RECLAMATION

Managing Water in the West

The Western Water Institutional Solutions-Western Water Information Network 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
Upper Colorado Region

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Contents

Page

Executive Summary

This research grew out of and cooperated with another Reclamation research effort, The Western Water Information Network (WWIN) Enterprise GIS Project, which provided the geographic data necessary to examine the environments and trends described above. Originally, these efforts were funded together, but it quickly became apparent that the examination of the trends in conflict and the environments conducive to it required a separate research effort. So, this work fulfills one of the original goals of the WWIN project, namely to describe and analyze the spatial and temporal distributions of conflict and collaboration.

As indicated, the WWIS project incorporated the GIS data from the WWIN project to look for the indicators or settings conducive to conflict or collaboration. All instances of conflict and cooperation from the WWIS UC events database were coded to the 6-digit accounting unit level to allow for a spatial comparison of conflict and cooperation throughout the UC Region. Data from the U.S. Bureau of Reclamation's Western Water Information Network (WWIN) relating to drought, water use, population, and endangered species, to name a few, are also available for the UC Region at the 6-digit HUC level.

Major Findings

Overall, a majority of events in the UC Region were cooperative. Intensities and issue types varied across space and time, with the majority of events relating to water rights, infrastructure, water quality, and intergovernmental relations. Statistical analysis uncovered no significant indicators of hydropolitical intensity. A potential relationship between drought frequency, groundwater withdrawals, and impaired waters and the intensity of accounting unit was found, although none of the regression models were statistically significant. Further studies need to be conducted to investigate this relationship.

Timeline analysis showed that despite the relationship of hydropolitical intensity to drought frequency, no consistent relationship between drought severity and intensity in any one year existed. The temporal analysis showed how events can travel through space, time, and intensity. In terms of stakeholder involvement, there was great variation in the local, state, and federal government agencies each had the highest percentage of involvement in different issue categories. Regional governments (i.e. Colorado River Commission) and conservation districts had the highest percent of their involvement in cooperative interactions, while the stakeholder groups with the highest percentages of involvement in conflictive events were railroads and environmental groups.

1 Introduction

In the western United States (the West), water resources are becoming increasingly utilized as human populations multiply. Water users' rights in the West are established according to the prior appropriations doctrine. 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. Because of this, the prior appropriations doctrine does not facilitate water conservation (Thompson 1999; Kenney 2004).

As more people use water, the amount available to others decreases. In the upper Colorado basin alone, water use increased by over 500,000 acre-feet from 1971 to 2004. Exports of water out of the basin grew by nearly 200,000 acre-feet during this same time, while agricultural water use grew by over 150,000 acre-feet (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, as there is little water unappropriated in the West (Platt 2004; Cortese 2003). According 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."

As competition between water users and water use sectors increases, the potential for conflict increases. The potential for conflict also increases when political entities sharing a water resource have differing institutions for governing the resource (Jarvis, et al. 2005). Research has shown that cooperation is more prevalent than conflict in international river basins (Wolf 1998; Yoffe 2001), however, as the demand for water approaches or meets available supply, intranational conflicts may increase (Postel and Wolf 2001). A study by Fesler (2007) found that in the state of Oregon, as in international river basins, cooperation is however, more common than conflict.

This project will build on the work that has been done on both the international river basin scale and on an intrastate scale by studying cooperation and conflict on an interstate scale in one of the West's most important sub-regions, with respect to freshwater, the USBR's Upper Colorado (UC) Region. The UC Region covers portions of seven states and includes both the upper Colorado River basin and the upper Rio Grande River basin. The region is the source of freshwater for some of the largest and fastest growing cities in the U.S., including Denver, CO, Las Vegas, NM, Los Angeles, CA, and Phoenix, AZ, none of which is within the UC Region (NRC 2007). As populations continue to grow in this region and water becomes increasingly utilized, water resources managers will have to deal with competing uses and conflict over available water more frequently. The objective of this project is to gain an understanding of hydropolitics in the UC Region, and to determine if there are indicators of cooperation and/or conflict that can help managers to proactively plan for conflictive situations.

