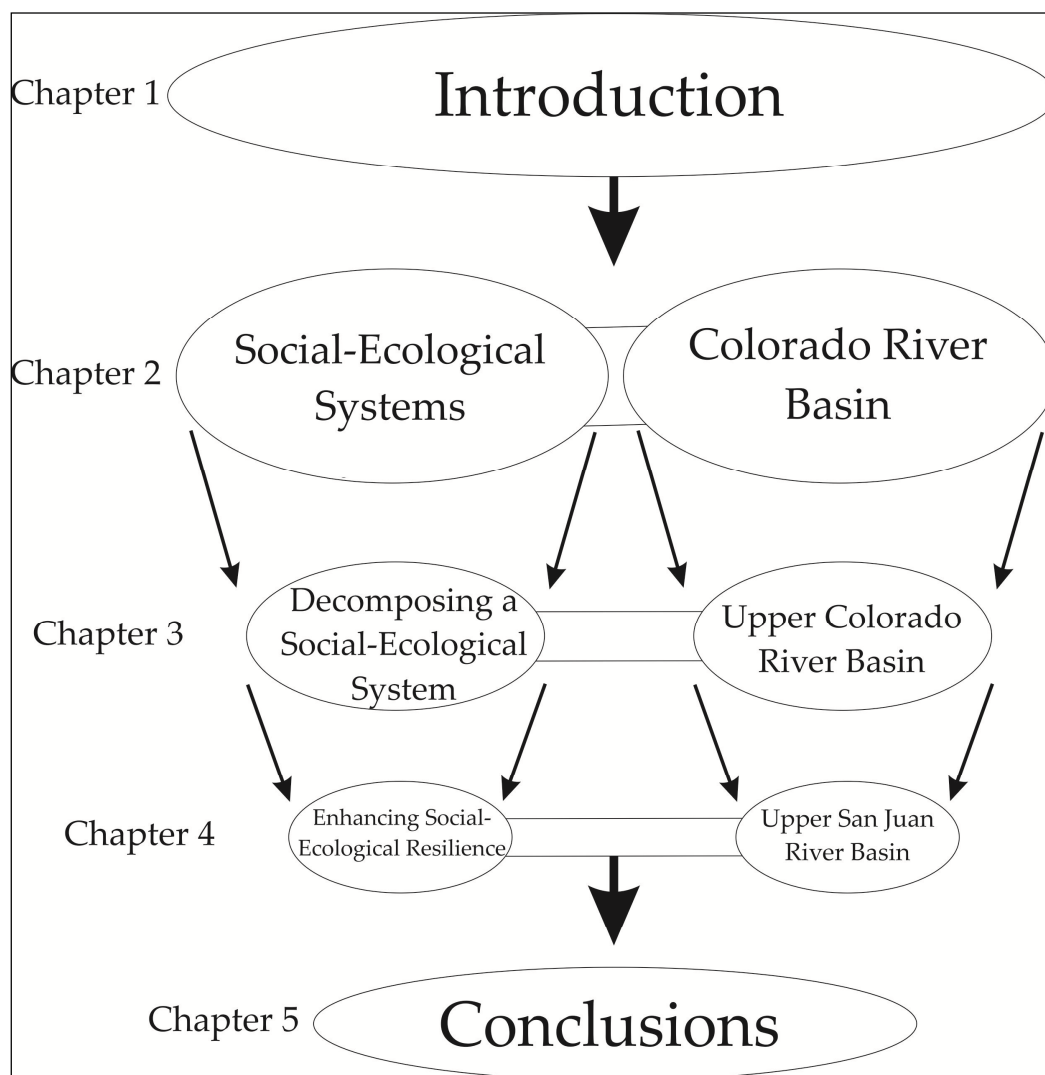


Figure 1.5: Schematic of the dissertation.



## CHAPTER 2: SOCIAL-ECOLOGICAL RESILIENCE - A PRIMER

*"We are concerned with the...interrelation of...cultures and site, as expressed in the various landscapes of the world." - Carl O. Sauer*

In order to answer the question: *How do stakeholder groups enhance resilience in a social-ecological system?*, this chapter provides background information on social-ecological systems, resilience, and water resources.

Questions guiding this chapter are: *What is a social-ecological system?*, *What is resilience?*, and *How can these be studied?* In the second part of the chapter, the Colorado River basin is discussed as an example, and introduced as the study area for this project.

### **Resilience in Social-Ecological Systems**

"Resilience-based ecosystem stewardship is a fundamental shift from steady-state resource management, which attempted to reduce variability and prevent change, rather than to respond to and shape change in ways that benefit society" (Chapin et al. 2009: 5). Resilience comes out of the broader subject of ecological sustainability and was first defined by the ecologist C.S. Holling as "a measure of the ability of...systems to absorb changes of state

variables, driving variables, and parameters, and still persist” (Holling 1973: 17). There are at least 10 varying definitions of resilience used in both the social and natural sciences [See Brand and Jax 2007 and Norris et al. 2008 for extensive comparisons of these definitions]. Studies of resilience are becoming increasingly common in the literature of many disciplines, including geography (Zimmerer 2010), and have been expanded to describe complex coupled social-ecological systems (SES) (Gunderson 2000; Holling 2001; Gibbs 2009).

Social-ecological systems are intricately linked living and non-living systems. Each system is composed of interdependent units that might contain interdependent subsystems. From a human perspective, we depend on ecosystems, which are influenced by human activity (Chapin et al. 2009). Essentially, an SES consists of humans with interdependent relationships amongst themselves that are “mediated through interactions with biophysical and non-human biological units” (Anderies et al. 2004: 3). In many cases, humans have invested resources, physical and/or institutional, to deal with internal and external disturbances (Anderies et al. 2004). A good example of an SES is a river basin or watershed (Figure 2.1). The inter-relationships are easy to conceptualize in a river basin. Because water is essential to all

terrestrial life, it ought to be understood as part of a dynamic system (Carpenter and Biggs 2009). Further, “[e]very human activity affecting land use and land cover not only affects the hydrologic processes of interception, infiltration, evapotranspiration, aquifer storage, and runoff...but by altering water quality it also modifies plant-soil-water relationships” (Westcoat and White 2003: 65). The concept of social-ecological systems provides a framework with which to study resilience from the perspective of water resources.

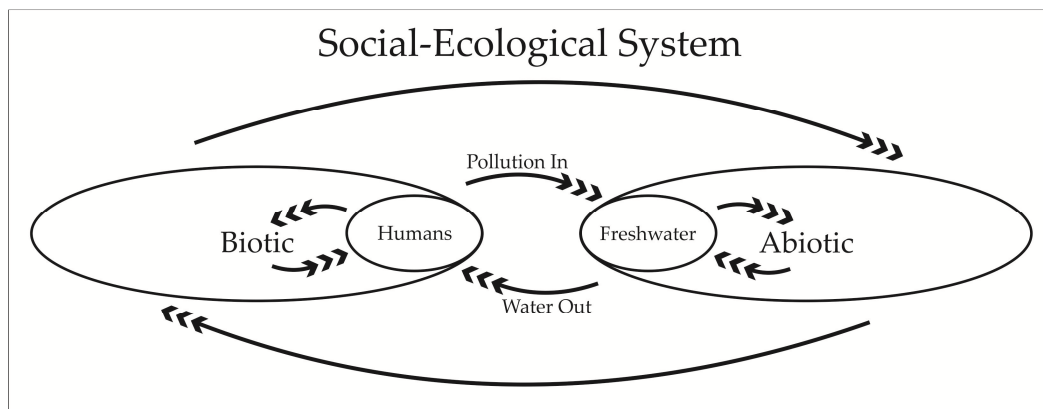


Figure 2.1: Conceptualization of a social-ecological system. The arrows represent interactions and influence between different components.

In terms of SESs, “[s]ystem resilience refers to the amount of change a system can undergo and still retain the same controls on function and structure while maintaining options to develop” (Nelson et al. 2007: 398).

Moving to a definition relating to the study of human institutions managing natural systems, Adger defines social resilience as “the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change” (Adger 2000: 1). In a discussion of resilience in the management of water systems, Wolf (2007) uses concepts of hydropolitical resilience and vulnerability in the context of sustainability. Hydropolitical resilience refers to “the complex human-environmental system’s ability to adapt to permutations and change within these systems. Hydropolitical vulnerability is defined by the risk of political dispute over shared water systems” (Wolf 2007: 5). The common point in these three definitions is the ability of systems to respond to perturbations, and adapt to change.

Perturbations cause stress to resource systems, and can increase the potential for conflict. Studies of hydropolitics (Waterbury 1979; Wolf 1995) have been conducted to better understand the potential for conflict over shared international waters. Hydropolitics “relates to the ability of geopolitical institutions to manage shared water resources in a politically sustainable manner, i.e. without tensions or conflict between political entities” (Wolf 2007: 5). Institutions should not only be able to respond to

perturbations, but also be able to plan for a desired system state (Wolf 2005; Nelson et al. 2007). Long-term sustainability<sup>3</sup> is the goal (Kofinas and Chapin 2009: 66). Institutional capacity to respond to perturbations varies from place to place, depending on the characteristics of both the biophysical and geopolitical settings. Wolf and others (2003) found that conflict was more likely to occur when a system is exposed to rapid changes, either physical or institutional, and sufficient institutional capacity to absorb these changes is lacking. In other words, institutional capacity makes systems more resilient in the face of rapid change. It has also been suggested that conflict reduces social learning, which inhibits resilience (Galaz 2005). Taking these together implies that system resilience is not static, and has a before-and-after relationship with conflict.

Some authors initially argued that the term resilience is inappropriate for the study of SESs. Anderies and others (2004) contend that the term

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<sup>3</sup> Sustainability is a somewhat nebulous term. For this dissertation Tietenberg's (2000: 606) definition is the starting point: "[R]esource use by any generation should not exceed a level that would prevent future generations from achieving a level of well-being at least as great." Adding to this, societal activities should not compromise the provision of ecosystem services for future generations. Further, sustainability in social-ecological systems goes beyond the biophysical, and includes socio-economic and geopolitical aspects. The crux of sustainability is society's ability to live within its means. It might be easier to identify aspects of a social-ecological system that are not sustainable, and correct them in order to live more sustainably, than it is to identify what is sustainable and implement it. This would suggest an adaptive approach to living sustainably based on the history of the system, present circumstances, and modeling future scenarios with the best available data.

robustness should be used instead, as these systems are designed and controlled by humans, and are “affected by the reflexive nature of humans” (Janssen 2006: 128). The concept of robustness comes from the field of engineering, and refers to a system’s ability to maintain a level of performance when subjected to perturbations (Anderies et al. 2004). Further, humans have the ability to anticipate potentially undesirable situations, and to craft new institutions and technological solutions to adapt to changes. It is recognized by these authors that not all variability can be removed from the system, and therefore vulnerability cannot be eliminated, and that resilience is an important aspect to consider when studying social-ecological systems (Anderies et al. 2004; Janssen 2006). This group’s stance on the use of resilience changed when the same authors stated that “[t]he ideas of resilience and robustness have developed in ecology and engineering, respectively. Both can be applied when analyzing the persistence of SESs” (Janssen et al. 2007: 309).

Resilience comes in many forms: material, social, cultural, ecological, and intellectual (Kofinas and Chapin 2009: 66). Wolf and others (2003) suggest that the following institutional arrangements might enhance resilience in international river basins: 1) international agreements and institutions, such

as treaties and river basin organizations. Analogous arrangements in intranational basins could be interstate compacts and river commissions, 2) a history of collaboration on projects, such as infrastructure and planning efforts, 3) positive political relations, and 4) higher levels of economic development (Wolf et al. 2003). Further, Galaz (2005) contends that social learning is also needed to build resilience in SESs, and that conflict “seriously inhibits the possibilities of learning and adaptation” (Galaz 2005: 567). This suggests a before and after relationship between conflict and resilience. If a system has resilience, it is less likely to experience conflict. If a system experiences conflict, it reduces its resilience. Further, institutional capacity, which increases system resilience, is enhanced through cooperation.

The common pool resources literature offers further insight into enhancing resilience through increased institutional capacity. Studies have shown that collaborative governance, where local groups develop institutions to manage shared resources, is proving to be a successful governance model for preventing overharvesting and associated conflicts and ecosystem degradation (Ostrom et al. 1999; Agrawal 2001; Dietz et al. 2003). This is in contrast to Hardin’s (1968) assertion that users of a commons, who are caught in a cycle of over-exploitation of a resource and unable to change their

situation, need external authorities, centralized government or private sector organizations, to solve the problem. Without this external authority, the resource will be exhausted due to the cumulative impacts of multiple self-interested individuals, ultimately leading to a tragedy of the commons (Hardin 1968).

Because no two rivers are the same (White 1957), there is no one-size-fits-all management program for water, a common pool resource. Several factors have been found to foster institutional capacity in water resources governance, and enhance resilience. Characteristics of resources, resource users, and institutional arrangements are the main categories (Ostrom 1990; Dietz et al. 2003). A key characteristic in such management programs is that the resources have clearly defined boundaries. Establishing clearly defined resource boundaries is essential because managers need to know how much of the resource is available, who can and cannot access the resource, and where monitoring programs should be implemented to enhance sustainability.

Excludability and monitoring are not the only issues to consider, as common pool resources do not always remain in the same location (Ostrom 1990; Dietz et al. 2003). Because of the nature of water, the domain of the resource can move from one user's rights domain to another's (Giordano



2003). This increases the potential for conflict between stakeholders, especially when political entities sharing a water resource have differing institutions for governing the resource (Jarvis et al. 2005).

Knowing how many people utilize a resource, where it is being used, and for what purpose, are all important considerations for water resources managers. When managers know where all users are, they can map water use in the management region, and tailor programs and policies for specific locations. Locally devised regulations that are easily enforced, with managers who are accountable can strengthen institutional capacity (Ostrom 1990; Dietz et al. 2003). Government transparency and accountability promote cooperation with and between stakeholder groups sharing a resource (Agrawal 2001; Dietz et al. 2003). Public participation enhances transparency, as it gives stakeholders opportunities to provide input into the process, and gives them access to information about changing resources (Delli Priscoli 1982; Delli Priscoli and Homenuck 1986; Mitchell 1989).

It is important that institutions can adapt to change as resource use within the management area changes, or as resource characteristics change (Ostrom 1990; Agrawal 2001; Dietz et al. 2003). Further, it is beneficial if rules evolve with changes in technology, society, and the economy (Dietz et al.

2003). Because of the varying social, political, and physical settings for water resources, management programs tailored to specific regions help to reduce stress in a resource system when change occurs (Delli Priscoli 1978; Dietz et al. 2003). Coordination between levels of government helps to reduce the potential for conflict, as overlapping jurisdictions and institutions can create tension. When conflict does occur, users should have rapid access to low-cost conflict-resolution mechanisms so that perturbations do not become protracted problems in social-ecological systems (Ostrom 1990). All of these factors strengthen institutional capacity.

Institutional capacity is an essential component of resilient SESs. The previous discussion provides an overview of institutional capacity and its relationship to resilience and conflict. It also outlines institutional characteristics that help to increase sustainable use of resources. Conflict ensues when institutional capacity is insufficient to deal with a perturbation, whether biophysical, socioeconomic, or geopolitical. Therefore, it stands to reason that patterns observed in conflictive and cooperative interactions are indicators of social-ecological resilience. In order to study this further, this project's region of interest is presented as an example.

## **The Colorado River Basin: An Exemplary Social-Ecological System**

With climate models identifying the American Southwest as a region likely to be impacted by climate change (Seager et al. 2007), it is here where this study is focused. As noted by Carl Sauer, there is a fundamental truth about the region:

*A very simple expression can be used to define this Southwest area: all life forms in this part of the world survive and develop because of the fact that they find effective means of economizing in water – the “limited good,” whether for the plant world or advanced society, throughout the Southwest. Water is the first, the general physical link (Sauer 1945: 253).*

Because of the centrality of the resource in this arid region, this research focuses on fresh water in order to better understand social-ecological resilience. The following section presents the Colorado River basin as a real-world example of an SES, and introduces the basin as the study area for this research. In reality, there are an infinite number of variables in any social-ecological system. Key features of the Colorado River basin SES are used to lay the foundation for a study of resilience. Since this dissertation looks at social-ecological resilience from a water resources perspective, fresh water will be the starting point for decomposing the system (Ostrom 2007). The following section describes the Colorado River basin SES conceptual model (Figure 2.2). [See Appendix II for the USBR description of the biotic and

abiotic components of the Colorado River basin included in the report to Congress proposing much of the infrastructure present in the basin today.]

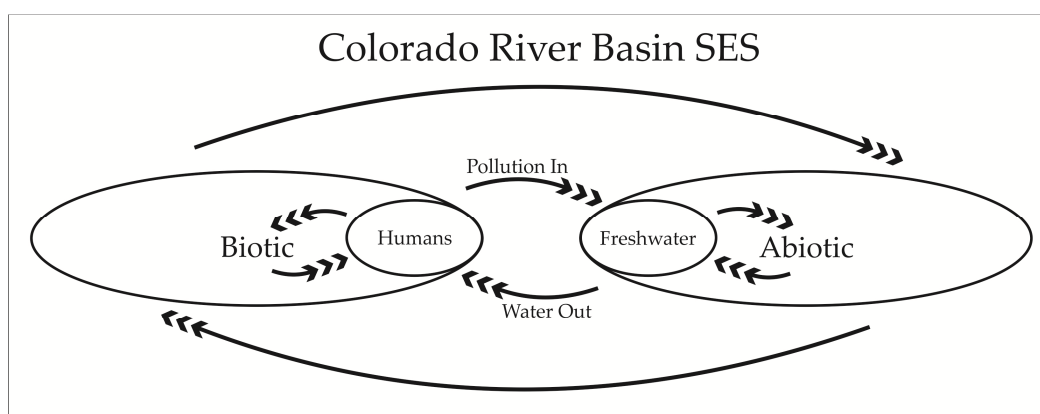


Figure 2.2: Conceptualization of the Colorado River basin social-ecological system. The arrows represent interactions and influence between different components.

### *The Abiotic Component*

Covering an area of approximately 250,000 square miles (655,000 km<sup>2</sup>) (UNEP 2009, 73), the Colorado River basin (Figure 2.3) has collected annual flow volumes ranging from three and twenty-two million acre-feet<sup>4</sup> (MAF) since 1890, on average 13 to 15 MAF (USGS 2004: 3; Seligman 2006: 67). Most of this runoff comes from snow melt in the upper basin (Figure 2.4)<sup>5</sup>. By 2035,

<sup>4</sup> Acre-foot: the volume of water required to cover one acre of land to a depth of one foot; 325, 851 gallons.

<sup>5</sup> The river channels within the basin have intentionally been left off of some figures to reinforce the

the basin is projected to experience high runoff variability as a result of climate change (DeStefano et al. 2010: 24).