Based on these objectives, the project focused on four primary research questions:

1. How did the intensity of cooperation and conflict change USBR's UC Region from 1970 to 2005?

2. Did the spatial distribution of cooperation and conflict in the region change between 1970 and 2005?

3. Over what water resources issues were people interacting, and how did these issue types change across space and time?

4. Are there indicators of conflict and mechanisms that foster cooperation within the UC Region?

2 Methods

2.1 Creation of a Water Events Database

The Western Waters Institutional Solutions (WWIS) UC project relies upon three types of data: (a. media reports of conflict or cooperative events, (b. legal cases dealing with water conflicts and (c. geospatial data gathered from a wide variety of governmental and non-governmental agencies. The first two data sets were used to compile the so-called “hydropolitical database”. The geospatial data sets were primarily drawn from Reclamation’s Western Water Information Network, an enterprise geographic information system (GIS) application housed in the Bureau of Reclamation’s Denver Technical Service Center.

2.1a Media Reported Events

Ten media outlets were used for the Upper Colorado (UC) regional analysis (Table1). For development of the hydropolitical database, a team of trained coders was assembled to search through the media stories found on Lexis-Nexis and code hydropolitical events to a scale ranging from -5 (high conflict) to 0 (neutral) to +5 (high cooperation) (Table 2). It is important to realize that coding is based on **actions** taken by the various institutions and not on the **attitudes** expressed implicitly or explicitly in the media stories (Smith et al. 2001).

A hydropolitical event is any interaction between parties that is action-defined and recorded and made available to the public. To be relevant to this study, an event had to: (a. 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) (b. affect water bodies within the Bureau of Reclamation’s Upper Colorado Region management area, and (c. have occurred between 1970 and 2005. The year 1970 is the earliest year for which articles are available in the Lexis-Nexis database.

Table 1. Media Publications Used in this Research.

Newspaper	Search Hits	Events	Earliest Date
Albuquerque Journal	1141	1682	1995
Santa Fe New Mexican	834	1069	1994
Salt Lake Tribune	448	629	1994
Denver Post	994	562	1994
Associated Press Newswire	5394	421	1977
Rocky Mountain News	825	299	1994
Albuquerque Tribune	250	214	1995
Deseret Morning News	115	104	2003
New York Times	4091	29	1970
Wyoming Tribune-Eagle	88	26	1997

2.1a.1 Event Intensity

The conflict-cooperation scale used in this research is based upon similar scales present in the academic water conflict literature. The major event databases focus on all types of political interactions that occur at the international and/or intranational scale. Two are most important to this research: the Conflict and Peace Data Bank (COPDAB) and the Intranational Political Interactions (IPI) project. COPDAB was one of the first event databases and was created in the 1960s (Azar 1980). Its main focus is on international events with a small section devoted to intranational actions in highly conflictive countries. The Intranational Political Interactions (IPI) project was started in the early 1990’s and was one of the first event databases to focus solely on intranational events (Moore and Lindstrom 1996).

While political scientists have been analyzing event data, natural resource scientists and managers have not utilized this resource when discussing conflict over natural resources. One hindrance has been that these databases are focused on diplomatic and militaristic behaviors and they have not been well suited to environmental issues (Schrodt 1994). The Freshwater Transboundary Dispute Database (TFDD) is the only event database solely devoted to natural resource-related interactions. The TFDD classification scheme was created by modifying the COPDAB ranking system to adjust for water resource management issues and concerns at the international level (Yoffe 2001).

Further modifications were made to adapt the TFDD classification scheme to the intranational scheme used in this research. Removing extreme classifications like ‘declaration of war,’ from the international scale was required because extreme events of this nature are highly unlikely to occur within the United States. The Intranational Political Interactions (IPI) was used to describe to local political actions in each intensity level. Additional intranational cooperative actions were modified from Keltner (1994) and were created to mirror those conflictive classifications.