The Colorado River originates in the Rocky Mountains of Colorado and Wyoming, and carves deep canyons on its way to the Gulf of California. Geologic uplift increases the cutting power of the river, and makes the canyons through which it flows more spectacular. As the Colorado River erodes the land, it picks up a tremendous amount of silt when it makes its way out of the mountains. The iron-rich sediment it transports led Spanish explorers to name it the Red, or Colorado River. Prior to the damming of the river, these sediments travelled to the Gulf of California and built up a delta. These sediments would periodically choke the Colorado's flow, and cause it to deposit them and move to a new channel (USBR 1946; Reisner 1987).

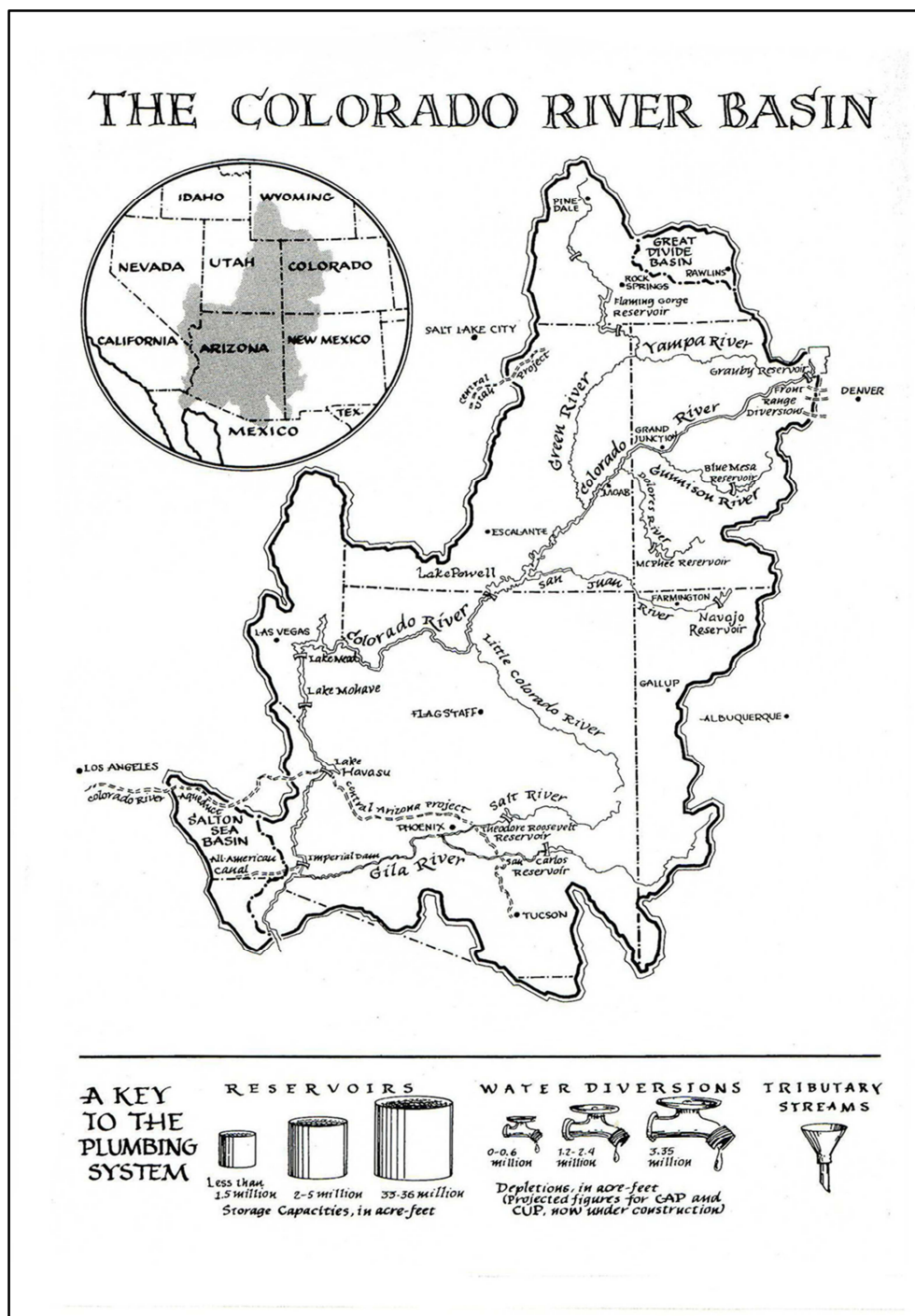


Figure 2.3: The Colorado River Basin and Its Plumbing. From *Western Water Made Simple*, by the High Country News. Copyright © 1987 High Country News. Reproduced by permission of Island Press, Washington, D.C.

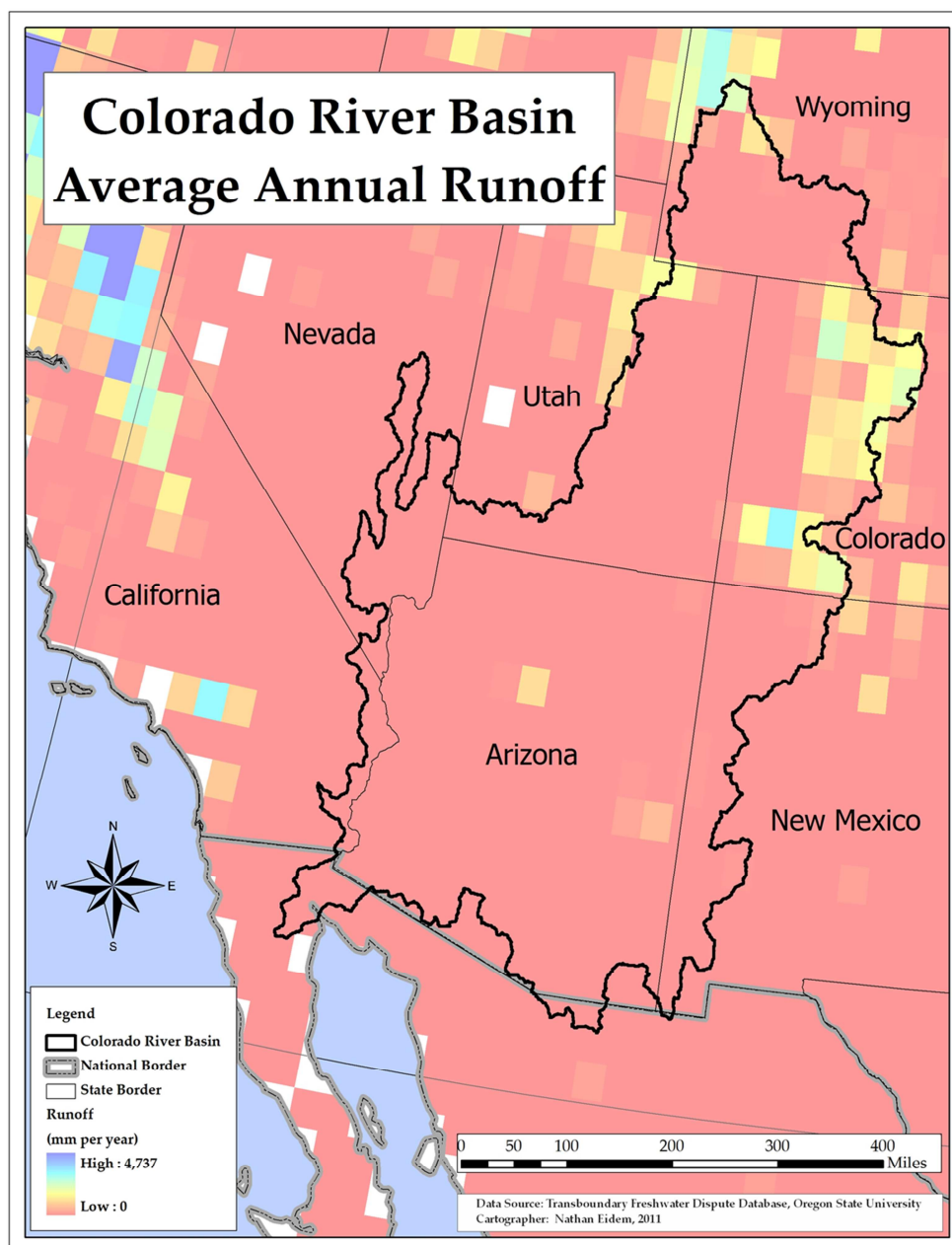


Figure 2.4: Most of the basin's runoff originates in the Rocky Mountains of Colorado and Wyoming as snow.

Climatologically, the Colorado River basin is an arid region. The majority of flows originate from snow melt and precipitation in the high Rockies of the upper basin. Before the development of infrastructure, flow volumes varied greatly by season. Peak flows occur in the spring, and slow to a trickle in the dry summer months (USBR 1946; Reisner 1987). The physical characteristics of the Colorado River basin give rise to the types of life it contains.

### *The Biotic Component*

The distribution of water in the region helps to give life to a variety of ecoregions (Figure 2.5 and Appendix III) and land covers (Figure 2.6). Humans have lived in the Colorado River basin for thousands of years, and settlements and agriculture also contribute to the land cover patterns observed. Plants and animals in the basin vary with the topography and local climate. Alpine species dominate in the mountainous headwater regions, and transition to those adapted to the shrub land and desert regions in the lower portion of the basin (USBR 1946). Prior to the development of infrastructure, the Colorado River delta supported populations of large cat species and



waterfowl (Reisner 1987). Further, a variety of unique native fish thrived in the silt-laden waters created by the interactions of precipitation and geology in the basin.

By 1894, federal fish surveys had been conducted in much of the Colorado River basin, and "[t]hough the families and species constituting the fish fauna are very few, they are of unusual interest to the student of geographic distribution" (Evermann and Rutter 1894: 475). Of the 32 fish species observed in the basin, 60 percent belonged to the minnow family, and 25 percent to the sucker family. Further, 28 of 32 species were "thus far known only from this basin" (Evermann and Rutter 1894: 475). "It is thus seen that over 78 percent of the species of fishes now known from the Colorado Basin are peculiar to it. This is a larger percentage of species peculiar to a single river basin than is found elsewhere in North America" (Evermann and Rutter 1894: 475).

In addition to plants and animals, humans have lived in the basin for thousands of years. A diversity of Native American Tribes lived in the basin prior to European colonization. Exploration began with the Spanish in the 1500s, but large-scale settlement did not begin until the 1800s. Mining

brought people to the basin seeking fortunes. Many turned to farming after having little luck with metals. Settlers moved west to acquire land for farming and ranching. As the settlers came, surviving Native Americans were forced onto reservations, and became part of the U.S. federal bureaucracy (USBR 1946).

These brief descriptions of the abiotic and biotic components of the Colorado River basin illustrate the foundational relationships in a social-ecological system. The interplay of climate and geology created a silt-laden river with wildly varying flows that supported unique species, both in and out of the water. The next section incorporates the human component into the social-ecological system model, by focusing on human-fresh water interactions.

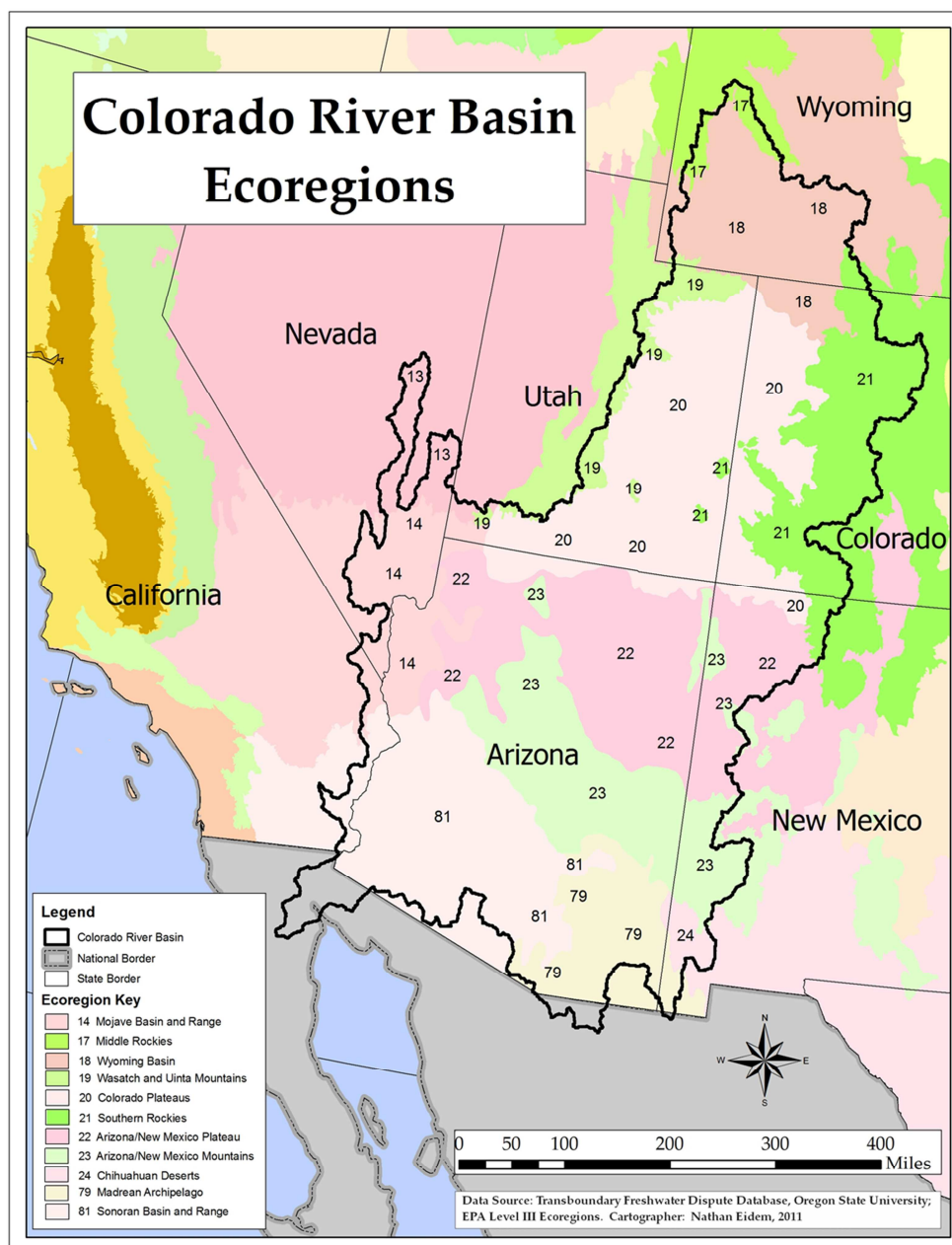


Figure 2.5: U.S. EPA Level III Ecoregions. The green areas represent montane ecoregions, while the pink regions represent plateaus and deserts. See Appendix III for EPA descriptions of the ecoregions within the Colorado River basin.



Figure 2.6: Land cover in the basin ranges from shrub-covered desert to forest-covered mountains, and includes cultivated crops and human developed locations.

*A History of Human-Fresh Water Interaction in the Colorado River Basin*

Humans have relied on the Colorado River for water as long as they have been in the basin. Irrigation is essential to agriculture in this arid region, and has been practiced in some form for thousands of years (USBR 1946; Worster 1985; Reisner 1987; Adler 2007). Neither American settlements nor agriculture would be possible in the region without the manipulation of the flow of the Colorado River. It is one of the most developed rivers in the world, with a series of dams holding four-years-worth of supply on reserve (Reisner 1987: 125). Canals and tunnels divert some of this restrained water away from the river channel, including out-of-basin transfers. Nearly one-third of the Colorado's annual flow leaves the basin (Lewis 2006: 107) and enters both the Pacific and Atlantic Oceans at southern California, southern Texas, and southern Louisiana. It rarely makes it all the way to its natural delta at the Gulf of California in Mexico (Seligman 2006). A visualization of this manipulation helps to further conceptualize the social-ecological system (Figure 2.7). In order to understand this plumbing, it is necessary to start with a discussion of the Prior Appropriations Doctrine.

## ...AND ITS PLUMBING

MAP AND PLUMBING COMPILED  
AND EDITED BY MARY MORAN  
RENDERED BY LESTER DORÉ

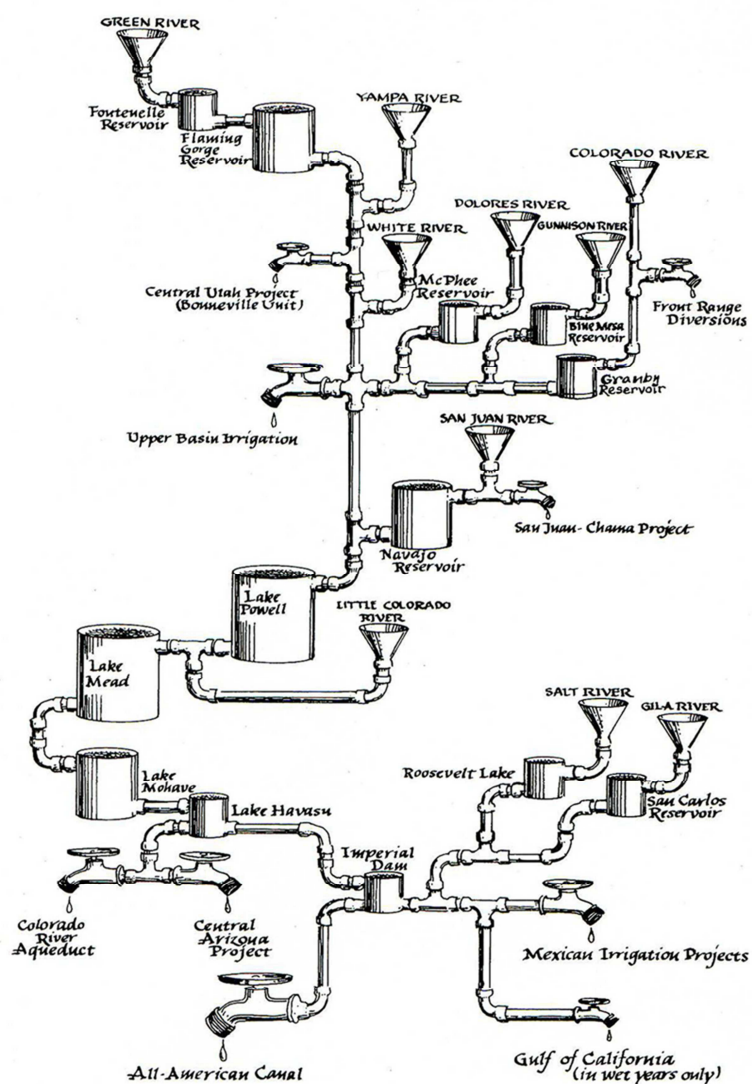


Figure 2.7: The Colorado River Basin and Its Plumbing. From *Western Water Made Simple*, by the High Country News. Copyright © 1987 High Country News. Reproduced by permission of Island Press, Washington, D.C.

*Prior Appropriations and Water in the West*

Out of necessity, institutions have been created to help prevent conflicts over fresh water in this water scarce region. The law governing water rights in the western United States (West) is the starting point for any discussion of institutions. Here, water users' rights are established according to the prior appropriations doctrine. The allocation system came out of the mining camps of California in the 1800s. Miners diverted water from streams and rivers to help them extract valuable gold from mines lacking sufficient local water supplies. When new mining operations were established upstream from existing mines, the downstream mines were useless after stream flows were depleted. This led to conflicts between the mining camps, many of which were violent, and discouraged investment in mining and agriculture, which require a reliable water supply (Kenney 2004). The prior appropriations doctrine provided an allocation system that protected water users' rights to divert sufficient quantities of water to sustain their operations against potential future water diversions (Thompson 1999; Kenney 2004).

The two main tenants of this doctrine are the concepts of first-in-time, first-in-right, and the use-it-or-lose-it principle. Those who appropriate water from a stream have a senior right to the original amount diverted. Those with

junior water rights will only get water once the senior rights have been satisfied. If a senior water rights holder fails to use his entire allocation, the unused portion is no longer his. Because of this, the prior appropriations doctrine does not facilitate water conservation. The use-it-or-lose it principle does not apply to federal reserved water rights (e.g. Native American water rights) (Thompson 1999; Kenney 2004). The prior appropriations doctrine has been criticized for being antithetical to modern values favoring sustainability and instream uses (Wilkinson 1992). As thoroughly discussed by Hundley, Jr. (1975), Worster (1985), Reisner (1987), Wilkinson (1992), Getches (1997), Seligman (2006), and others, prior appropriations and the institutions that grew out of the doctrine were based in the value system that led to the plumbing of the Colorado River.

*A Drop to the Sea Is a Drop Wasted*

The title of this section was the guiding principle for the development of water resources in the West. As is the case in the broader history of the West, interest groups outside of the region pushed for the technological-control of nature in order to generate wealth (Worster 1985; Reisner 1987;



Cronon 1991). The construction of infrastructure on the Colorado River is no different, and was done with Gifford Pinchot's brand of conservation in mind. As opposed to John Muir's belief that nature should be preserved (preservationist philosophy), Pinchot sought to maintain the productive capacity of a natural resource (conservationist philosophy) (Cutter and Renwick 1999: 40-41). This split in resource management philosophies can be traced to the Hetch-Hetchy Valley in California. Bordering the Yosemite Valley, a favorite of Muir, Hetch-Hetchy was seen by developers as an ideal location to build a dam and reservoir to provide water for San Francisco. Proponents claimed it would enhance the beauty of the valley by creating a clear lake for tourists (Muir 1912). A former ally of Muir's, Gifford Pinchot, supported the project while Muir fought to preserve it in its natural state. In response to the suggestion that creating the dam would increase the valley's beauty, Muir stated, "Dam Hetch Hetchy! As well dam for water-tanks the people's cathedrals and churches, for no holier temple has ever been consecrated by the heart of man" (Muir 1912: 262). The dam was ultimately built, but signaled the beginning of the fight between those advocating a conservationist philosophy and those advocating a preservationist philosophy (Cutter and Renwick 1999).

Today, water is put to use for agriculture, domestic purposes, power generation, industry, and recreation. Driven by the conservationist philosophy, the USBR saw the water of the Colorado as an economic commodity for the nation:

*Thousands of acres of desert land in the Colorado River Basin produce nothing more than sagebrush or cacti. Millions of acre-feet of water waste annually into the Pacific Ocean. Billions of tons of copper, coal and other minerals lie buried in mountains. In their present state this land, this water, and these minerals are not wealth because they are not being utilized economically. They can, however, become wealth or produce wealth. Man's ingenious nature has assured him of this. Water can be brought to this land to produce crops; these minerals can be mined and processed with an abundance of low-cost hydroelectric energy made available; trade can be established; and in general, the wealth produced can be converted into more and better opportunities for the American people (USBR 1946: 211).*

The infrastructure required to produce this wealth and the water that it manipulates is governed by a series of “international treaties, interstate compacts, federal statutes, and U.S. Supreme Court and other federal court opinions” (Seligman 2006: 16). There are so many documents governing the Colorado, that it has been referred to as the “paper river” (Marston 1987: 160). Collectively, these institutions are known as the “Law of the River” (Seligman 2006). [See Seligman 2006 for a thorough compilation of the law of the Colorado River.] Cooperation birthed interstate compacts and Congressional

Acts that funded the plumbing of the Colorado River. The infrastructure allowed for American settlement of this arid region, and the people became dependent on the infrastructure and those who build and maintain it (Worster 1985).

Distributive politics, where only benefits, and not costs, are considered (Ingram 1990: 9), led to the massive scale of infrastructure development observed today, and pork-barrel politics allowed for supportive local stakeholder groups to get their projects approved in Congress. Mutual noninterference in Congress allowed for projects to get funded without scrutiny (Ingram 1990: 38-39). To put it another way, Senators and Representatives voted for each other's projects to secure funding for their own. This in turn made voters happy, and the cycle continued, especially since costs were largely transferred to the entire nation. This coalition became powerful, and directed the trajectory of the Colorado River basin SES. Natural systems were of no concern.

As discussed previously, the federal government was aware of the unique fish species in the Colorado River basin. Even though this information was available, the USBR was silent on the fish when describing the Colorado's

native biology in a proposal to Congress for infrastructure development within the basin (USBR 1946). Later in the same report, the USBR does discuss the issue of fish habitat. The tone is very positive for sport fish, such as trout, and almost faults the natural processes in the Colorado River basin for an inability to maintain these species along its entire course. Further, the Bureau recognizes that infrastructure development negatively impacted native fish, noting that "...most of the native fishes apparently suffered from the man-made changes in the river and are no longer abundant" (USBR 1946: 252). Although the majority of native fish were unique to the Colorado River, they are not of the sporting variety, and seen as non-existent or not worthy of inhabiting the Colorado. The USBR would improve the river by removing the silt, and stocking it with more worthy species. In some parts of the basin, removing silt was not the only job to be done.

In order to further transform the Colorado River into a sport fishing paradise, the USBR, U.S. Bureau of Sport Fisheries and Wildlife, and state officials from Wyoming and Utah dispensed more than 20,000 gallons of poison into the river to eradicate fish in a stretch of the Green River in the early 1960s. It was the largest experiment of its kind ever attempted. The

public supported the plan, as it could bring money from tourism to their localities. Some scientists feared it would further harm native species downstream, already in decline following the construction of the first dams on the river. However, no permits were required, and the environmental impact statement was years away, so these warnings were ignored (Adler 2007: 108-110).

The poisoning was successful, allowing for the new reservoir behind Flaming Gorge Dam to be stocked with trophy fish. Those who predicted it could harm downstream fish were also correct, as efforts to detoxify the downstream reaches were unsuccessful. Fish were non-existent in parts of the Green River below the dam after the poisoning. Eventually, rivers where fish had been accidentally eradicated were recolonized, but the composition of the community changed as habitat was opened to invaders. The negative outcomes of this eradication program ultimately brought scrutiny to the USBR's unquestioned plan when, in 1963, the Secretary of the Interior issued a directive requiring the review of projects and evaluation of potential negative impacts by outside experts (Alder 2007: 108-110). This started a shift from a

purely conservationist approach to water resources management in the Colorado basin and beyond.

### *The Rise of the Preservationist Philosophy*

Starting during the Johnson administration with the National Environmental Policy Act and the predecessor to the Endangered Species Act, a new era of water resources planning emerged. The Endangered Species Act and Clean Water Act became law during the Nixon administration. The Carter and Reagan administrations further influenced a shift in water resources planning out of environmental and budgetary concerns, respectively. Taxpayers were tired of paying for projects that did not benefit them, and were becoming increasingly aware of the environmental costs that were ignored when the basin-wide planning for development occurred. Environmental groups, namely the Sierra Club, helped get this ball rolling when they opposed major dams on the Colorado River in the mid-1960s. The group brought the issue to the nation's attention, illustrating the influence non-local interest groups can have in complex systems (Cronon 1991).

The Sierra Club, founded by John Muir in 1892, representing the

preservationist philosophy in natural resources management, challenged a series of proposed dams in the Grand Canyon region. The USBR argued "that tourists would better appreciate the beauties of the Grand Canyon from motorboats" (Reisner 1987: 296). This was a similar argument used by those promoting the dam in the Hetch-Hetchy Valley (Muir 1912). In June of 1966, the Sierra Club ran full-page advertisements in major U.S. cities' newspapers attacking the dams and the USBR's logic. Echoing Muir's statement about flooding Hetch-Hetchy and cathedrals, one of the ads asked the question, "Should we also flood the Sistine Chapel so tourists can get nearer the ceiling?" (Reisner 1987: 296). The public responded by flooding the USBR with letters objecting to the dams. This did not sit well with the proponents of infrastructure in the federal government. The day after the ads ran, the IRS opened an investigation into the tax-exempt status of the Sierra Club (Reisner 1987).

Within the USBR there was also an effort to undermine the credibility of the Sierra Club's Executive Director, David Brower, who was responsible for the advertisements. In September of 1966, a member of the Sierra Club wrote

a letter to Arizona Congressman, Morris K. Udall<sup>6</sup>. He was "offended and ashamed" that Udall had "been subjected to public name-calling by the Executive Director of the Club." He also states, "I have tried to do what little I could about it as an individual member of the club." Two days later, Udall sent a reply<sup>7</sup>. In it he writes, "It is a satisfying thing to know that you and other people have also encountered these difficult traits in his personality and attitude." While these letters do not point to a plan to undermine Brower's credibility, a letter from then Assistant to the Commissioner of the USBR, Ottis Peterson, to then Commissioner, Floyd Dominy, does<sup>8</sup>. The brief letter reads:

*This is the man who wrote Representative Udall apologizing for the attack David Brower made on him.*

*I am seeking to cultivate him as another source to attack Brower from within the club.*

While this clearly states that Peterson was seeking Sierra Club members to attack Brower, a more interesting point arises. The fact that correspondence between an Arizona Congressman and a citizen from California turned up in

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<sup>6</sup> Letter, Thomas H. Jukes to Morris K. Udall, September 6, 1966, Box 18, Folder - Sierra Club 1966-1967, Accession Number 02129, Floyd E. Dominy Papers, American Heritage Center, University of Wyoming. (\* This folder also contains the files denoted by an asterisk.)

<sup>7</sup> Letter, Morris K. Udall to Thomas H. Jukes, September 8, 1966 \*

<sup>8</sup> Letter, Ottis Peterson to Floyd Dominy, October 27, 1966 \*  
Letter, Ottis Peterson to Thomas Jukes, October 27, 1966 \*



the hands of the Commissioner of the USBR provides insight into the relationship between the dam builders and top-level politicians in Washington D.C.

This is not the only example of this relationship. Correspondence between David Brower and Colorado Representative, Wayne N. Aspinall, also turned up in Dominy's files<sup>9</sup>. The first two letters focus on a news photo stunt at a National Reclamation Association meeting, where neither party knew they were to be photographed together. After being surprised by the situation, Aspinall stated that Brower had lied about the extent to which the Grand Canyon dams would flood the National Park. Brower requested that Aspinall document any false statements he had made, and Aspinall said he was busy, but would get to it in several weeks. Brower replied, again requesting documentation. In an unsigned draft letter, a response is given to Brower's second letter, detailing Brower's "errors of commission, omission, half truths, and distortion..." regarding the Grand Canyon dams.

One final example of this relationship exists from May of 1965, which relates to Glen Canyon Dam. The Sierra Club had not challenged Glen

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<sup>9</sup> Letter, David Brower to Wayne N. Aspinall, November 19, 1966 \*

Letter, Wayne N. Aspinall to David Brower, November 22, 1966 \*

Letter, David Brower to Wayne N. Aspinall, November 28, 1966 \*

Draft Letter, Unsigned [Wayne N. Aspinall] to David Brower, Undated \*

Canyon Dam in exchange for the denial of funding for the Echo Park Dam.

Brower regretted this decision, which led him to fight harder against the Grand Canyon dams (Reisner 1987). Morris Udall wrote the following to Floyd Dominy<sup>10</sup>:

*The March '65 issue of the Sierra Club Bulletin has an article called "Some Recent Observations on Glen Canyon" by P.T. Reilly on Lake Powell.*

*If you think it advisable, I think an answer should be made and I would be happy to make a brief speech on the Floor setting the record straight.*

In his response, Dominy writes<sup>11</sup>:

*I certainly think it advisable that a reply be made on the House floor to the Sierra Club attack on Glen Canyon Dam and Reservoir in the March 1965 issue of the club magazine, and I am pleased that you plan to handle it.*

*This appears to be a revival of the wild and irresponsible charges made against the dam and reservoir site during the Congressional consideration of the upper basin project.*

These letters provide a glimpse into the struggle between those seeking to control nature for the benefit of humans and those seeking to preserve it playing out decades after the debate over how to manage nature began. Both

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<sup>10</sup> Letter, Morris K. Udall to Floyd Dominy, May 4, 1965 \*

<sup>11</sup> Letter, Floyd E. Dominy to Morris K. Udall, May 13, 1965 \*

Udall and Aspinall had their own projects to bring home to constituents. At this point in time, the Colorado River Basin Project Bill had not yet gained enough support in Congress to pass. Many projects were at stake, and proponents had to work together to get the bill passed in 1968. The point of these letters is not to address the disagreement between Brower and the Sierra Club, but rather to highlight the behind-the-scenes communication between Congress and the USBR during the dam-building era. When a non-governmental organization turned public sentiment against the status quo, those in power tried to silence them in order to protect their projects. [For a thorough discussion on David Brower and the conflict between the Sierra Club and USBR in the Colorado River basin, see Reisner 1987.]

Preservationists were backed by institutional changes in 1963 after the fish poisoning program in the Green River went wrong. The compromise over Glen Canyon Dam and Echo Park Dam further increased their influence. When the issue over dams in the Grand Canyon became the focus of attention, those in control realized their plans were in jeopardy—not just these dams, but all future development of the basin—and acted to counter the rising influence of the preservationists. For more than 50 years, the conservationist philosophy guided the development of the Colorado River basin, and now the

preservationists were starting to change the game. Ultimately, the Colorado River Project Act would shape the future of basin.

### *Native American Water Rights*

When discussing water resources in terms of Pinchot and Muir, it is easy to lose track of another important consideration, Native American water rights. The USBR offers the following:

*These Indians and their resources in land and water rights are the special concern of the Federal Government. The Federal responsibility is specifically set out in various treaties, statutes, and agreements under which definite legal rights have been vested in individuals and tribes. There are also certain moral obligations of the Government to these Indians because of its disregard of their legal rights over a long period. These rights and obligations were recognized by the Colorado River Compact Commission as evidenced by article VII of the compact which reads as follows: "Nothing in this compact shall be construed as affecting the obligations of the United States of America to Indian Tribes." One of the Government's objectives in the development of the basin must be not only the protection of the Indian's purely legal rights but the discharge of its moral obligations as well (USBR 1946: 261).*

These legal and moral obligations will play a key role later in this dissertation. Even though Tribes in the region held a priority date of 1868 for water in the Colorado River, and the Colorado River Compact of 1922 did not affect federal obligations to them, their rights were ignored for more than a century. These

rights took a back seat to westward expansion and associated infrastructure development.

### *Increasing Demand*

The Colorado River, or “American Nile” (Reisner 1987: 125), is the lifeblood of the American Southwest. It provides nearly 30 million people with water and power in cities including Las Vegas, Denver, Phoenix, and Los Angeles (Seligman 2006). Originating in the Rocky Mountains of Wyoming and Colorado, water from the Colorado River's northern most tributaries travels, on a good year, nearly 1,700 miles (2,736 km) to the Gulf of California. Along this journey it is diverted and put to a variety of uses, which are not always compatible. Demand for Colorado River water continues to grow within and outside the basin.

In the upper Colorado River basin alone, water use increased by over 500,000 acre-feet (600,000,000 m<sup>3</sup>) from 1971 to 2004. Exports of water out of the basin grew by nearly 200,000 acre-feet (200,000,000 m<sup>3</sup>) during this same time, while agricultural water use grew by over 150,000 acre-feet (190,000,000 m<sup>3</sup>) (USBR 2004; 2005; 2006). Agriculture is the largest user of water in the region (Solley et al. 1998; Gollehon and Quinby 2000; Brown 2006).

Water is increasingly being transferred away from agriculture to meet the needs of growing urban populations and instream uses, primarily habitat for endangered species (Platt 2004; Cortese 2003). Further, Native American tribes are asserting their right to the water owed them by treaties, and multiple settlements have been signed to accommodate these rights. This adds more potential stress to the system. According to the U.S. Bureau of Reclamation (USBR) (2003: 3), “the demands for water in many basins of the West exceed the available supply even in normal years.” Irrigation and domestic supply projects have been constructed to meet some of the needs of Native American Tribes. Both the United States and Mexico utilize the Colorado for irrigating approximately 4.5 million acres of land (Seligman 2006). The recreation industry utilizes the river for rafters, and several former mining towns are now ski towns (e.g. Breckenridge, Aspen, Telluride, and Silverton, Colorado). The plumbing of the river to meet these demands, and the history of resource use in the basin have changed the levels of silt, salt, and pollutants in the Colorado River basin (Adler 2007). Many things have changed in the basin, but the foundation built on the conservationist philosophy remains.

The previous discussion, based on a simple conceptual model of a

single resource in a social-ecological system, illustrates how complex the relationships between the abiotic and biotic components of the world can be, especially when human devised institutions are involved. Because of this complexity, a framework for analysis is required to prevent research from becoming too sprawling.

### **Studying Social-Ecological Systems**

As this chapter has shown, conceptualizing social-ecological systems and resilience requires a range of information from a range of disciplines. It is easy to get side-tracked in the SES web while conducting research, thus a framework for analysis is helpful. Using Ostrom's framework for decomposing social-ecological systems, Chapter Three provides an answer to her question (Ostrom 2007: 8): "What patterns of interactions and outcomes—such as overuse, conflict, collapse, stability, increasing returns—are likely to result from using a particular set of rules for the governance, ownership, and use of a resource system and specific resource units in a specific technological, socioeconomic and political environment?" In answering this question, this

research will provide insight into the processes that create social-ecological resilience.

The latter part of this chapter has served as the initial decomposition of the study area, the Colorado River basin, by laying out the major components of the social-ecological system important to this study. Chapter Three further breaks the system apart based on two of the key institutions in the basin, the Reclamation Act of 1902 and the Colorado River Compact of 1922. The 1902 Act created the Reclamation Service, now the U.S. Bureau of Reclamation (USBR). The Colorado River is managed by two USBR management regions: the Upper Colorado (UC) Region and the Lower Colorado (LC) Region, which comes out of the 1922 Compact. The next step in this decomposition is a change in geographic scale to the upper Colorado River basin. This is followed by another scale change to the upper San Juan River basin in the fourth chapter.

The relationship between conflict, institutional capacity, and social-ecological resilience discussed in the first part of this chapter guides the following chapters. Since conflict and cooperation play an important role in system resilience, the next chapter identifies a theoretically resilient



watershed, and presents an analysis of interactions over fresh water in the upper Colorado River basin.