In event databases that comprise a wide variety of information types, conflictive intensity is one of the most important classifications categories. Conflictive intensity corresponds to what action actually occurred-- from a verbal argument, to a litigation, to a violent protest, to a war. 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 2004b). It is important to note that while a series of events may pass through several conflictive intensities over time, the process does not necessarily evolve linearly. It may become cooperative at any point (Keltner 1994). Experts agree that there are different levels or intensities of conflict. Previously, there has been less agreement as to the specific identification of those levels or degrees of conflict or cooperation (Keltner 1994). Thus, event data structures have evolved into expertly judged weighting systems, and have been created and validated to measure intensity (Shellman 2004).

After taking into account the two modifications listed above, a scale was constructed in which the conflict-cooperation intensities range between 5 (most cooperative) and -5 (most conflictive). Neutral events are ranked zero (Table 2). This scale is a reduction to a 11 point scale from a 20 point scale used by IPI and a 15 point scale used in TFDD and COPDAB.

Table 2: 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, adjudication 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

2.1a.2 Issue Classification

Events were categorized in terms of not only intensity, but also by issue type. By using and modifying the Transboundary Freshwater Dispute Database (TFDD) (Yoffe 2001), other international event databases and organizational methods (Azar 1980; Keltner 1994; Rodik et al. 2003; Macomber et al. 2005), and making use of the conflict risk factors articulated in the 2003 Bureau of Reclamation water manager survey, several issue categories were created to classify event information. Two overarching water resource management schemes, water-supply and water-allocation, form the basis of this classification. This framework is essential for consistency and objectivity. Guidelines for classifying events were created to ensure repeatability, and to make for a transparent methodology for database creation. Without such a framework, the coding of both intensity and issue type would be completely subjective, and could vary significantly by each person performing the coding.

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 (Table 3). 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. Specific examples from the WWIS event database, including both the intensity and issue categories, are presented in Table 4.

Table 3: Definitions of issue types used in WWIS and a comparison to TFDD issue types

Broad Issue	TFDD Issue	WWIS Issue	WWIS Definition
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	Infrastructure	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.

Table 4: Examples of coded events from the WWIS event database

Event date	Basin	Issue Type	Intensity Value	Event Summary
19-Oct-03	Upper Pecos, Lower Pecos, Rio Grande-Amistad	Water Rights	-1	Op-ed piece opposed to the high cost of NM program to buy land and thus water rights to meet water deliveries to TX.
19-Nov-85	Jordan	Infrastructure	4	A vote in 12 Utah counties approved a $335 million property tax increase to help pay for the Bonneville Unit of the Central Utah Project, which includes construction of reservoirs, aqueducts and pumping plants.
2002	Upper Canadian	Water Rights	-4	The most recent lawsuit concerning water rights Permit 71 was filed in 2002 by the city of Raton in NM District Court claiming storage rights to water from Eagle Nest reservoir.
31-May-03	Mimbres	Water Quality	3	The NM Gov.'s administration has agreed to accept a guarantee from Phelps Dodge Mining Co. to cover more than half of the $484 million bond the state demands to ensure cleanup of the company's three huge copper mines in Grant County. Before it becomes final, the agreement must be approved by the state's Water Quality Control Commission and Mining Commission.

2.1b Legal Cases

A separate legal events database was created. Using the Westlaw legal database all federal cases from the District Courts, Circuit Courts of Appeal, and the Supreme Court of the United States were searched. Only cases in which a judge issued a final judgment or order are available in the Westlaw database; cases in which a negotiated settlement was reached are not included. A final judgment is 'final' in the sense that a judge, having heard both parties, has determined what the law requires on an issue (or issues). The judgment may not resolve every issue in the case or even the main issue. A case that has reached final judgment on one issue may continue on other issues, and most judgments can be appealed. District Court judgments may be submitted for rehearing before the same judge or appealed to the Circuit Court of Appeals. Circuit Court judgments may be appealed to a committee of all the judges in the Circuit or to the Supreme Court (termed a "petition for certiorari"). This events data set includes judgments, appeals, requests for rehearing, and petitions for certiorari. The legal cases are classified by the same issue types as the media events. Based on the intensity scale used to code media events, all legal cases in the database have two intensities: -4 for the litigation and 0 for the ruling. However, because of the bias in the Westlaw legal database, these events were not included in the statistical analysis. Including only legal cases ruled on by a judge would skew the level of conflict in the analysis by not accounting for out-of-court settlements, which have intensities of -4 litigation and 4 for the settlement.

2.1c Geospatial Data

Geospatial data were gathered from a host of sources including the Environmental Protection Agency, the US Geological Survey, NatureServe, The Drought Mitigation Center, The U.S. Bureau of the Census and others. Data on the following variables were compiled and then assigned to USGS 6-digit accounting units: population growth, drought frequency, water quality (EPA impaired waters), mean annual precipitation, number of endangered species, and ground water usage. These variables were thought to be associated with water conflict in a survey of Reclamation water managers Reclamation conducted in 2002-2003, and served as the independent variables in the analysis. Data covered the same period of record for all accounting units; however data were not available for all years in the study period. The area of study was the Upper Colorado Region (Figure 1) and the units of analysis were USGS 6-Digit Accounting Units. All events and geospatial data were coded to these units.

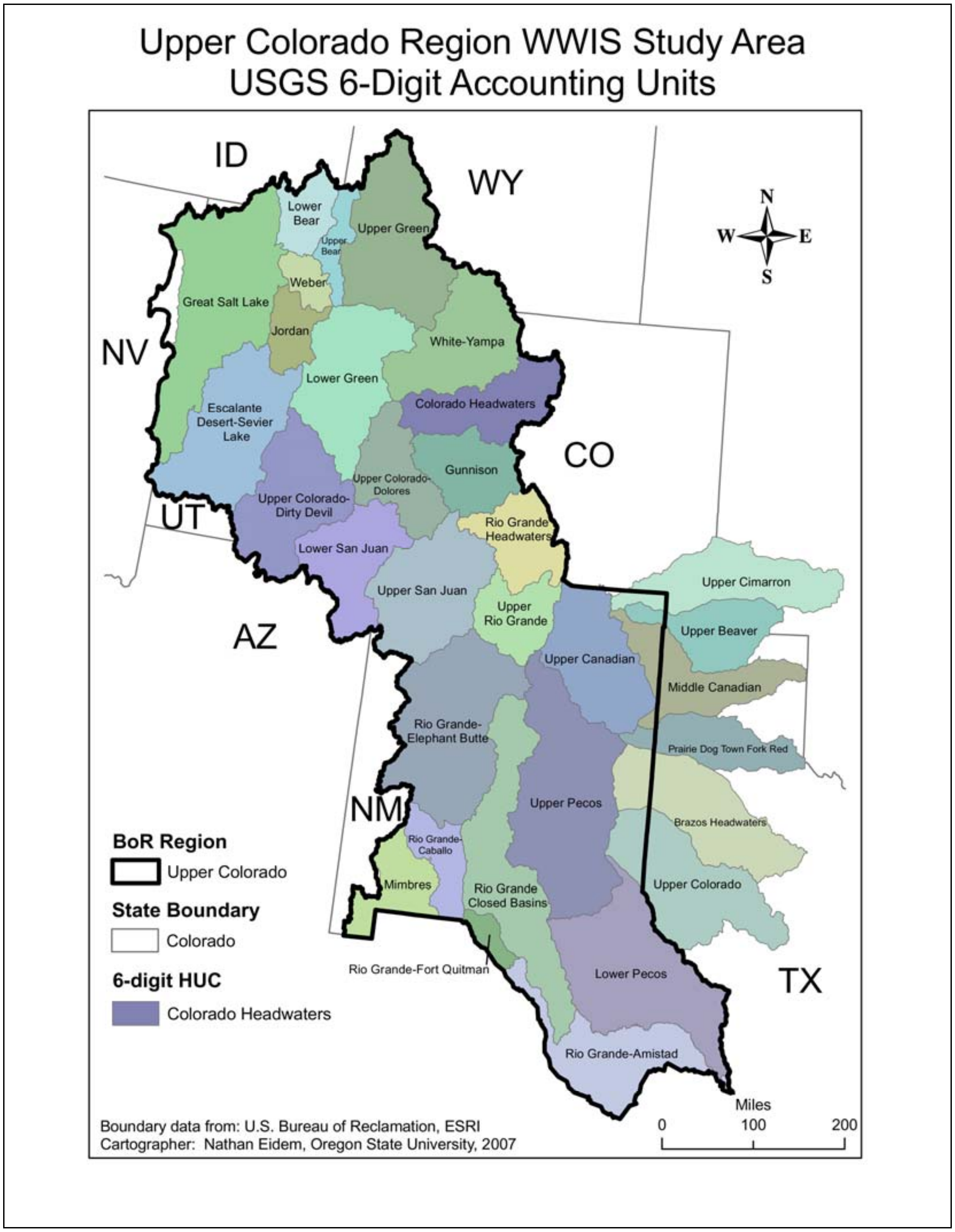

Figure 1. USGS 6-digit accounting units in the Upper Colorado Region.

2.2 Data Analysis

Multiple data analysis methods were used in this study. Summary statistics were calculated for each coded variable. Totals for each conflict-cooperation intensity and issue type were calculated for each accounting unit and year, and summary statistics for stakeholders involved in events were calculated for the UC Region. Summary statistics and weighted average intensities were then mapped, using ArcMap, to look for spatial patterns in the data. Data were mapped at the 6-digit accounting unit level to look for patterns within the larger UC Region. Next, non-parametric multiplicative regression was used to test spatial correlations between independent variables and weighted average intensities. In order to look for temporal patterns in the data, qualitative timeline analysis was employed. Weighted average intensities were also used to create timelines of intensity. An analysis of the relationships between stakeholder groups and their relation to events was also conducted.