### CHAPTER 3: DECOMPOSING A SOCIAL-ECOLOGICAL SYSTEM: INTERACTIONS OVER FRESH WATER IN THE UPPER COLORADO RIVER BASIN<sup>12</sup>

*“The key is assessing which variables at multiple tiers across the biophysical and social domains affect human behavior and social-ecological outcomes over time.”*

– Elinor Ostrom

As discussed in the previous chapter, social-ecological systems are complex networks including humans and nature. Looking at every component of the system simultaneously would likely be impossible. Therefore, it is necessary to study components that can be linked in future analyses. This chapter presents the decomposition of the Colorado River basin social-ecological system, in order to answer the question: *How do stakeholder groups interact over fresh water?* Using interactions of cooperation and conflict over water resources, a tributary watershed exhibiting social-ecological resilience is identified for further analysis. Chapter Four utilizes this watershed as the subject of a case study for understanding how stakeholder groups enhance resilience, thus contributing to system sustainability.

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<sup>12</sup> Portions of this chapter appear in 1) Eidem, N. 2008. The WWIS-WWIN Collaboration: An Analysis of the Social, Economic, and Biophysical Environments Supportive of and the Historic Trends in Conflict and Cooperation in the Bureau of Reclamation's Upper Colorado Region 1970-2005. *Western Water Institutional Solutions Project Report*. U.S. Bureau of Reclamation. and 2) Eidem, N.T, K.J. Fesler, and A.T. Wolf. 2012. Intranational Cooperation and Conflict over Freshwater: Examples from the Western United States. *Journal of Contemporary Water Research and Education*. In Press.

Ostrom proposes an analytical framework consisting of multiple tiers of variables for decomposing social-ecological systems, starting with four broad first-tier variables (Ostrom 2007: 7):

1. *A resource system (e.g., fishery, lake, grazing area),*
2. *The resource units produced by that system (e.g., fish, water, fodder),*
3. *The users of that system, and*
4. *The governance system*

This framework provides a method for operationalizing a social-ecological system for further analysis. For this study, the Colorado River basin is the resource system, fresh water is the resource unit of interest, the users of this water provide the interactions for this analysis, and the “Law of the River” is the governance system in the basin. Once again, Carl Sauer is called upon, this time to provide support for beginning this geographic analysis with these modern institutions:

*If you are going to study man, you should study man in terms of his entire period of existence in the area in which you are interested. My guess is that you can begin the study of man in the Southwest twenty-five thousand years ago or whenever he first came; or you can begin fifty years ago, when American civilization began rolling (Sauer 1945: 255).*

The modern Colorado River is nothing like it was in the time of the first immigrants to the Southwest because of the “plumbing” constructed to

regulate its flows during the American era. The infrastructure is the physical manifestation of a cultural shift in the region. This change in culture not only shaped the river, but also the interactions between people over water resources.

Ostrom (2007: 9) breaks each of the first-tier variables down into several second-tier variables based on previous research, in order to provide analysts starting points for studying complex social-ecological systems. This study focuses on Ostrom's (2007: 8) question: "What patterns of interactions and outcomes – such as overuse, conflict, collapse, stability, increasing returns – are likely to result from using a particular set of rules for the governance, ownership, and use of a resource system and specific resource units in a specific technological, socioeconomic, and political environment?" The second-tier variables analyzed here are at the Interaction (I) and Outcome (O) levels, specifically I3 (deliberation processes), I4 (Conflicts among users), O1 (social performance measures), and O2 (ecological performance measures) (Ostrom 2007: 9). This chapter discusses the interaction variables, while outcomes are discussed in the next chapter.

As part of the broader Western Water Institutional Solutions project, an event database of interactions of conflict and cooperation over fresh water was

constructed for the USBR's UC Region. Funded by the USBR's Science and Technology Program, the purpose of the WWIS project is to provide water managers with tools to help detect conflictive situations, mitigate against future conflict, and aid in settling disputes. The project was created to help address Reclamation's growing concerns about the potential for conflict over scarce water resources in the western U.S. Events of cooperation and conflict were coded to USGS 6-digit hydrologic accounting units (Figure 3.1), and by interaction intensity, issue type, and broad stakeholder groups involved. These data provide a historical snapshot of interactions in the UC Region between 1970 and 2005, and allow for trends to be analyzed over time. Further, the event database was coupled with the Western Water Information Network (WWIN) in order to determine if events correlate to institutional, bio-physical, and socio-economic variables. The goals of the WWIS project are to gain an understanding of settings conducive to cooperation and conflict, learn how these interactions vary across time and space, and to provide insight into how conflicts are resolved. This research fills a gap in the literature by providing insight into cooperation and conflict over water resources on and intranational-interstate scale. As discussed previously, the event data approach used in this dissertation is based on



Figure 3.1: USGS 6-digit accounting units (watersheds) in the upper Colorado basin.

studies conducted at the international river basin scale (Wolf et al. 2003) and the intranational-intrastate scale (Fesler 2007). The following is a discussion of some of the major findings from the UC Region study.

### **Interactions over Water Resources in the USBR UC Region<sup>13</sup>**

The UC Region Event Database collected 3,867 interactions for analysis. From 1970 through 2005, a majority of events in the UC Region were cooperative, 1,584 (41%) to 1,455 (38%) (Figure 3.2). Neutral events occurred most frequently, followed by mild dissent (-1) and mild support (+1). Several lawsuits (-4) occurred during this time period along with several settlements (+4). Nearly one-quarter of all events coded were extreme (+/- 4 and +/- 5), with less than 1.5% being the most extreme. Of all the extreme events, 392 were cooperative and 336 were conflictive. Intensities varied across the UC Region, with no discernible geographic pattern.

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<sup>13</sup> See Eidem 2008 for additional analysis of interactions in the USBR UC Region. Available at: [http://www.usbr.gov/research/science-and-tech/projects/download\\_product.cfm?id=282](http://www.usbr.gov/research/science-and-tech/projects/download_product.cfm?id=282)

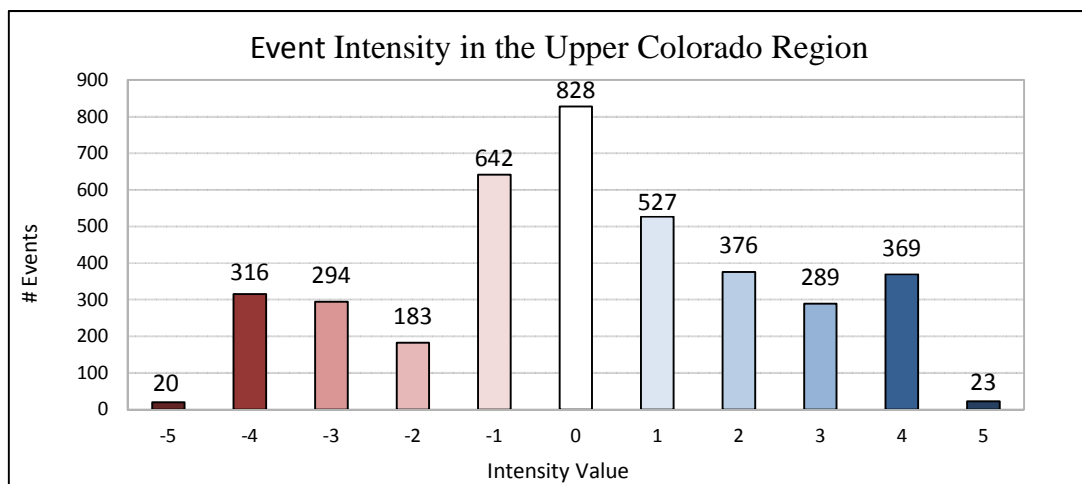


Figure 3.2: Distribution of events in an intranational-interstate region. n = 3,867. Data Source: UC Region Event Database

In terms of issue type, the majority of events related to water rights, infrastructure, water quality, and intergovernmental relations, respectively. Water rights events tended to be more conflictive (328, 41%) than cooperative (284, 35%). Litigations are the main mechanism stakeholders have to alter a water right, thus the high frequency of -4 intensity events. There is also a lot of mild verbal dissent and support over water rights events. This holds true for all issue types.

Hydropolitical events relating to infrastructure tended to be more cooperative (399, 51%) than conflictive (237, 30%). A high proportion of +2 and +4 events coded to this issue type shows that people are willing to not only make proposals for collaboration, but also form collaborative groups when



infrastructure is involved. Interestingly, the rivers of the UC Region are some of the most heavily developed in the world, but the region has the lowest percentage of events in this category compared to the previous studies at different scales of analysis (Wolf et al. 2003; Fesler 2007).

Water quality events tended to be more conflictive (288, 43%) than cooperative (239, 36%). The largest number of conflictive events was permit violations (-3). There were also a large number of +4 events, indicating a willingness to work together to manage water quality.

There were more events of intergovernmental conflict (278, 45%) than cooperation (239, 39%). The largest number of both conflictive and cooperative events were mild verbal dissent (-1) and support (+1). This is an example where conflict is greater than cooperation, but it is mostly talk.

In the UC Region, as was found in previous studies of event data at different scales, conflict is not as prevalent as cooperation in water resources interactions. Stakeholder interactions occur over a variety of issue categories, and are more likely to be low intensity than high intensity. The cooperative trend observed at multiple scales goes against traditional thinking about fresh water interactions, that conflict is the norm. This analysis provides insights into interactions over water resources in the West, and leads into the

decomposition of the Colorado River basin.

### **Upper Colorado Decomposition**

The first step in this decomposition reduces the size of the study area based on available data. The UC Event Database used the USBR UC Region as the study area. Events were not coded for the Lower Colorado Region (Eidem 2008). Thus, only the area where the UC Region overlaps the Colorado River basin is available for further social-ecological system analysis (Figure 3.3). The remainder of the chapter discusses fresh water in the study area, and the relevant events from the UC WWIS database.

### **Water Resources in the Upper Colorado River Basin**

The upper Colorado River basin is the source of water for some of the largest and fastest growing cities in the U.S., including Denver, CO, Las Vegas, NV, Los Angeles, CA, and Phoenix, AZ, none of which is within the UC Region (NRC 2007). The rivers of the region are fed primarily by snowmelt in the Rocky Mountains, and travel through some of the driest parts of the U.S. (USBR 2006). According the USBR, portions of the UC Region are highly

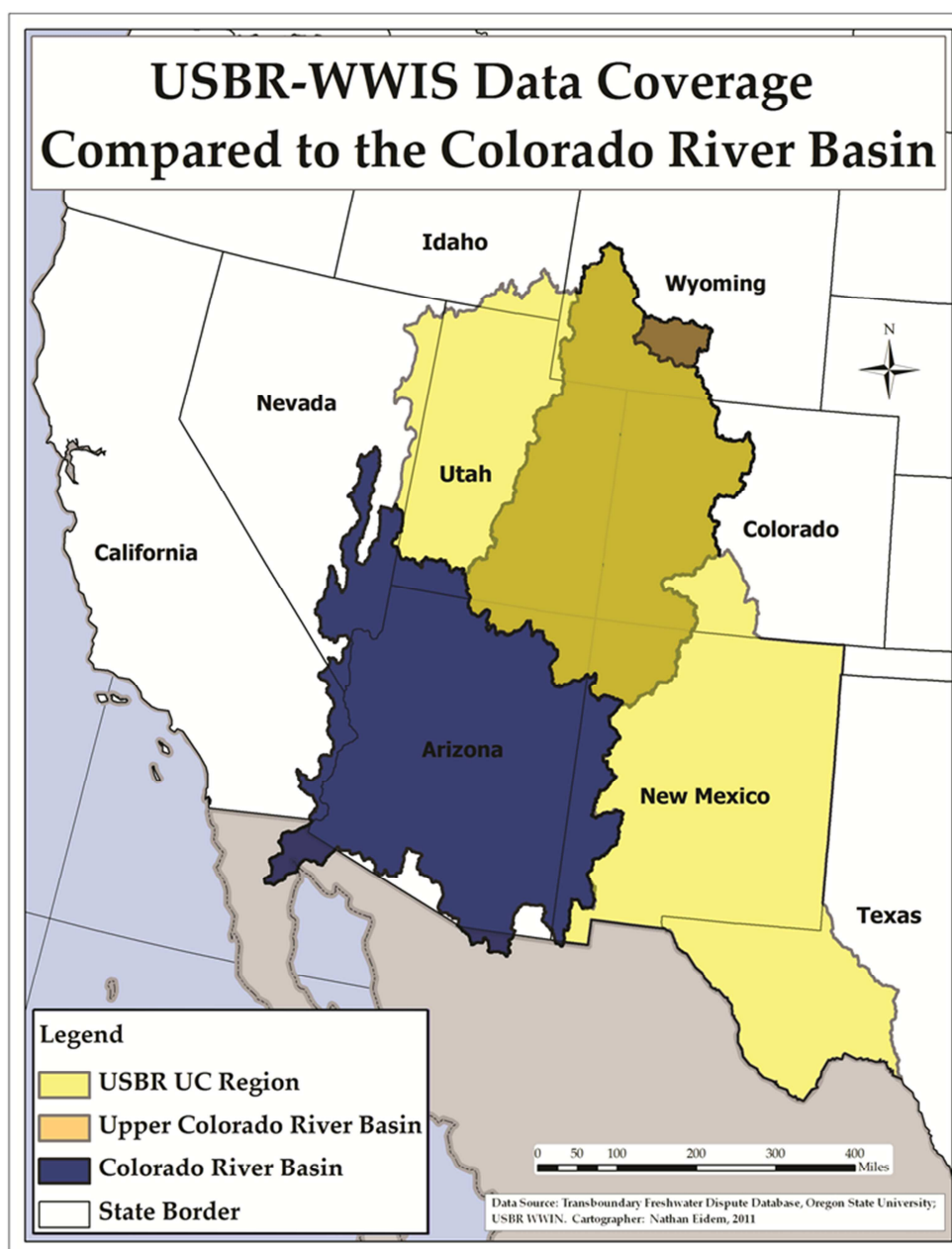


Figure 3.3: The intersection of these regions illustrates a step in the decomposition based on location.

likely to experience water supply crises by 2025 (USBR 2005: 3). Several components of the Law of the River relate directly to the UC basin, and this research (Table 3.1). The Law of the River is comprised of a variety of institutions such as compacts and Acts of Congress. The foundation of this institutional web is the 1902 Reclamation Act, which provided federal funds for irrigation projects in the West, and created the U.S. Reclamation Service, later renamed the U.S. Bureau of Reclamation, to build them. In 1922, water was allocated between the upper and lower Colorado River basins as part of the Colorado River Compact (Seligman 2006; USBR 2009).

Table 3.1: Elements of the Law of the Colorado River important to this dissertation.

Major Components of the Law of the Colorado River Relating to this Research	
1902	Reclamation Act
1922	Colorado River Compact
1948	Upper Colorado River Basin Compact
1956	Colorado River Storage Project Act
1963	Animas-La Plata Project Compact
1968	Colorado River Basin Project Act
1973	Endangered Species Act
1986	Animas-La Plata Cost Sharing Agreement
1988	Colorado Ute Indian Water Rights Settlement Act
2000	Colorado Ute Settlement Act Amendments
2005	San Juan Basin/Navajo Nation Water Rights Settlement Act
2009	Omnibus Public Lands Management Act

The upper basin states agreed to a compact in 1948 in order to allocate their portion of the Colorado River. Four dams were authorized by the 1956 Colorado River Storage Project Act to store water in the upper Colorado basin, in part to start putting the 1922 allocation to use. Further development of upper basin allocations was put into motion in 1963, when Congress prioritized water use in the upper San Juan River basin, as part of the Animas-La Plata Project Compact created by Colorado and New Mexico (Seligman 2006; USBR 2009).

Although infrastructure was still being constructed in 1973, thus reducing available habitat for native fish, the Endangered Species Act became law this year. This would eventually change water resources planning and management in the Colorado River basin, as the damming of the river put some fish species in danger of extinction. In 1986, cost-sharing requirements for Animas-La Plata project beneficiaries increased, ultimately leading to a smaller version to be constructed. Two years later, the federal government and Colorado-Ute settled reserved water rights claims by trading these rights for rights to water stored in future federal projects. The settlement was amended in 2000, and included provisions for protecting and restoring habitat for endangered and threatened species living in the San Juan River. Further

Native American water rights claims were settled in 2005 when the Navajo Nation agreed to give up water rights in the San Juan River basin in exchange for a water supply project (Seligman 2006; USBR 2009). The Omnibus Public Lands Management Act of 2009 includes provisions for the creation of a fund for the USBR to use to settle tribal water rights claims, with priority given to some New Mexico settlements (Benson 2011). Infrastructure-related institutions are a large part of the Law of the River. These components of the Law of the River provide background information for a discussion of interactions in the UC basin.

### **Resilience in the Study Area**

In order aid in the identification of a case study within the UC basin, the study area is further limited based on the primary question guiding this research is: *How do stakeholder groups enhance resilience in a social-ecological system?* This question implies that there is already resilience present in the Colorado River basin social-ecological system. Based on a similar analysis of interactions over fresh water at the international river basin scale (Wolf et al. 2003), where international treaties were found to be indicators of institutional capacity, interstate compacts, the intranational equivalent, are used to identify

a theoretically resilient watershed in the upper Colorado River basin. As discussed previously, institutional capacity increases social-ecological resilience. The upper San Juan basin has the most interstate compacts governing it, and is therefore, theoretically, the most resilient watershed in the region of analysis (Table 3.2; 3.3). While the content of these compacts is important, it is the collaboration between stakeholders that created them that is important for this step in reducing the size of the region of interest. As discussed previously, cooperation fosters institutional capacity, which in turn increases system resilience. The following section provides an analysis of interactions in the narrowed study area.

### **Interactions over Fresh Water in the Upper San Juan Basin**

The upper San Juan basin encompasses 8,900 km<sup>2</sup> (3,400 mi<sup>2</sup>), and portions of three states, Arizona, Colorado and New Mexico. Precipitation in the basin varies with the different climate types in the hydrologic unit. The major tributaries within the basin include the San Juan, Animas, Florida, La Plata, Los Pinos, and Mancos Rivers.

Table 3.2: The number of interstate compacts governing each watershed in the upper Colorado River basin. Source: Eidem 2008

<b>Watershed</b>	<b># Interstate Compacts</b>
Upper San Juan	4
Upper Green	3
Lower Green	3
White-Yampa	2
Colorado Headwaters	2
Gunnison	2
Upper Colorado - Dolores	2
Upper Colorado - Dirty Devil	2
Lower San Juan	2

Table 3.3 Interstate compacts governing the upper San Juan basin. Source: TFDD, U.S. Interstate Compacts.

<b>Compact Name</b>	<b>Signatory States</b>	<b>Year</b>
Animas-La Plata Compact	Colorado and New Mexico	1969
Colorado River Compact	Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming	1922
La Plata River Compact	Colorado and New Mexico	1922
Upper Colorado River Basin Compact	Arizona, Colorado, New Mexico, Utah, and Wyoming	1948



Of the events coded between 1970 and 2005, 561 were coded to the upper San Juan accounting unit (Table 3.4). This is the highest total within the upper Colorado River basin. Events of cooperation outnumbered those of conflict 247 to 193. Of these events, 60 were extreme cooperation (+4 and +5) as compared to 40 events of extreme conflict (-4 and -5). There were seven +5 events, and zero events coded to -5. Nearly 50% of interactions in the upper San Juan focused on infrastructure or water rights. Further, six of seven category +5 interactions coded to the watershed related to these issue types, five of which were water rights events.

Table 3.4: Events coded to the upper San Juan watershed by issue type, conflict, and cooperation. Data Source: WWIS UC Region Event Database

Issue Type	# Events	# Cooperation	# Conflict
Infrastructure	158	80	47
Water Rights	104	54	35
Water Quality	82	30	35
Drought	51	11	19
Intergovernmental	46	18	25
Conservation	37	19	8
Instream Use	31	12	10
Groundwater	23	11	4
Fish Passage	14	6	4
Transfer	11	4	6
Flooding	4	2	0
Invasive Species	0	0	0

Looking at weighted average intensities (Eidem 2008: 20) of events from the UC event database<sup>14</sup>, interactions over fresh water start out slightly conflictive, but are cooperative for most of the time period in the upper San Juan basin (Figure 3.4). Only two years on the graph, 1995 and 2002, were on average conflictive. As discussed previously, this is an indicator of institutional capacity in the upper San Juan basin.

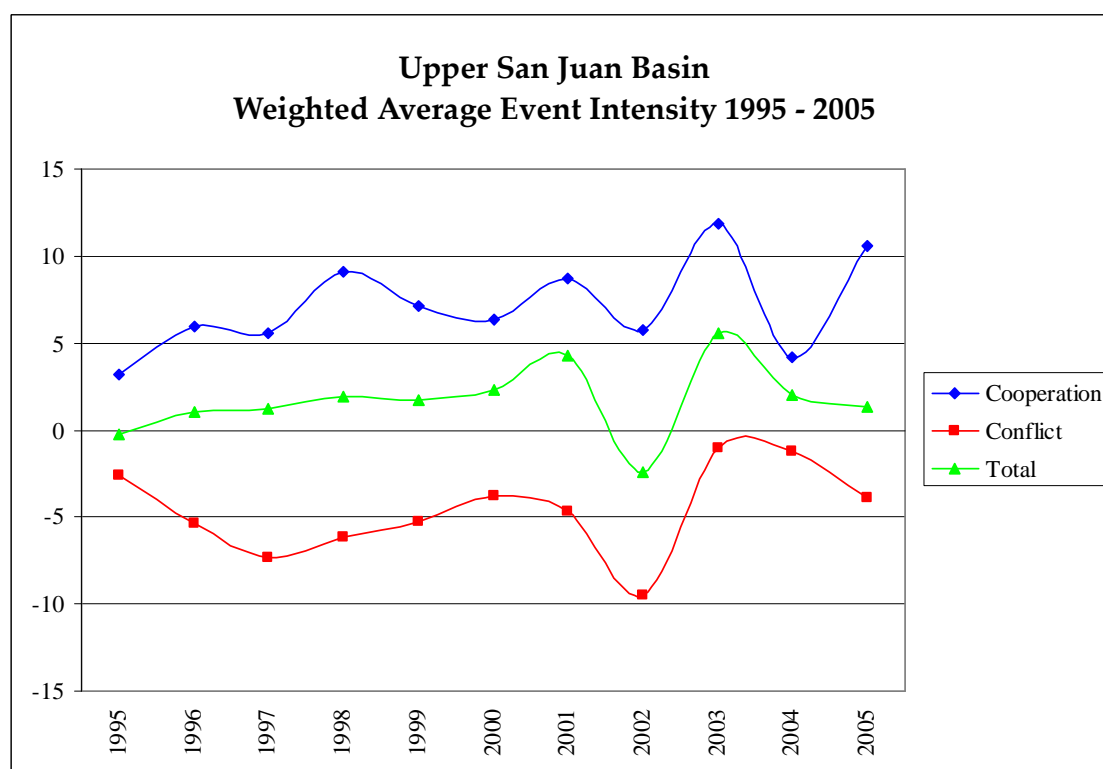


Figure 3.4: Weighted average intensities for events coded to the upper San Juan accounting unit between 1995 and 2005. n = 513. Data Source: UC Dbase

<sup>14</sup> Timelines created from the UC WWIS Event Database were started with 1995 data, due to the limited availability of online sources prior to this year. See Eidem 2008: 53-54 for more information.

In order to uncover outcomes produced by these interactions, a case study was selected from the basin. Chapter Four presents the Animas-La Plata Project as a case study for understanding how stakeholder groups enhance resilience in a social-ecological system, thus contributing to system sustainability. Using the UC WWIS event database along with information gleaned from the literature and informal oral history style interviews, outcomes resulting from a portion of interactions captured by the event database are discussed.

#### **CHAPTER 4: ANIMAS-LA PLATA: ENHANCING SOCIAL- ECOLOGICAL RESILIENCE IN A RUBE GOLDBERG WORLD**

*"We are co-designing our environment with nature or God, whichever you prescribe to."* - Jerome Delli Priscoli

Between 1970 and 2005, interactions in the upper San Juan basin were more often cooperative than conflictive, and tended to focus on issues of water rights and infrastructure. The issue types are not surprising given the history of the Colorado River. It has been dammed, diverted, and regulated in order to allow for the modification of the natural ecology to one more controlled for American settlements. The Animas-La Plata Project (ALP) is a part of this legacy, and a major institutional change to water resources management in the upper San Juan River basin. Conceived in the early development phase of the Colorado River basin, the project was initially planned to provide water for irrigation, generate hydroelectric power, provide flood control, and retain silt. The story of the ALP is a classic example of conflicting interests in the American West: planned dams and diversions, which would benefit citizens within the project boundaries, are challenged by naturalists representing endangered fish, all while Native American Tribes in the project region assert their right to water allocated to them by treaties in the late 19<sup>th</sup> century.

Conflict is not the only side of the story, however, as there are examples of extreme cooperation and compromise. As the story unfolds on a small scale, the events reflect broader societal shifts in attitude about the value of nature and human efforts to alter and control it. This chapter examines the stakeholder interactions that led to the construction of ALP, and answer the question: *What social-ecological outcome did it produce?*

The Animas-La Plata project history spans more than 50 years from its proposal to the completion of Ridges Dam. The project has been the center of major conflict and cooperation. A lot of people at the local, state, and federal level worked to keep the original project alive, kill it, or change its purpose. Many turning points occurred over the project's half century history. There are many differing perspectives on the project, and a turning point for cooperation may also be the starting point of tangential conflict, and vice versa. The adage "you can't please all of the people all of the time" is quite appropriate to the situation surrounding the ALP project and more generally water resources in the upper San Juan River basin.

### **Animas-La Plata**

The Animas-La Plata Project (ALP) was proposed in the 1940s as a

broad development plan for the Colorado River basin, and authorized by Congress in 1968. It was originally authorized as a multi-purpose project for irrigation, hydroelectric power generation, flood control, and silt retention. Following the authorization of the project, Colorado and New Mexico approved the Animas-La Plata Project Compact in 1969. Involving environmental interests, Native American water rights, municipal uses, and irrigation, the project has been the focus of debate since near the time of its authorization. The ALP links the major hydropolitical issues that are being experienced across the western United States: American Indian water rights, instream water rights, and traditional project-oriented uses. [For more information on the politics surrounding the ALP, see: Ingram 1990; Gosnell 2001; Hayes 2001; Pollack and McElroy 2001; Ellison 2009; and Ellison and Newmark 2010.]

#### *Major Animas-La Plata Turning Points<sup>15</sup>*

The ALP is a major institutional change to the upper San Juan basin. Ultimately, the project was constructed even with major challenges from

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<sup>15</sup> Sources for this section: USBR WWIS UC Event Database; USBR 1946; Reisner 1987; Pollack and McElroy 2001; USBR 2006; Ellison 2009; the Durango Herald 2009; and oral history style interviews conducted with key stakeholders.

opponents, albeit a scaled down version. [See Appendix IV for a detailed timeline of events.] The first challenge to the project came at the end of the Carter administration in late 1980, when all public works construction was put on hold. This put the future of the project in question, although Reisner notes that it was spared because of the potential for settling Native American water rights claims (Reisner 1987: 328), which is exactly what happened. In 1986, the project would get new life when the Colorado Ute Indian Water Rights Settlement was signed, which would ultimately ensure the construction of the ALP. This was ratified by Congress two years later. Also in 1986, local New Mexico governments signed a landmark agreement to collectively manage their share of ALP water, in order to fund increased local cost sharing requirements implemented by the Reagan administration. The San Juan Water Commission was created out of this collaborative effort. This is the highest form of cooperation (+5), unification of government power and responsibility. The resulting Joint Powers Agreement was the direct result of the ALP, and was noted by multiple stakeholders as a significant event in the history of the Animas-La Plata Project.

Two opinions from the USFWS would further influence the ALP. In 1990, it was determined the ALP would jeopardize the endangered fish in the

basin, the Colorado pikeminnow. No reasonable and prudent alternative was offered. In 1991, the agency offered a reasonable and prudent alternative to the project in its Final Biological Opinion. The Recovery Implementation Program that was included in the opinion was critical to the construction of ALP. The day after the opinion was released, a groundbreaking ceremony was held. Four months later, the Sierra Club Legal Defense Fund filed a lawsuit to stop construction. Here is another example of larger outside forces influencing local issues (Cronon 1991). Another lawsuit was filed in 1996, this time by proponents of the project against the EPA. They claimed that the agency was obstructing the implementation of the Ute Settlement Act.

That same year, a major step toward consensus was taken. Colorado Governor Roy Romer called a meeting of stakeholders to try and reach an agreement. The lawsuits were put on hold, and the meeting would lead to a scaled down version of the project, ALP-Lite, which was formally proposed by the Department of the Interior in 1998. Because of the reduction of the size of the ALP, the main beneficiaries of the original project, agricultural water users, were removed from the project. In 2001, the Commissioner of Reclamation approved construction to begin. In April 2009, the Durango Pumping Plant was started, and water storage commenced. The events surrounding the



Animas-La Plata Project provide another example of the struggle between stakeholders representing the conservationist philosophy and those representing the preservationist philosophy. The following is a synopsis of stakeholder input and thoughts on ALP collected from interviews.

*Stakeholder Thoughts on the Animas-La Plata Project*

The project brings out a range of opinions depending on which stakeholder group one talks with. Traditional Western water users, irrigation and power, favored the project as they would have been the primary beneficiaries. Many water user associations were formed with agreements signed for the cooperative management of water from the project. Multiple environmentalists said it was an “economic dog” from the beginning. In the 1980s and 1990s, because of the Endangered Species Act, the project was downsized to ALP-Lite. Water users, who were the original beneficiaries of the project, felt that their interests were ignored as the project was downsized. Native Americans benefitted greatly from the downsizing, as they became the primary beneficiaries. As one former federal government employee stated:

*The project became an Indian water rights project, and therefore, did not need to be economically feasible. The Animas-La Plata project was wrapped in an Indian blanket to gain approval. The project will go down as the Golden Fleece of all Golden Fleeces.*

In the 1990s, President Clinton, Secretary of the Interior Babbitt, the Southern Utes, and the Ute Mountain Utes began collaborating. Originally, the Clinton administration opposed the project, but backed it once it had been considerably scaled down. President George W. Bush too would sign on to the project. Utes were hired to build the Ridges Dam portion of the project with federal tax dollars. The workers also had to be trained in dam construction, which was viewed by some as a waste of time and money. The Utes wanted a settlement with a fixed quantity of water as opposed to a percentage. The Southern Ute Tribe, through federal reserved water rights, could take over a large share of Colorado and New Mexico water, which makes environmental groups unhappy, as they believe the water should be left in the channel. The project will also benefit the Navajo Nation by creating a new municipal water supply line. Environmentalists and water users see the project as a cash generating mechanism for Native Americans. As one environmentalist summed up her vision of the future of ALP water:

*Ultimately, there is no market for the Ridges water. As oil and gas revenues decline, the price of water will increase. The tribe will market this water to Las Vegas, Los Angeles, Phoenix, whoever is the highest bidder, and will become a broker of water. The tribe doesn't need money, but is financially smart.*

There was still a lot of opposition to the project in 2008, even though it was nearly operational. The environmental community sees itself as the watchdog of the USBR, as it feels the agency has consistently ignored instream needs for power and water development. Water user groups are quick to point out that a "cottage industry" formed around opposition to the ALP project. An employee of a water user association stated, "Opposing the ALP was their [environmentalists] reason for waking up in the morning." Despite the perceived favoritism for Native American interests, many Utes still feel they were robbed when the project was downsized.

Each party at the table has an objective, and as one regional water resources manager said, "represents the interests of his or her organization and sticks to this position." This sentiment was echoed by other interview subjects who felt that stakeholder groups are focused on their interests, and conflict occurs when a group believes it has been wronged. It was also suggested that interactions between stakeholders influence the potential for future interactions. Some felt that parties who have been involved in a conflict

are less likely to cooperate with an opponent in the future. Further, there is also a tendency for groups to cooperate with those whom they have cooperated in the past. Local water managers are caught in the middle. Much of the deliberation took place in Washington D.C., which is out of the jurisdiction of those who deal with conflict daily. USBR employees in area offices are left with the task of mopping up the mess. This puts them in a difficult situation, especially when some stakeholder groups do not fully trust the USBR. In the end, multiple interview subjects indicated that a history of cooperation exists in the upper San Juan basin, which could help to build trust and collaboration. The next section discusses the social-ecological outcome produced by the ALP compromise.

### **Outcome: Enhanced Social-Ecological Resilience**

While there has been much opposition to the ALP, when looking at the events leading to its construction from a social-ecological systems perspective, the project is a milestone in resilience building. As society in the region depends on the river and constructed infrastructure, an adaptive management approach becomes necessary for achieving a sustainable future. Such an approach requires the use of institutions and technology to meet the needs of

both nature and society, and to remedy conflicts that began long before the Animas-La Plata Project was proposed to Congress. This is especially true when the Law of the River is entrenched in the region, and there are such divergent interests competing for limited fresh water supplies. The following sections discuss the facets of social-ecological resilience that came out of the interactions leading to the construction of the ALP, broken down by the project's three main stakeholder groups other than the USBR.

#### *Native American Water Rights*

This issue is the most significant component of resilience to come out of ALP. As part of the settlement with the U.S. government, tribes relinquished claims to an 1868 priority date for water rights in return for physical water stored and transported via ALP, and gave up the right to sue the government in the future over these claims. This settles conflicts that were hanging over the basin for well over a century, and frees up time and resources to pursue other avenues for creating a sustainable water future for the region.

#### *Endangered Species*

Although there were concerns about the impacts of ALP on endangered

species in the basin, the project gives fish in the region a chance at survival. Had the ALP not been constructed, the Colorado pikeminnow likely "would be unable to survive in the San Juan River if no further action were taken to recover the fish" (Pollack and McElroy 2001: 645). The ALP compromise included "powerful tools for protecting and recovering the native fish community" (Pollack and McElroy 2001: 645). These are: (1) limitations on depletions by the ALP, (2) seven years of research on fish in the San Juan River, (3) reoperation of Navajo Dam based on guidelines developed by the biologists conducting the research, (4) reoperation of Navajo Dam to mimic natural flows for the life of the ALP, and (5) protection of these flows by government entities for the benefit of native fish, and a USBR commitment to the San Juan Recovery Implementation Program (Pollack and McElroy 2001: 645-647).

After the efforts to improve the habitat of the Colorado pikeminnow were implemented, USFWS biologists acknowledged that the San Juan Recovery Implementation Program has "(1) brought otherwise disparate interests together; (2) provided real water to work with for the protection of the fish and other species; (3) given legitimacy to the concept that fish and other species deserve water for survival; and (4) has provided a steady source

of funding for environmental protection. In the end, biologists contend that it was the Bureau's agreement to spill water from Navajo Reservoir to mimic the natural hydrograph that produced the necessary conditions for program success" (Ellison 2009: 385).

#### *Non-Indian Water Users*

When negotiating settlements with the federal government, the Tribes did not want to deprive non-Indian water users in the region "of the water rights that they have used for generations", and viewed ALP as the only way to accomplish this (Pollack and McElroy 2001: 641). This consideration helps to create a base for future collaboration which will be required to achieve sustainability in the basin. This also allows municipalities that were original project beneficiaries to plan for future growth without fear of losing water supplies to an 1868 priority date. The changes in cost-sharing requirements forced municipalities to relinquish sovereignty over Colorado River water rights, and share water through a regional authority. This unification helps to prevent future conflicts over fresh water in the basin, thus further increasing social-ecological resilience.

## Summary

Without a discussion of the interactions surrounding the ALP, it is just another project on the Colorado River that alters the natural hydrology of the basin. However, the project represents the culmination of intense debate, deliberation, and ultimately compromise between stakeholder groups that will help to create a sustainable social-ecological system by remedying unsustainable aspects of the system. Environmental stakeholders succeeded in reducing the size of the project, and established instream flows for native fish as a management priority in the basin. Municipal water users in the upper basin secured their share of the 1922 Colorado River Compact, and created regional authorities to govern the water equitably amongst them for future use. Native Americans secured a physical supply of fresh water promised them in 1868. These accomplishments are monumental, and can be viewed as a successful example of how technology and institutions can be used together to increase sustainability.

Social-ecological resilience is not a straight forward concept, and requires collaboration and compromise based on local conditions. The ALP and all of the institutional changes surrounding it enhance resilience in the upper San Juan basin, which in turn enhances social-ecological resilience in



the Colorado River basin, of which it is a component. This finding leads to a discussion of overall conclusions in the next chapter.

## CHAPTER 5: CONCLUSIONS

*"Competition has been shown to be useful up to a certain point and no further, but cooperation, which is the thing we must strive for today, begins where competition leaves off."* - Franklin D. Roosevelt

The previous chapters have presented the concept of social-ecological systems and resilience. Understanding the interconnections and feedbacks between nature and society is essential if we are to achieve sustainability. This is especially true in the face of perturbations, such as climate change, that could significantly change the earth system. It would be ideal if a silver bullet were discovered to solve the problems created by humans extracting resources from the system, and discharging pollutants into it, however this is wishful thinking. Instead, understanding component systems and how they relate to each other can provide insight into the larger system. The discussion of the Colorado River basin social-ecological system presented in this dissertation provides an example of such a component system, and a connecting point for future studies. This chapter draws from this discussion to answer the central research question: *How do stakeholder groups enhance resilience in a social-ecological system?*

The technological-fix to allow American settlement in the arid West

forever changed the region's ecology. However, it is not simply a technological problem, as none of the infrastructure would have been constructed without the institutional-fix implemented to prevent conflict, the Prior Appropriations doctrine. First-in-time, first-in-right, use-it-or-lose-it, and the allowance out-of-stream diversions are the tenants of the doctrine, and provide the foundation for all the Colorado River is today. Despite all of the baggage in the basin, there is a history of conflictive and cooperative interactions between divergent stakeholder groups that have resulted in increased social-ecological resilience.