5,036 hydropolitical events were coded for this project. Of these, 23% were not included in the analysis. Following the example of Fesler (2007), events were not included if they affected the entire UC Region equally, an entire state equally, or if the events were not specifically focused on the region (i.e. events that affected all western basins). The objective of this project is to uncover settings conducive to conflict and cooperation within the UC Region. Inclusion of these events in the analysis would mask the true intensity of interaction within accounting units, thus giving a skewed view of the region. Data were analyzed using a multi-method approach. Summary statistics were calculated for the events database. Data were then mapped using ArcMap.

2.2a Dependent Variables

The dependent variables used in the analysis are the weighted average event intensities. Weighted event intensities were used following the example of Yoffe and Larson (2001). In their research, the anti-logs of coded intensity values were used to separate the cardinal difference between two event categories at any point on the intensity continuum of international basins at risk (BAR). Anti-logged re-centered values, in their view, provided a more representative portrait of the magnitude of international event categories. In their words,

> *"It is our contention that the distance between any two events should increase as the intensity associated with those events increases. That is to say, the cardinal difference between event categories 6 and 7 should be greater than the difference between event categories 1 and 2, because, intuitively, the difference between the signing of a treaty and unification into one nation (categories 6 and 7) is far more significant than the difference between mild verbal support and official verbal support (categories 1 and 2)." (Yoffe and Larson 2001, p. 24)*

This is a valid assumption when considering the amount of time, money, and effort invested in interactions at the extremes of the continuum. Squares of events' intensities were used as weights in this study. The method of squaring event intensity was adopted from the work of Fesler (2007) in a study of conflict and cooperation over freshwater in Oregon. This weighting system is used because of the modifications made to the intensity continuum discussed earlier. The BAR study focused on international river basins, where a formal declaration war is the most extreme form of conflict and unification into a single nation is the most extreme form of cooperation. These extremes are not possible in an intranational setting, and therefore the differences between the intensity levels are not as great as those at the international scale.