Focusing on individual stakeholder groups' interests hinders resilience building when there is no willingness to compromise. This creates a cycle of conflict that makes systems more vulnerable. The complexities of the present make it irrational to look at the Colorado River with tunnel vision on a single issue. Instead, stakeholder groups can only hope to change the trajectory of the leviathan as it moves forward in time. Compromise is the only vehicle for creating a sustainable society. The Animas-La Plata project provides a perfect example of how stakeholders build resilience through cooperation and conflict. The construction of the project was the only way to move forward, thus making the social-ecological system more resilient.

Environmental interest groups calling for no new infrastructure were focused on instream flows without considering the social aspect of the system at the present time. They ignored the broader societal benefits to the settlement of Native American water rights claims, which were settled without protracted litigation through the construction of ALP (Pollack and McElroy 2001). Tribes were promised by treaty a priority date of 1868 to all waters flowing through their lands, which equates to the entire flow of the San Juan River. This could have turned the cities in the region into ghost towns. Now that this issue is settled, stakeholders in the basin can turn their focus to other issues, and enhance other components of resilience.

While the focus on preserving some of the last remaining natural flows in the basin at the cost of congressionally authorized infrastructure is not without merit, it lacks vision for the future of the social-ecological system as a whole. Those who opposed the construction of the ALP project solely because it increases infrastructure in the upper San Juan basin fall into the panacea problem of the "blueprint approach to governance" (Ostrom and Cox 2010: 452). They battled against another example of panacea thinking, dam the rivers so no water is wasted (USBR 1946). This management strategy created the problem for all of the fish in the first place, including the endangered

Colorado pikeminnow and razorback sucker. This is counterproductive in the face of a changing climate, which requires real solutions for achieving sustainability in our complex coupled world in the near term.

Having said this, it is important not to forget history in the case of Animas-La Plata. The root of this conflict is the fight between those seeking to preserve nature and those seeking to control it for human use. When looking at the history of the Colorado River basin, there was a push for westward expansion, driven by the idea that a drop of fresh water reaching the ocean is a wasted drop. Following the conservation philosophy of Gifford Pinchot, maintaining the productive capacity of this water resource (Cutter and Renwick1999: 40) became the priority, which provided the impetus to build dams and diversions under the auspices of the Prior Appropriations Doctrine.

This went virtually unchallenged until the 1960s, when the large fish eradication program in the Green River led the Secretary of the Interior to issue a directive aimed at preventing such ecological catastrophes in the future. This forced the preservationist philosophy into a well-oiled political machine determined to build as much infrastructure on the river as possible. When the Sierra Club began challenging projects on the Colorado, and getting results, those with power attempted to stop the rebellion. As noted by

Worster, "[b]ureaucracies, like natural organisms, have an intense desire to survive and reproduce themselves, to extend their range and influence even where they are beset by hostile forces" (Worster 1985: 238).

Groups guided by the preservationist philosophy were gaining ground in a race in which those following the conservationist philosophy had a 60-year lead. The development of infrastructure on the Colorado River continued, but nature was becoming a consideration. Major environmental legislation (e.g. the Endangered Species Act) soon followed, and Presidential support for the status quo began to wane, thus giving preservationists more power. Projects were put on the shelf, or cancelled because of the changes that were occurring. The Animas-La Plata project, which was conceived during the early planning phases of Colorado River development, however, could not be killed because of the rights of Native Americans ignored for decades. As discussed previously, the United States has obligations, both legal and moral, to Tribes in the Colorado River basin. The preservationists would ultimately get ALP reduced in size, but it was constructed to fulfill these rights, ultimately enhancing social-ecological resilience.

Those advocating for preservation may have lost the Animas-La Plata battle, as the project was ultimately constructed. However, as discussed in the

previous chapter, the changes to ALP and accompanying requirements for fostering more natural flows are a turning point in the war between preservationists and conservationists. The Animas-La Plata compromise legitimized the concept of water for non-human species, and provides an example for using the river regulating technology for mimicking natural conditions. The preservationists were successful in changing the rules governing the system to incorporate nature, which also enhances resilience.

#### *Conflict, Cooperation, and Resilience*

Looking at the turning points in the ALP conflict through the conservationists versus preservationists lens sheds new light on the relationship between conflict, cooperation, and resilience. Looking first at conflict, it has been suggested that it has a before-and-after sort of relationship with resilience. Systems lacking resilience foster conflict (Wolf et al. 2003). On the other hand, conflict inhibits social learning, thus reducing resilience (Galaz 2005). Moving to cooperation, resilience can be enhanced when stakeholder groups work together, as it builds institutional capacity (e.g. signing of interstate compacts and formation of river basin organizations). The Animas-La Plata compromise adds to this discussion.

Resilience within a social-ecological system is heavily influenced by interactions between people. These interactions occur in an existing institutional setting, which might need adjustment from time to time. This is the case in the Colorado River basin. Institutions were created with the conservationist philosophy in mind, and based on the Prior Appropriations Doctrine. These institutions govern the interactions over its water, and led to the most heavily developed river in the United States (Seligman 2006). All of this infrastructure devastated the ecology of the river system, thus reducing its resilience. This suggests that cooperation and institutional capacity building can lead to a decrease in social-ecological resilience, when institutions only focus on the social aspect of the system.

Even though cooperation might create institutional capacity in the social system, it might leave the ecological system vulnerable to perturbations. The only way to rectify this is sometimes through conflict. This suggests an additional relationship between conflict and resilience. In the case of the Animas-La Plata project, preservationists' only option for changing the institutional setting to include nature was conflict. Compromise ultimately won the day, but only after protest. By establishing nature as part of the institutional setting, social-ecological resilience is increased.



So, how do stakeholder groups enhance resilience in a social-ecological system? Essentially, they interact with each other and try to reconcile their differences. These interactions are governed by present circumstances, but are rooted in interactions of the past. If a conflict is not resolved, or if a stakeholder group is left out of the decision-making process, institutions created in the future could be undermined by it. Conflict will persist until the issue is resolved, which becomes increasingly difficult as more time progresses, and new institutions are created. As time passes, society evolves based on the institutional setting. If a conflict remains unresolved for an extended period of time, and reemerges, any settlement could make the evolved society more vulnerable, as it has developed on a different timeline. The point is, social-ecological systems are not static, and conflicts arising should be resolved before the system evolves and new layers of complexity are added.

Enhancing social-ecological resilience, including improving habitat, requires the consideration and use of a variety of strategies, as resilience comes in many forms: material, social, cultural, ecological, and intellectual (Kofinas and Chapin 2009: 66). This is evidenced in the upper San Juan basin by the favorable response of the endangered Colorado pikeminnow to

spillages from Navajo Dam, required as part of the ALP compromise (Ellison 2009). Because no two rivers are the same (White 1957), infrastructure might not be the best solution in another basin experiencing a similar problem.

Building resilience requires the consideration of local conditions and institutional settings.

Society has always been rooted in nature, but we have manufactured new relationships while attempting to control some of its processes. The resulting complicated social-ecological systems (Worster 1985; Fiege 1999) are a mix of natural systems, technology, and institutions. Our actions have reduced the resilience of natural systems, in turn making society more vulnerable to changes, be they social, political, or environmental (Adger 2000). “System resilience refers to the amount of change a system can undergo and still retain the same controls on function and structure while maintaining options to develop” (Nelson et al. 2007: 398). We have created a tangled web of both technological and institutional fixes, which will require creative and adaptive thinking to unravel. Institutions should not only be able to respond to perturbations, but also be able to plan for a desired system state (Wolf 2005; Nelson et al. 2007). In many cases, humans have invested resources, physical and/or institutional, to deal with internal and external disturbances (Anderies

et al. 2004).

While an institutional approach to solving water problems has been advocated (Gleick 2002), where appropriate, the utilization of existing technology in new ways, as was done in the upper San Juan basin, will help to achieve the long-term goal of sustainable social-ecological systems (Kofinas and Chapin 2009). Researchers and policy makers should avoid panacea thinking, and focus on system components and adaptive management. Local conditions and the views of multiple stakeholder groups should be considered in order to help reduce the potential for future conflicts (Bowonder 1987). Out of these small studies come larger comparisons and analyses of interrelations between them, which will ultimately help in understanding the entire earth system. Understanding how the different component systems relate to each other will help to foster sustainability in the face of future uncertainty.

This dissertation analyzes social-ecological resilience in the Colorado River basin with fresh water as the focus. The methods employed could be used to decompose any river basin in the world, or any other user defined region of interest. Further it is not limited to water resources. Social-ecological systems contain webs of different resources and stakeholders. Whatever the resource, and wherever the case, interactions and turning points

in history can she light onto the roots of conflict, and how resilience is enhanced.

Ostrom's framework (2007) is a good starting point for studying complex social-ecological systems, especially for geographers. In her description of the framework, the term "spatial" is used throughout the text, illustrating the importance of the concept when studying these systems. This dissertation illustrates that when coupled with an event database of interactions, case studies can be highlighted from large regions for more in-depth analysis of the historical and cultural components of the system in order to understand the interactions between resource users and resulting outcomes. The inclusion of a temporal component provides insight into the history behind current events and conditions (Russell 1997).

The event database approach used in this dissertation is useful for a preliminary scoping of an area of interest. There are limitations to the data, including the lack of electronic versions of historical documents. From the perspective of a manager or policy-maker trying to minimize conflict, this could be problematic. The seeds of conflict may be planted many years before the actual event occurs. As one water manager stated after reviewing preliminary results of the UC Region analysis, "You've got an interesting

study, but it is useless for me. I'm dealing with conflict today that started in the 1960s, before the beginning of your time frame." The example of the Colorado River basin supports this statement. Those involved in natural resources policy-making need to understand the history of a region before making decisions. Time constraints likely would limit one's ability to conduct archival research and the like. Instead, policy-makers should open lines of communication with as many stakeholder groups as possible in order to get a sense of what is important to them, and to learn about the history of a region. Understanding how people interact over resources through time could aid in crafting institutions that could make the earth system more resilient.

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## APPENDICES

### Appendix I

The event intensity and issue type classifications used to code events for this research.

- Types of actions used in the conflict-cooperation scale in detail

Classification		Included Actions	Theme
-5	Hostility	Protests, personal threats, vandalism, private citizen shooting, and arrests. Police forces called out in small numbers (arrests) and violent instances involving private citizens causing injury, destruction, or death. Construction of water project against major stakeholders wishes on small (local) scale.	Small scale acts of police force, violence, and threats
-4	Litigation	Litigation- filing and appeals, appeal of administrative actions or permit denials. Does NOT include judicial rulings. Dissolution of agency or management groups. Formal filing of protest of agreements, creation of opposition groups (needs two events: one conflictive and one cooperative)	Judicial intervention or Management group dissolution.
-3	Dispute	Halting negotiations, refusal to be involved or to include other stakeholders in negotiations or settlements. Regulatory violations- illegal water withdrawals. Regulatory enforcement actions, fines. Permit application or proposal denials from authorities. Expressed intent to litigate, impose economic sanctions and other violent threats.	Cooperative group meltdown or authoritative regulatory action.

-2	Disagreement	Official refusal of proposed settlements or negotiations, threat to halt negotiations. Negotiations may fail, but without a complete withdrawal from them. Withdrawal of third party support--governmental, monetary or figuratively, and petitions, bill blocking. Other request denials.	Roadblocks or temporary failure of settlement or project progress.
-1	Difference	General statements of disapproval or opposition including Op-Ed, fact contention, report or findings review, preliminary refusal of proposals or settlements and warnings. Delay in negotiations or vote, and stakeholder exclusion from input.	Voicing opinions of opposition, but not in enough force to achieve project blockage.
0	Neutral or Insignificant	Indifferent statements, no comment statements. Court ruling, court or congressional testimony, congressional hearing, and fact clarification.	Events have no major effect on party interactions. Does not decrease nor increase conflictive intensity of interaction.
1	Similarity	General statements of approval or agreement including Op-Ed, fact agreement, preliminary approval of proposals, actions or bills. Inclusion of stakeholder input or review, following voluntary guidelines, court-mandated negotiations. Announcements including project or institution goals or policies and project proposals, research, and calls for more research	Voicing opinions of approval, but not with enough force to make major forward moves toward resolution.

2	Agreement	Acceptance of a preliminary proposal or settlement, calls for negotiation or mediation sessions. Third party support such as governmental or monetary assistance. Apologizing for past actions, meetings that are not for settlement or negotiations, dropping project opposition. Information release upon request, lawyer-recommended settlement acceptance.	Progress in stakeholder agreements and minor project support.
3	Assent	Agreeing to participate in and stakeholder inclusion in settlements and negotiations, preliminary settlement and negotiation agreement, resuming negotiations. Agreement to fix regulatory violations, basic water right and other permit approvals by an authoritative body. Creating forums. Preliminary settlement and negotiation agreement (still need official approval)	Preliminary agreement to settlement and regulatory compliance.
4	Cooperative Management	Out of court or negotiation agreement reached, bill passage; transfer of management-- including sales and leases. Formation of management groups across political lines, formation of advocacy groups, cooperative projects for watershed management, irrigation.	Legally binding cooperation actions like regulation approval and lawsuit settlements.
5	Formal Agreements	Compacts and official agreements signed or ratified between states, municipalities or nations. Formal signing of document, merger of private sector or unification of small scale (local) governmental body.	Major Alliance: Compacts and management or authorities group unification

- Definitions of issue types used in WWIS and a comparison to TFDD issue types.

<b>Broad Issue</b>	<b>TFDD Issue</b>	<b>WWIS Issue</b>	<b>WWIS Definition</b>
Supply	Water Quality	Water Quality	Surface or ground water does not meet local, state or federal standards for municipal use or endangered species regulations or alteration of those standards. May be due to numerous activities including but not limited to: violation of NPDES permit, discharge of toxic or hazardous waste or salt water intrusion. Includes stakeholder concern over potential degradation of water quality due to any activity. Includes fluoride additions to municipal water supply.
Supply	Water Quantity	Conservation	Water conservation measures not fully implemented. Includes agriculture, municipal, industrial uses and conveyance methods, and water usage limitations.
Supply	Water Quantity	Drought	Past, current, or future

			drought implications on water supply.
Supply	Water Quantity	Ground water	Withdrawing too much ground water too quickly thereby not allowing recharge of aquifer or other substantial water table lowering. Ground water use depletes surface water flows, or leads to land subsidence. Creation of new ground water supply source.
Supply	Infrastructure/ Development And Hydro-power/ Hydro-electricity	Infrastructur e	Water conveyance, storage, or treatment non-existent, in disrepair, inadequate or not predicted to meet future needs due to agricultural or municipal/population growth. Creating, expanding, and repairing these systems. New surface water source development and public works project funding. Includes conjunctive storage of excess surface water in ground water cavities. Also include issues over storm water and flood protection.
Supply	Infrastructure/ Development And Hydro-power/ Hydro-electricity	Fish Passage	Dam/hydropower facilities block fish passage or inhibit fish survival (but not in relation to water quality). Related actions include fish ladders, dam removal, and bypasses which may affect water supply.

Supply	Flood Control/ Relief	Flood	Reservoir levels decreased for future storage. Implies loss of water for future use and bypassed electrical generation.
Supply	n/a	Invasive Species	A non-agricultural species, invasive, exotic or native (e.g. Cottonwood regeneration) that are detrimental to water supply. Flora with high evapotranspiration rates that when removed could lead to higher flows or fauna with characteristics that impair water supply.
Allocation	Water Quantity	Water Rights	Water right in dispute or in litigation and basin adjudication. Also includes halts on development without a required water right and other issues related to property rights. Includes Native American claims to water and reactions to their claims. Includes lease and sale of water rights for consumptive use.
Allocation	Water Quantity	Instream	River flows/lake levels are too low to support threatened or endangered species due to high consumptive uses. Governmental institutions requiring higher instream flows, and other stakeholder



			groups obtaining/transferring water rights to instream uses. Includes water to comply with the Wild and Scenic Rivers Act.
Allocation	Joint Management and Technical Cooperation/ Assistance	Intergovernmental	Disputes over allocation of water among international, federal, state, local institutions, and other stakeholder groups and private citizens; including between Upper and Lower Colorado basins and other upstream/downstream entities. Includes allocations of diversions from federal projects (i.e. BOR reservoirs), allocation disputes from existing out-of-basin transfers and citizen or stakeholder voting. Also includes jurisdictional and management issues.
Allocation	Joint Management and Technical Cooperation/ Assistance	Transfers	Either local water will be transferred out of basin or an area basin relies on out-of-basin water-- includes both givers and receivers of water. A stakeholder searching to create an out-of-basin water supply or alter the amount of current out-of-basin supply. Involved stakeholders may refuse or agree to alter water quantity. (The dispute over

			the allocation of that water would be included in Intergovernmental. If the amount increases and there is a need or desire to increase storage it would be included in Infrastructure).
Allocation	Navigation	Navigation	Canal and lock proposal, maintenance, and building. Flow requirements for navigation.

## Appendix II

Portions of the USBR Report to Congress on the Development of the Colorado River (USBR 1946). The text provides insight into the mindset of the USBR when proposing infrastructure projects in the Colorado basin.

### *Physical Characteristics*

*The upper or northern portion of the Colorado River Basin in Wyoming and Colorado is a mountainous plateau, 5,000 to 8,000 feet in altitude, marked by broad rolling valleys, deep canyons, and intersecting mountain ranges. Hundreds of peaks in these mountain chains rise to more than 13,000 feet above sea level and many exceed 14,000 feet. There are many picturesque mountain lakes in these headwater sections. The southern portion of the basin is studded with rugged mountain peaks interspersed with broad, level, alluvial valleys and rolling plateaus.*

*The main stream and its principal tributaries in Colorado flow, for the most part, in deep canyons. The Green River, primary tributary of the Colorado River, flows in similar canyons in Wyoming, Colorado, and Utah and its chief tributaries, Yampa and White Rivers from the east, and Duchesne, Price, and San Rafael Rivers from the west, flow through rolling hills and canyons to reach the Green.*

*The San Juan River, a large tributary of the Colorado River from the east, drains mountain slopes and plateaus in southwestern Colorado, northwestern New Mexico, and northern Arizona and flows through a formidable canyon in southeastern Utah, joining the Colorado in Glen Canyon. The Glen Canyon section of the main stream and tributaries thereto are in deep canyons, draining a series of plateaus and mesas.*

*Below Glen Canyon is the awesome Grand Canyon where the Colorado has carved an unparalleled chasm. This canyon yawns above an inner gorge, rising in gigantic cliff-steps to the Colorado plateau, a mile above the stream bed. This great central plateau is a rolling expanse of brightly hued crags and cliffs, huge canyons, painted deserts, and extensive almost*

*inaccessible barren areas. Elevations on the mesas of the plateau section generally range from 4,000 to 6,000 feet. The principal tributaries in this section are the Little Colorado River on the east and the Virgin River on the west.*

*Emerging from the canyon country at the southeast corner of Nevada, the Colorado River courses through broad valleys bordered by mesas. The Gila River, main tributary in this section, rises in the mountainous region of southwestern New Mexico and drains most of southern Arizona.*

*Southwest of the Gila Basin the Colorado River continues through its great delta area to the Gulf of California (USBR 1946, 31).*

### *Geologic History*

*Rocks of all ages from those of the Archean Age, the oldest known geological period, to the recent alluvial deposits, including igneous, sedimentary, and metamorphic types, are found in the Colorado River Basin. The high Rocky Mountains which dominate the topography of the region are composed of granite, schists, gneisses, lava, and sharply-folded sedimentary rocks. Many periods of deposition and erosion have played a part in the present structure of these mountains. Ancient seas settled in the basin countless times, depositing beds of limestone, sandstone, and shale. Each time crustal forces of the earth elevated the region above sea level, erosion again began cutting them down.*

*During a relatively late geological period, called the Pleistocene or Glacial Age, glaciers occupied the high watershed of all the mountains in Colorado, Wyoming, and Utah. The Rocky Mountains in Colorado, the Wind River Mountains in Wyoming, and the Uinta and Wasatch Mountains in Utah, all have been materially affected topographically by these ancient bodies of ice.*

*In contrast to the folded rocks of the mountains which fringe the basin, the plateau country of southwestern Wyoming, eastern Utah, and*

*northern Arizona is composed principally of horizontal strata of sedimentary rocks. Many formations of hard sandstone and limestone separated by softer shale, often highly colored, have resulted in topographic and geological formations found in no other locality.*

*Slow but constant elevation of the land area has allowed the Colorado River and its tributaries to cut narrow deep canyons into the flat-topped mesas. This unique type of erosion reaches its culmination in the famous Grand Canyon. Here a broad area has been arched several thousand feet higher than the surrounding country, but the horizontal structure of the rock largely has been maintained. The river has cut through all the sedimentary rocks down to the oldest Archean granites.*

*The topography of the southern part of the basin is characterized by broad flat valleys separated by low ranges. The valleys are filled by large accumulations of alluvial gravels which all but bury the mountains. The ranges are mainly of igneous origin with granites and lava predominating. These rocks are part of the oldest known formation, the younger sedimentary rocks having been removed by erosion. Many mountain ranges are undoubtedly buried beneath the detrital material.*

*The present Gulf of California once extended much farther north than at present and filled what is now the Imperial Valley of California. The silt of the river was distributed far and wide in this sea which was partially cut off from the broad Pacific by a chain of islands. During and after the Glacial Period, when precipitation is believed to have reached its peak, the river had its greatest volume and transporting power. The stream then, as now, laden with the silts from the slopes of the Rocky Mountains and the Grand Canyon of Arizona, gradually built up a great delta which finally completely cut off a vast inland sea of brackish water. This ancient sea, known by geologists as Lake Cahuilla, covered an area of about 2,100 square miles (USBR 1946, 39).*

### *Climate*

*Climatologically, the Colorado River Basin has the extremes of year-round snow cover and heavy precipitation on the high peaks of the Rockies,*

*snow-capped 8 to 10 months a year, and truly desert conditions with very little rain in the southern area around Yuma, Ariz. The wide range of climate in the basin is caused largely by differences in both altitude and latitude and to a lesser extent by topographic features.*

*Extremes of temperatures in the basin range from 50° below zero to 130° above zero. The northern portion of the basin is characterized by short, warm summers and long, cold winters, many mountain areas being blanketed by deep snow all winter. A peculiar climatic condition exists in the Grand division in Colorado where high mountains tend to divert east-bound storms either to the north or to the south over lower passes in the Continental Divide. The southern portion of the basin has long hot summers, practically continuous sunshine and almost complete absence of freezing temperatures. Summer heat is not so oppressive as temperatures would indicate because of the low humidity. Summer nights, typical of the desert, are seldom too warm for comfort. The little Colorado River Basin is noted for its high percentage of sunshine—about 80 percent of the total possible.*

*The entire basin is arid except in the extreme high altitudes of the headwater areas. Rainfall is insufficient for the profitable production of crops without irrigation... Along the Mexican border the annual precipitation averages only about 2.5 inches while in the higher mountains in Colorado, Wyoming, and Utah, the average is around 40 inches. In the northern part of the basin most precipitation falls in the form of winter snows and spring rains. Summer storms are infrequent but sometimes of cloudburst intensity in localized areas. Winds of high velocity are common in some sections. In the more arid southern portion the principal rainy season is in the winter months with occasional localized cloudbursts in the summer and fall...*

*The length of growing season varies from about 80 days in the higher elevations of the northern mountainous sections to year-round in the lower semitropical southern areas. In the northern sections hailstorms and late spring and early fall frosts occasionally damage crops. Although the growing season of the higher agricultural areas in the Grand division is short, air drainage in localized sections along the foothills of the lower valleys is favorable for growing of such fruits as peaches, pears, cherries,*

*apricots, and berries. Because of the long growing season in the lower regions of the southern portion of the basin double-cropping is commonly practiced in the principal farming districts. Crops in some southern areas are seldom damaged by frost, by hail and by warm, dry summer winds (USBR 1946, 41).*

### *Virgin Conditions*

*The Colorado River, draining 242,000 square miles in this country, has the largest watershed of any stream in the United States outside of the Mississippi River Basin. Beginning high on the Continental Divide it empties into the Gulf of California.*

*Rain and snow fall in abundance on the Rocky Mountains rimming the upper part of the Colorado River Basin, but great expanses in the lower areas are comparatively dry. The average annual precipitation for the entire drainage area of less than 15 inches is near the lowest for the major river basins of America. Nearly 90 percent of the moisture that falls returns again to the atmosphere through evaporation, and only about 10 percent flows in the river channel. Yet about 10 percent of the scanty precipitation on so vast an area makes up the flow of the mighty Colorado River. The river grows almost to its full size from contributions of tributaries in the upper half of its drainage area, above Lee Ferry in Arizona. Below that only minor contributions are made by the Little Colorado and Virgin Rivers, and between Black Canyon (site of Boulder Dam) and the entry of the Gila River near the Mexican border inflow is insufficient to offset evaporation losses in the desert region...*

*Before man built the existing structures providing partial river control, seasonal flows of all streams fluctuated greatly. In the spring the Colorado River fed by melting snow was a mighty, raging torrent, reaching flood peaks of 250,000 second-feet<sup>16</sup> or more. Below the canyon section it overflowed its banks and inundated the country for miles around. In summer in years of low run-off its flow became a mere trickle by comparison,*

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<sup>16</sup> cubic feet per second (CFS)

sometimes dropping to 2,500 second-feet. The only sustained summer flow of most tributaries was the outflow from numerous mountain lakes fed by the melting of perpetual snow banks. The northern tributaries had greater sustained flows than those in the southern region, but they too were subject to great fluctuations.

The flow of the river also fluctuated greatly from year to year. At Lee Ferry, under virgin conditions, annual flows probably ranged from as little as 5,500,000 acre-feet. Flows of tributary streams were characterized by even greater variations, especially those of the lower region. Under virgin conditions the average annual flow of the Gila near Phoenix is estimated to have been 2,282,000 acre-feet, of which probably only about 1,270,000 acre-feet reached the Colorado because of losses in the lower river area.

The creeks and streams at higher elevations generally bring clear, pure water into the main Colorado River, although they become roily during the spring run-off. Soluble salts in quantities damaging to plant growth occur in isolated tributaries but the injurious effects are local and generally unimportant. Diluted by larger streams of the system, these soluble salts of tributary streams cease to be harmful...

Tributaries entering the middle and lower sections of the Colorado River, notably the San Juan, Little Colorado, and Virgin Rivers, have highly erosive watersheds and hence contribute great quantities of silt to the main stream. At normal flow stages little silt is carried, but more is picked up in spring and early summer when flows become high and turbulent. Occasional summer cloudbursts cut into unstable earth sections, flushing large amounts of mud and silt into the streams (USBR 1946, 55-56).

#### *Native Plant and Animal Life*

The flora and fauna of the Colorado River Basin are many and varied, including typical desert and alpine species. The higher areas are covered with forests of pine, fir, spruce, and silver-stemmed aspens, broken by small glades and mountain meadows. Pinon and juniper trees, interspersed with scrub oak, mountain mahogany, rabbit brush, bunch grasses and similar plants grow in the intermediate elevations of the mesa



*and plateau regions. Scattered cottonwoods and chokecherries grow in the canyons with the cliff rose, the redbud, and blue columbine. A profusion of wild flowers carpet many mountain "parks." In the lower region large areas are almost completely devoid of plant life while other sections are sprinkled with desert shrubs, Joshua trees, other Yucca plants, and saguaro cacti, some of the latter giant plants reaching 40 feet in height. Occasionally cottonwoods or desert willows are found along desert streams with mesquite and creosote bush or catclaw and paloverde.*

*The Colorado River Basin is the natural habitat of the bighorn sheep, ptarmigan, and wild turkey. Deer, elk, and antelope are found in the forested and more primitive areas. Mountain lions, wild cats, lynx, and other predatory animals are fairly common in remote areas. Coyotes inhabit the plains country where they prey upon gophers, cottontails, jackrabbits, and other smaller mammals. Fur-bearing animals in the mountains include beaver, fox, badger, ermine, muskrat, skunk, and mink. Ducks, geese, snipe, white-wing pigeons, quail, dove, and other birds are numerous. Snakes and lizards with other reptiles and amphibians are frequently found in the desert areas (USBR 1946, 39).*

### *Primitive Peoples*

*Archeological evidence indicates that the southern part of the Colorado River Basin was inhabited by ancient peoples—cave, cliff, and mud-house dwellers—eight to ten thousand years ago. Indian legends relate that these people were forced to leave the region because of volcanic eruptions in the vicinity of the San Francisco Peaks near Flagstaff, Ariz.*

*Ruins of dwellings and storehouses, and the remains of pottery, arrowheads, and other artifacts scattered throughout the Colorado River Basin bear mute evidence of the existence of scattered Indian tribes, many of whom had disappeared before the coming of the white man. Some of these, like the present-day Hopi, developed a simple agriculture and lived in permanent compact villages adjoining their cultivated fields. Some, like the*

*Pima-speaking tribes of southern Arizona, harvested seeds and fruits, irrigated their lands and had small village settlements. Others, like the Utes and Paiutes of the plateaus to the north, lived an open, roving life, depending for a livelihood on hunting animals and collecting herbs. They built crude shelters of bark or skins, and seldom resided permanently in large settlements. Dwellings in the valleys were mostly of adobe but other pueblos near and on the cliffs were made of stone. Virtually four-storied apartment houses containing hundreds of rooms have been found.*

*The present Navajos and Apaches entered the basin as roving bands about 600 years ago and established a civilization which has persisted to the present day. The Pimas, Maricopas, and Papagos of the lower Gila Valley are among the most advanced Indian tribes found in the United States. The Chemehuevi ("Digger Indians") of west-central Arizona are among the least progressive (USBR 1946, 45).*

### *Exploration*

*The deep canyons, obstructing cliffs, and desert wastes long hindered travelers in penetrating the Colorado River Basin. The Spanish conquistadors, exploring north from Mexico, were the first white men to enter the basin. In 1539 the Spanish explorer Francisco de Ulloa sailed to the head of the Gulf of California and because of the turbid water inferred that a stream entered the gulf in that vicinity. He did not see the river, but drew a rough map showing its supposed location...The Colorado River actually was discovered in 1540 by Hernando de Alarcon, who explored the stream from its mouth to a point...about 100 miles above the mouth of the Gila River...*

*As time passed, stories of these early Spanish explorers combined with Indian legends grew into fabulous tales of this unknown land. It was said that the Colorado had great falls and whirlpools and that it ran underground for hundreds of miles. So formidable were the actual conditions that the Colorado River was long considered a dangerous obstacle to be circumtoured.*

*Spanish explorations continued to the beginning of the nineteenth century, the region being covered rather thoroughly. During this period two missions were built along the Colorado River, both of which were later destroyed by Indians...[T]he Spaniards' main interest in the area lay in the exploitation of its mineral resources.*

*Venturesome traders, trappers, and explorers entered the area during the period 1820-1840. Beginning in 1824 General William Henry Ashley with a large band of expert trappers explored part of the Green River canyons...By the year 1840 this wilderness had been traversed throughout by white men except for the deep canyons of the Colorado...*

*The treaty of Guadalupe-Hidalgo, signed in 1848 at the end of the war with Mexico, and the Gadsden Purchase in 1853 gave to the United States much of the territory now included in the seven Colorado River Basin States...*

*In 1857 the War Department dispatched Lt. J.C. Ives to proceed up the Colorado River by boat as far as navigation was possible. He ascended in his steamboat only as far as Fort Callville near the head of Black Canyon, about 400 miles above the mouth of the river. It took him 5 days to navigate the last 20 miles.*

*In his report to the War Department, Lieutenant Ives said:*

*The region last explored is, of course, altogether valueless. It can be approached only from the south, and after entering it, there is nothing to do but leave. Ours was the first, and doubtless will be the last, party of whites to visit this profitless locality. It seems intended by nature that the Colorado River along the greater portion of its lone and majestic way shall be forever unvisited and unmolested.*

*In 1869, Maj. J.W. Powell succeeded in leading a river expedition down through the canyons of the river. In traveling by boat from Green River, Wyoming, to the mouth of the Virgin River in Nevada, a few miles above where Lieutenant Ives had been stopped, he achieved the hitherto impossible feat of traversing a thousand miles of unknown rapids and formidable canyons. He*

*became the first white man to gaze up the sheer walls of the Grand Canyon throughout its entire length and live to tell the tale.*

*Subsequently, Major Powell and others made additional voyages to explore the canyons. With the river explored, active investigation began to make it useful for man (USBR 1946, 46-48).*

### *Settlement*

*...The early settlers endured many hardships in caring homes from the wilderness—the rigors of an arid climate, the depredations of Indians and wild beasts, and the arduous and wearisome existence of frontier life.*

*Missionaries influenced early settlements in the basin. Father Kino, a Spanish priest, founded the first settlements subsequent to his visit to the region in 1691. Spaniards established resident fathers in the Santa Cruz River Valley as early as 1700, and soon after several missions were constructed on the banks of the stream.*

*Among the early colonizers of the basin were Mormon pioneers, who settled in small agricultural communities along river valleys, cultivated the more favorable farming lands adjacent to streams where irrigation water was readily accessible, and grazed livestock on nearby range lands. Old Fort Supply in Wyoming and Santa Clara, Utah, were established by Mormons in 1854. Mormon settlements spread into other parts of Utah, and in Arizona and Nevada in the 1860's and '70's.*

*The lure of gold was a chief factor influencing early settlements. Many a pioneer settler came seeking his fortune in the gold rushes, but, finding that his dreams of easy riches would never materialize, stayed to raise livestock or to farm.*

*Several rich mines were discovered throughout the basin by transient prospectors and these discoveries were responsible for a temporary population influx. Miners and prospectors pushed over the mountains from older mining*

*districts on the eastern slope of the Continental Divide. The placer ground at Breckenridge, Colorado, near the crest of the divide attracted the first settlers to this region in 1859. Within the next decade other mining camps were established near the mountain tops. Some miners turned to farming and found a lucrative business in supplying agricultural products to the mining communities. Settlement grew downward from the mountains into the valleys in this western slope section of Colorado, the advance being slowed somewhat by the hostility of the Indians who occupied the territory.*

*The greater part of the Uinta Basin in Utah was established as an Indian reservation in 1861.*

*Mining was active in southeastern Arizona from 1847 to 1860 under protection of the Federal Government, but during the Civil War hostile Indians caused nearly all of the early mining settlements to be abandoned. After the Civil War mining was resumed.*

*The establishment of amicable relations with the Indians and the construction of railroads through the basin finally made permanent settlement possible. The Union Pacific Railroad was completed to Green River, Wyo., in 1869. The Southern Pacific Railroad reached the Colorado River at Yuma, Ariz., in 1877, and the Atlantic and Pacific Railroad crossed the river at Needles, Calif., in 1883. With the coming of the railroads, navigation soon declined. Other than by railroad, early transportation was by horse and mule, pack train, or freight wagon traversing trails and primitive roads.*

*For many years mining was the leading industry in the Colorado River Basin but declined in relative importance with the development of irrigated agriculture. Many rich gold and silver lodes pinched out. Aspen, Telluride, and Silverton in Colorado, once prosperous cities pouring out gold and silver, became dozing towns. Production of copper, lead, and zinc became more important, and Arizona displaced Colorado as the leading producer of minerals in the basin. Where valuable mines were discovered, towns sprang up in their immediate vicinity, and where possible, irrigated agriculture was practiced nearby to supply the demands of local markets.*

*Cattlemen were attracted to the expansive grazing areas of the basin and in many sections were the first settlers.*

*Colonization in the basin has been accompanied by a continual search for a satisfactory irrigation water supply. Settlers migrated to areas more readily irrigated and concentrated along river courses. A few small settlements were made in favored isolated areas.*

*The history of early settlement along the lower reaches of the Colorado River is a story of community struggles with destructive floods. Many towns were established only to be abandoned later when it became evident to the settlers that it was impossible for them to control the rivers. Dams were repeatedly washed out, crops withered and died in time of drought, and flash floods ravaged the fields and towns.*

*Private and community efforts were responsible for the establishment of early settlements. Some present-day settlements, however, followed in the wake of Federal Reclamation developments. These projects, making available new areas of fertile farm land and attracting many new settlers, have been the nuclei around which farming communities and trade centers have evolved (USBR 1946, 48-49).*

## Native Americans

*...With the coming of the whites and the subsequent confinement to reservations their earlier methods and customs have changed but through the assistance of the government their present agricultural activities have become considerably enlarged and modern methods are being adopted.*

*Within the Colorado River Basin...are 29 Indian reservations...The Indian land totals 26,823,062 acres, of which 1,271,117 acres are in trust allotments, 24,557,040 acres in tribal ownership and 994,905 acres in Government ownership...The largest single group is the Navajos in Arizona and New Mexico...*

*With few exceptions the Indians within the Colorado River Basin exist on a much lower than average standard of living. The Federal Government is obligated to provide them with resources sufficient to enable them to attain economic independence at a level comparable with other citizens of the area. In*

*some instances the full development of the Indian's present resources in land and water will accomplish this result. In other cases some additional resources must be acquired. Only after their economic independence at a reasonable level is attained can these Indians be expected to become integrated with the social, economic, and political life of the Nation. The guidance, protection, and assistance necessary to attain this end are Federal responsibilities (USBR 1946, 261).*

*[Fish in the] Upper Colorado Basin*

*...The tributaries of the Green River division in the upper basin originate in high mountains. The streams are clear and cold.*

*The principal headwaters of Green River lie in the western slope of the Wind River range of mountains in Wyoming. Lakes at the origin of many of these streams have a variety of trout, principally cutthroat and mackinaw. In the upper reaches of the streams, the cutthroat trout is the most abundant species, being replaced by the rainbow trout at lower levels. Brook and brown trout are present, but not numerous. A fairly abundant form, which is becoming increasingly popular, is Williamson's whitefish. Below the city of Green River, Wyo., trout fishing becomes less and less important, and in the main stream within Utah the only species of importance is the channel catfish. The California golden trout has been planted in a few of the high streams.*

*In the Grand division, the headwaters of the Colorado River and its principal tributaries in Colorado have cutthroat and brook trout as the main species, but at lower levels, the rainbow trout is most numerous. Brown trout are abundant in several places, notably the Gunnison River. Some miles east of the city of Grand Junction, channel catfish replace trout and become the important species thence down stream in the main river. Large-mouth black bass are present also. Few fish of value are found in the reaches above and below Moab, Utah.*