Three weighted averages were calculated: weighted average intensity (positive, neutral, and negative events), cooperative weighted average intensity (only positive events), and conflictive weighted average intensity (only negative events). The maximum weighted average intensity possible is 25 (most cooperative), while the minimum is -25 (most conflictive).

Weighted Average Intensity =

$$\frac{[(25*a) + (16*b) + (9*c) + (4*d) + (e) + (-25*f) + (-16*g) + (-9*h) + (-4*i) + (-j)]}{(a+b+c+d+e+f+g+h+i+j+n)}$$

Cooperative Weighted Average Intensity =

$$\frac{[(25*a) + (16*b) + (9*c) + (4*d) + (e)]}{(a+b+c+d+e)}$$

Conflictive Weighted Average Intensity =

$$\frac{[(25*f) + (16*g) + (9*h) + (4*i) + (j)]}{-(a+b+c+d+e)}$$

a = # +5 events
b = # +4 events
c = # +3 events
d = # +2 events
e = # +1 events
f = # -5 events
g = # -4 events
h = # -3 events
i = # -2 events
j = # -1 events
n = # 0 events

As an example, let us say that there were 100 events coded for a hypothetical basin with the following breakdown of events by intensity: +5 = 6, +4 = 10, +3 = 10, +2 =10, +1 = 10, 0 = 10, -1 =10, -2 = 10, -3 = 10, -4 = 10, and -5 = 4. Using these values, weighted average intensity is calculated using the previous equation:

Weighted Average Intensity =

$$\frac{[(25*6) + (16*10) + (9*10) + (4*10) + (10) + (-10) + (-4*10) + (-9*10) + (-16*10) + (-25*4)]}{(6+10+10+10+10+4+10+10+10+10+10)}$$

$$= \frac{(150+160+90+40+10-100-160-90-40-10)}{100}$$

Weighted Average Intensity = 0.5

2.2b Independent Variables

The following variables were used as independent variables in the analysis: dam density, population growth, drought frequency, water quality, mean annual precipitation, endangered species, and water withdrawals. These variables were selected based on information obtained from a survey of water managers in the region and from the literature.

The WWIN dataset contained 27 categories for the previously listed variables. Variables were divided into the following number of categories: water quality – 5 categories; population – 2 categories; drought frequency – 5 categories; endangered species – 5 categories; water use – 8 categories; dam density – 1 category; and precipitation – 1 category. A correlation matrix of all variables compiled from the WWIN was created to assess the data for multicollinearity. Variables with a bivariate correlation of greater than 0.80 were eliminated as independent variables (Larson 2004). After removing the highly correlated categories, the following 20 combinations remained: water quality – 5 categories; population – 1 category; drought frequency – 5 categories; endangered species – 5 categories; water use – 3 categories; dam density – 1 category; and precipitation – 1 category.

The number of variables was further reduced by combining the categories of selected independent variables; leaving the following nine variables: water quality, population density, dam density, drought frequency, mean annual precipitation, endangered species, irrigation withdrawals, domestic withdrawals, and groundwater withdrawals. Each case was assigned a 0 or 1 (dummy or indicator variable) for all variables, based on the following criteria.

Water Quality: 0 = no portion of the accounting unit has greater than 10% of its waters listed as impaired; 1 = some portion of the accounting unit has greater than 10% of its waters listed as impaired.

Population Density: 0 = accounting unit has less than the median population density; 1 = accounting unit has greater than the median population density.

Drought Frequency: 0 = more than 50% of the accounting unit experiences a Palmer drought index rating of -3 less than 10.12% of the time; 1 = more than 50% of the accounting unit experiences a Palmer drought index rating of -3 more than 10.12% of the time. This division point was selected, as this was how data were aggregated in the WWIN dataset.

Mean Annual Precipitation: 0 = accounting unit has less than the mean, mean annual precipitation; 1 = accounting unit has greater than the mean, mean annual precipitation.

Endangered Species: 0 = more than 50% of the accounting unit has less than 40 endangered species; 1 = more than 50% of the accounting unit has more than 40 endangered species.