*In the San Juan division, the upper reaches of the eastward-flowing tributaries of the Colorado River in southern Utah contain the usual forms of trout in some abundance. The main stream in this area is practically inaccessible, for no roads cross it. Its value as a fishing stream may be*

*discounted at present. The San Juan River and tributaries provide a satisfactory general trout habitat at the higher elevations and channel catfish habitat in the lower reaches (USBR 1946, 250-251).*

*[Fish in the] Lower Colorado Basin*

*...In the four divisions of the lower basin the cold-water fish are confined almost wholly to the higher elevations in the Virgin, Little Colorado, and Gila divisions. In the Boulder division a beautiful trout stream has been created immediately below Boulder Dam by drawing off cold, clear water from the depths of the reservoir and stocking this portion of the river with rainbow trout.*

*In the lower divisions of the Colorado the main Colorado River flows largely through a deep canyon and receives water chiefly from a few principal rivers that are sufficiently large to flow throughout the year. It also receives flood waters of many intermittent streams. Trout are found only at the higher elevations. Rainbow and brown trout are the chief species. After these streams flow out of the mountains, they contain catfish, bass, sunfish, crappies, channel catfish, and bonytails. A great many of these streams sink into the desert and disappear along their lower reaches. Surveys made of many of these headwater streams, having heavy fishing pressure, show them to have considerable recreational value.*

*In the Boulder division a rather complete survey of the river from the Nevada-California line to the Gulf of Mexico has been made by the California Division of Fish and Game. This lower section of the Colorado is characterized by warm, silty water fluctuating considerably in volume with a shifting bottom. It is very deficient in fish food due to the high turbidity, the unstable bottom, and the fluctuations in level. Fishes are not abundant except in backwaters, the small temporary lakes that are formed behind the shifting sand bars of the channel in the reservoirs, and in the main irrigation canals. The chief fishes at present are introduced varieties, most of the native fishes apparently suffered from the man-made changes in the river and are no longer abundant.*



*Largemouth bass, carp, catfish, and bluegill sunfish are the most abundant species in the reservoirs of the main river. Mullet are abundant as far upstream as Imperial Dam. Trout are not ordinarily found in the main river except for the stretch of from 20 to 30 miles of cold, clear water that is drawn off from the deeper portions of Boulder Dam. The main irrigation canals in the lower portions of the basin are ordinarily filled with water throughout the year and contain large numbers of fish wherever the current is not too swift. The main power reservoirs that are proposed for almost the total length of the Colorado River will flood several hundred miles of the main stream. The degree of turbidity of the water in the main Colorado River is so great due to the tremendous loads of silt carried that it is quite unproductive of fish foods. The shifting bottom also smothers food organisms. Therefore, it is felt that the desilting of the river and the formation of these tremendous lakes will undoubtedly add considerably to the fishery values of the main river.*

*When the upper basin reaches its ultimate development there is some possibility that the fisheries in the lower basin may suffer from the excess quantities of alkali that will be leached out of the irrigated land and returned through drains into the river. When Davis Dam is completed it will flood the trout waters below Boulder Dam and destroy this fishery. It will have some beneficial effect, however, in reducing the silt carried into Havasu Lake (USBR 1946, 252-253)*

## Appendix III

Primary Distinguishing Characteristics of Level III Ecoregions of the Colorado River Basin. From *PRIMARY DISTINGUISHING CHARACTERISTICS OF LEVEL III ECOREGIONS OF THE CONTINENTAL UNITED STATES*, U.S. EPA, July 2010. [ftp://ftp.epa.gov/wed/ecoregions/us/Eco\\_Level\\_III\\_descriptions.doc](ftp://ftp.epa.gov/wed/ecoregions/us/Eco_Level_III_descriptions.doc)

14. MOJAVE BASIN AND RANGE – This ecoregion contains broad basins and scattered mountains that are generally lower, warmer, and drier, than those of the Central Basin and Range (13). creosote bush-dominated shrub community is distinct from the saltbush–greasewood and sagebrush–grass associations that occur to the north in the Central Basin and Range (13) and Northern Basin and Range (80); it is also differs from the palo verde–cactus shrub and saguaro cactus occur in the Sonoran Basin and Range (81) to the south. Most of this region is federally owned and grazing is constrained by the lack of water and forage for livestock. Heavy use of off-road vehicles and motorcycles in some areas has made the soils susceptible to wind and water erosion.

17. MIDDLE ROCKIES - The climate of the Middle Rockies lacks the strong maritime influence of the Northern Rockies (15). Mountains have Douglas-fir, subalpine fir, and Engelmann spruce forests, as well as some large alpine areas. Pacific tree species are never dominant and forests can have open canopies. Foothills are partly wooded or shrub- and grass-covered. Intermontane valleys are grass- and/or shrub-covered and contain a mosaic of terrestrial and aquatic fauna that is distinct from the nearby mountains. Many mountain-fed, perennial streams occur and differentiate the intermontane valleys from the Northwestern Great Plains (43). Granitics and associated management problems are less extensive than in the Idaho Batholith (16). Recreation, logging, mining, and summer livestock grazing are common land uses.

18. WYOMING BASIN - This ecoregion is a broad intermontane basin interrupted by hills and low mountains and dominated by arid grasslands and shrublands. Nearly surrounded by forest covered mountains, the region is somewhat drier than the Northwestern Great Plains (43) to the northeast and does not have the extensive cover of pinyon-juniper woodland found in

the Colorado Plateaus (20) to the south. Much of the region is used for livestock grazing, although many areas lack sufficient vegetation to support this activity. The region contains major producing natural gas and petroleum fields. The Wyoming Basin also has extensive coal deposits along with areas of trona, bentonite, clay, and uranium mining.

19. WASATCH AND UINTA MOUNTAINS - This ecoregion is composed of a core area of high, precipitous mountains with narrow crests and valleys flanked in some areas by dissected plateaus and open high mountains. The elevational banding pattern of vegetation is similar to that of the Southern Rockies (21) except that areas of aspen, interior chaparral, and juniper-pinyon and scrub oak are more common at middle elevations. This characteristic, along with a far lesser extent of lodgepole pine and greater use of the region for grazing livestock in the summer months, distinguish the Wasatch and Uinta Mountains ecoregion from the more northerly Middle Rockies (17).

20. COLORADO PLATEAUS - Ecoregion 20 is an uplifted, eroded, and deeply dissected tableland. Its benches, mesas, buttes, salt valleys, cliffs, and canyons are formed in and underlain by thick layers of sedimentary rock. Precipitous side-walls mark abrupt changes in local relief, often from 1,000 to 2,000 feet. The region contains a greater extent of pinyon-juniper and Gambel oak woodlands than the Wyoming Basin (18) to the north. There are also large low lying areas containing saltbrush-greasewood (typical of hotter drier areas), which are generally not found in the higher Arizona/New Mexico Plateau (22) to the south where grasslands are common. Summer moisture from thunderstorms supports warm season grasses not found in the Central Basin and Range (13) to the west. Many endemic plants occur and species diversity is greater than in Ecoregion 13. Several national parks are located in this ecoregion and attract many visitors to view their arches, spires, and canyons.

21. SOUTHERN ROCKIES - The Southern Rockies are composed of steep, rugged mountains with high elevations. Although coniferous forests cover much of the region, as in most of the mountainous regions in the western United States, vegetation, as well as soil and land use, follows a pattern of elevational banding. The lowest elevations are generally grass or shrub covered and heavily grazed. Low to middle elevations are also grazed and covered by a variety of vegetation types including Douglas-fir, ponderosa pine, aspen, and juniper-oak woodlands. Middle to high elevations are

largely covered by coniferous forests and have little grazing activity. The highest elevations have alpine characteristics.

22. ARIZONA/NEW MEXICO PLATEAU - The Arizona/New Mexico Plateau represents a large transitional region between the semiarid grasslands and low relief tablelands of the Southwestern Tablelands (26) in the east, the drier shrublands and woodland covered higher relief tablelands of the Colorado Plateau (20) in the north, and the lower, hotter, less vegetated Mojave Basin and Range (14) in the west and Chihuahuan Deserts (24) in the southeast. Higher, forest-covered, mountainous ecoregions border the region on the northeast (21) and south (23). Local relief in the region varies from a few feet on plains and mesa tops to well over 1000 feet along tableland side slopes.

23. ARIZONA/NEW MEXICO MOUNTAINS - The Arizona/New Mexico Mountains are distinguished from neighboring mountainous ecoregions by their lower elevations and an associated vegetation indicative of drier, warmer environments, which is due in part to the region's more southerly location. Forests of spruce, fir, and Douglas-fir, that are common in the Southern Rockies (21) and the Uinta and Wasatch Mountains (19), are only found in a few high elevation parts of this region. Chaparral is common on the lower elevations, pinyon-juniper and oak woodlands are found on lower and middle elevations, and the higher elevations are mostly covered with open to dense ponderosa pine forests. These mountains are the northern extent of some Mexican plant and animal species.

24. CHIHUAHUAN DESERTS - This desert ecoregion extends from the Madrean Archipelago (79) in southeastern Arizona to the Edwards Plateau (30) in south-central Texas. The physiography is generally a continuation of basin and range terrain that is typical of the Mojave Basin and Range (14) and the Central Basin and Range (13) to the west and northwest, although the patterns of alternating mountains and valleys is not as pronounced as in Ecoregions 13 and 14. Vegetative cover is predominantly desert grassland and shrubland, except on the higher mountains where oak, juniper, and pinyon woodlands occur. The extent of desert shrubland is increasing across lowlands and mountain foothills due to the gradual desertification caused in part by historical grazing pressure.

79. MADREAN ARCHIPELAGO - Also known as the Sky Islands in the United States, this is a region of basins and ranges with medium to high local relief, typically 3,000 to 5,000 feet. Native vegetation in the region is mostly

grama-tobosa shrubsteppe in the basins and oak-juniper woodlands on the ranges, except at higher elevations where ponderosa pine is predominant. The region has ecological significance as both a barrier and bridge between two major cordilleras of North America, the Rocky Mountains and the Sierra Madre Occidental.

81. SONORAN BASIN AND RANGE – Similar in topography to the Mojave Basin and Range (14) to the north, this ecoregion contains scattered low mountains and has large tracts of federally owned land, a large portion of which is used for military training. However, the Sonoran Basin and Range is slightly hotter than the Mojave and contains large areas of palo verde-cactus shrub and giant saguaro cactus, whereas the potential natural vegetation in the Mojave is largely creosote bush. Winter rainfall decreases from west to east, while summer rainfall decreases from east to west.

## Appendix IV

### Timeline of Events Relating to the Animas-La Plata Compromise

The following timeline was created using multiple sources: the USBR WWIS UC Event Database; USBR 1946; Reisner 1987; Pollack and McElroy 2001; USBR 2006; Ellison 2009; the Durango Herald 2009; and oral history style interviews conducted with key stakeholders.

- March 1946 – The Animas-La Plata Project is listed as a potential project for construction in a report to Congress on the development of the Colorado River basin.
- April 11, 1956 – Congress authorizes a feasibility study for the Animas-La Plata Project as part of the Colorado River Storage Act.
- January 1, 1962 – The USBR finds the ALP to be “engineeringly sound and financially sound and feasible.”
- September 26, 1968 – As part of the Colorado River Basin Project Act of 1968, Congress authorizes construction of the ALP. The original project consisted of two reservoirs and a diversion, which included 48 miles of canals and tunnels. This would have diverted more than 191,000 acre-feet of water to Colorado and New Mexico for irrigation, municipal and

industrial uses.

- September 1, 1979 – The ALP was expanded to include two new reservoirs, Ridges Basin and Southern Ute.
- July 1, 1980 – The USBR released the Final Environmental Statement for the ALP.
- 1980/81 - At the end of the Carter administration, all public works projects scheduled for construction were suspended, including the ALP. Had this not been the case, the project would most likely look different today.
- 1985 – The Reagan Administration, along with fiscal conservatives, and environmentalists work on Congressional amendments requiring higher local cost sharing requirements for new water projects.
- March 5, 1986 – In order to raise the higher local share of construction costs, the San Juan Water Commission is formed with the signing of the Joint Powers Agreement. Members include the cities of Aztec, Bloomfield, and Farmington, New Mexico, San Juan County and the San Juan Rural Waters Users Association. By entering into this agreement, all members agreed that water allocated to them through the ALP “should be held for the use and benefit of all the citizens,

municipalities, water users associations and other water users in San Juan County, New Mexico.” (SJWC 1986) Essentially, these governments agreed to manage ALP water collectively, and share all costs associated with the construction of the ALP.

- July 1, 1986 – A cost-sharing arrangement was accepted by the Department of the Interior, which would require states and local partners to provide 38 percent of the project’s up-front funding.
- December 10, 1986 – The Colorado Ute Indian Water Rights Final Settlement Agreement was signed. One of the most influential events related to the ALP project, as it would later bring about major changes.
- November 1, 1988 – The Colorado Ute Indian Water Rights Settlement Act was passed by Congress, which resolved senior water rights claims by both the Southern Ute Indian and Ute Mountain Ute Tribes. In addition to allowing for future development, the Act protected existing water uses.
- 1990 – The Bush administration urges federal agencies to settle Native American water rights claims out of court.
- May 4, 1990 – The USFWS issued a draft biological opinion, concluding the ALP would jeopardize the existence of the Colorado pikeminnow.



No reasonable and prudent alternative to the ALP was identified.

- October 22, 1991 – Citing compliance issues with the Clean Water Act, NEPA and the Administrative Procedures Act, the Sierra Club Legal Defense Fund filed a Notice of Intent to sue over the ALP.
- October 23, 1991 – The razorback sucker was listed as a federally protected endangered species.
- October 25, 1991 – The USFWS issued a Final Biological Opinion. It offered a reasonable and prudent alternative, which limited depletions from the Animas River to 57,100 acre-feet annually in order to protect the pikeminnow. This Biological Opinion removed impediments to ALP construction. Requirements for spillages from upstream Navajo Reservoir were included to mimic natural flows. It also included the San Juan Recovery Implementation Program, an endangered fish recovery program aimed at helping the Colorado pikeminnow.
- October 26, 1991 – A groundbreaking ceremony for the ALP was held near Durango.
- February 25, 1992 – The Sierra Club Legal Defense Fund, representing the Four Corners Action Coalition, Sierra Club, Colorado Wildlife Federation, Taxpayers for the Animas River and Southern Utah

Wilderness Alliance, filed a lawsuit to stop construction of the ALP.

- April 23, 1992 – Construction was halted pending the completion of the Environmental Impact Statement started in 1980.
- September 17, 1992 – An injunction was granted, prohibiting all ground-disturbing activities related to the ALP in order to protect cultural resources.
- June 19, 1996 – A lawsuit was filed against the EPA by the Southern Ute Indian Tribe, Ute Mountain Ute Tribe and the Animas-La Plata Water Conservancy District. The suit claimed the EPA was obstructing the implementation of the Colorado Ute Mountain Water Rights Settlement Act.
- October 9, 1996 – Supporters and opponents of the ALP met with the Governor of Colorado, the Lt. Governor and the Secretary of the Interior to discuss unresolved concerns in an attempt to reach consensus on future project alternatives. Several pending lawsuits were put on hold, as the participants reached a “Stand Still” agreement.
- August 11, 1998 – In order to address concerns over Endangered Species and Clean Water Act requirements, the Department of Interior recommended a scaled-down version of the project, ALP “Lite”. The

project will no longer have an irrigation component. It will be used instead to fill water rights of two Ute Indian Tribes. Because of this, traditional cost-benefit analyses do not apply.

- December 21, 2000 – The USBR released an EIS and Record of Decision that identified ALP Lite as the preferred alternative. Congressional authorization was still needed, as the alternative provided benefits to the Colorado Ute Indian Tribes that were not exactly the same as those laid out in the 1988 Ute Settlement Act. Congress gave authorization in the Colorado Ute Settlement Act Amendments of 2000. The Navajo Nation becomes a stakeholder in the project, as the Amendments included the Navajo Nation Municipal Pipeline.
- November 9, 2001 – The USBR Commissioner granted approval to begin construction on the ALP project.
- April 1, 2002 – The following four tasks were started: 1) cultural resource mitigation program field work; 2) inlet conduit pipeline sleeve construction; 3) haul road construction by Weemuniche Construction Authority; and 4) final route selection for the Navajo Nation Municipal Pipeline.

- June 1, 2002 – Construction on the inlet conduit to Ridges Basin Dam began.
- November 1, 2002 – Construction was started on Ridges Basin Dam.
- January 1, 2003 – The cost for the project is projected to increase from \$338 million to \$500 million, and the estimated completion date is pushed back to 2011 from 2009.
- May 9, 2003 – Construction was started on the Durango Pump Plant.
- January 1, 2004 – Excavation of the Durango Pumping Plant, intake structure, and fish bypass were nearly completed. Additionally, Ridges Basin Reservoir was renamed Lake Nighthorse in honor of a champion for the project, retiring Colorado Senator Ben Nighthorse Campbell.
- April 13, 2005 – The Durango City Council voted to pay over \$1 million as a down payment for water from the ALP. This did not guarantee water, but ensured the city a better buy-in cost when the project is completed. The Animas La Plata Water Conservancy District board voted to buy 700 acre-feet of water from the ALP for a drinking water district in La Plata County.
- May 19, 2005 – The House Appropriations Committee earmarked \$56 million for the project in the 2006 federal budget.

- August 13, 2005 – Two hundred people gathered at the Ridges Basin Dam site and watched workers spread impervious clay on the excavated floor of the reservoir.
- November 8, 2005 – Congress allocated \$56 million for the ALP project in the 2006 budget, \$4 million more than the Bush administration recommended.
- February 18, 2006 – The federal government purchased more than 100 acres of land it had condemned for just over \$3 million in order to further ALP construction.
- July 19, 2007 – The U.S. House of Representatives approved \$60 million for the ALP, \$2 million more than requested in President George W. Bush's budget and \$3 million less than the Senate version.
- September 6, 2007 – As part of a five year project in the Ridges Basin, SWCA Environmental Consultants collected between 800,000 and 900,000 artifacts from prehistoric peoples who lived in the project area, which would be under water in the future.
- November 10, 2007 – A topping-out ceremony was held at the completed Ridges Basin Dam.
- December 18, 2007 – In order to ensure the water used to fill Lake

Nighthorse would be clean, the Durango city council started a project to redirect outflow from the city's sewage treatment plant, even though this water is treated.

- October 17, 2008 – A ceremony was held as the ALP was 97 percent completed. Federal, state and local government officials, members of three tribes, and Colorado and New Mexico residents were in attendance.
- January 13, 2009 – Construction was started at Ridges Basin for a project to supply drinking water to southwest La Plata County.
- March 15, 2009 – Congress approved \$5 million for the ALP, the majority of which will be used for the Navajo Nation Municipal Pipeline.
- April 20, 2009 – The USBR started the Durango Pumping Plant and began storing water for ALP customers.