Irrigation Withdrawals: 0 = accounting unit has less than the median irrigation withdrawals; 1 = accounting unit has greater than the median irrigation withdrawals.

Domestic Withdrawals: 0 = accounting unit has less than the median domestic withdrawals; 1 = accounting unit has greater than the median domestic withdrawals.

Groundwater Withdrawals: 0 = accounting unit has less than the median groundwater withdrawals; 1 = accounting unit has greater than the median groundwater withdrawals.

Dam Density: 0 = accounting unit has less than median dam density ; 1 = accounting unit has greater than median dam density.

With the exceptions of dam density and irrigation withdrawals, the variables used in this analysis were prominently mentioned in a 2003 survey of Reclamation water managers. Dan density and irrigation withdrawals were included following the example of previous work studies conducted by the TFDD team at Oregon State University. Data were converted to dummy variables in order to standardize the independent variables, and test for presence or absence of each criterion (Ramsey and Shafer 2002). This was done for the following reason. Data were not available for all years of the study in any of the 6-digit accounting units. Not all of the data categories are collected annually, and many of the data sets were aggregated from county level data. Because of this, an assumption was made that basins had the same relationship with each other with respect to the independent variables for the entire study period from 1970-2005. That is to say, for example, that basins with above median population densities in 2000 had above median population densities in 1970 and 2005.

3 Results and Discussion

3.1 Event Intensity

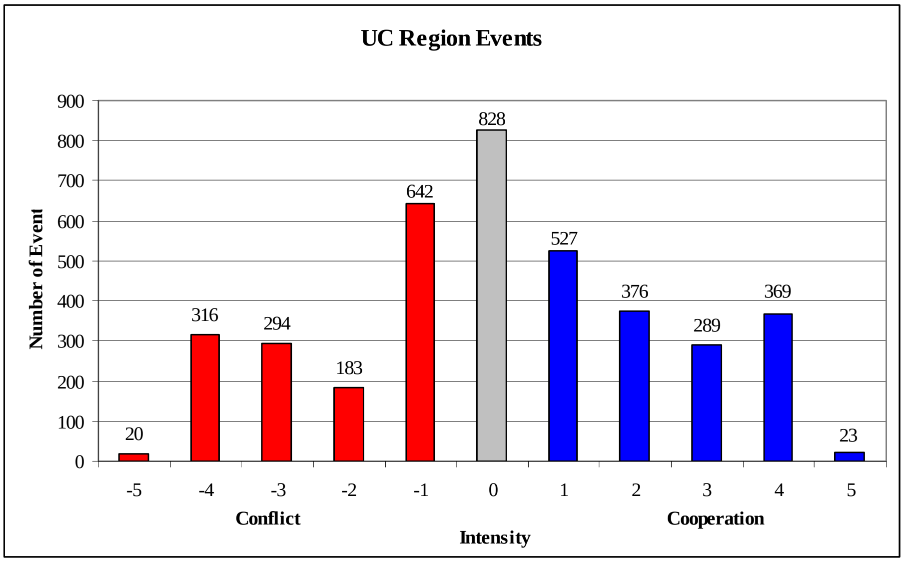

Figure 2. Distribution of hydropolitical events.

Of the 3,867 events analyzed, there was a nearly normal distribution of cooperative and conflictive events (Figure 2): 1,584 (41%) cooperative and 1,455 (38%) conflictive, the ratio equaling 1.09 (cooperative to conflictive). This pattern has been observed at both the international and U.S. state level scales (Yoffe et al. 2003; Fesler 2007). The most frequently occurring intensities were 0, -1, and +1, respectively. Events ranked 0 are neutral, while +1 and -1 ranked events refer to mild verbal support and dissent.

Although the study covered the years 1970 through 2005, the majority of events (3,485, 90%) occurred after 1994 (Figure 3). This reflects the nature of the Lexis-Nexis news coverage, much of which was only available after 1994. Looking at the distribution of intensities over time, there is an increasing number of low ranked events over time (Figures 3 and 4).

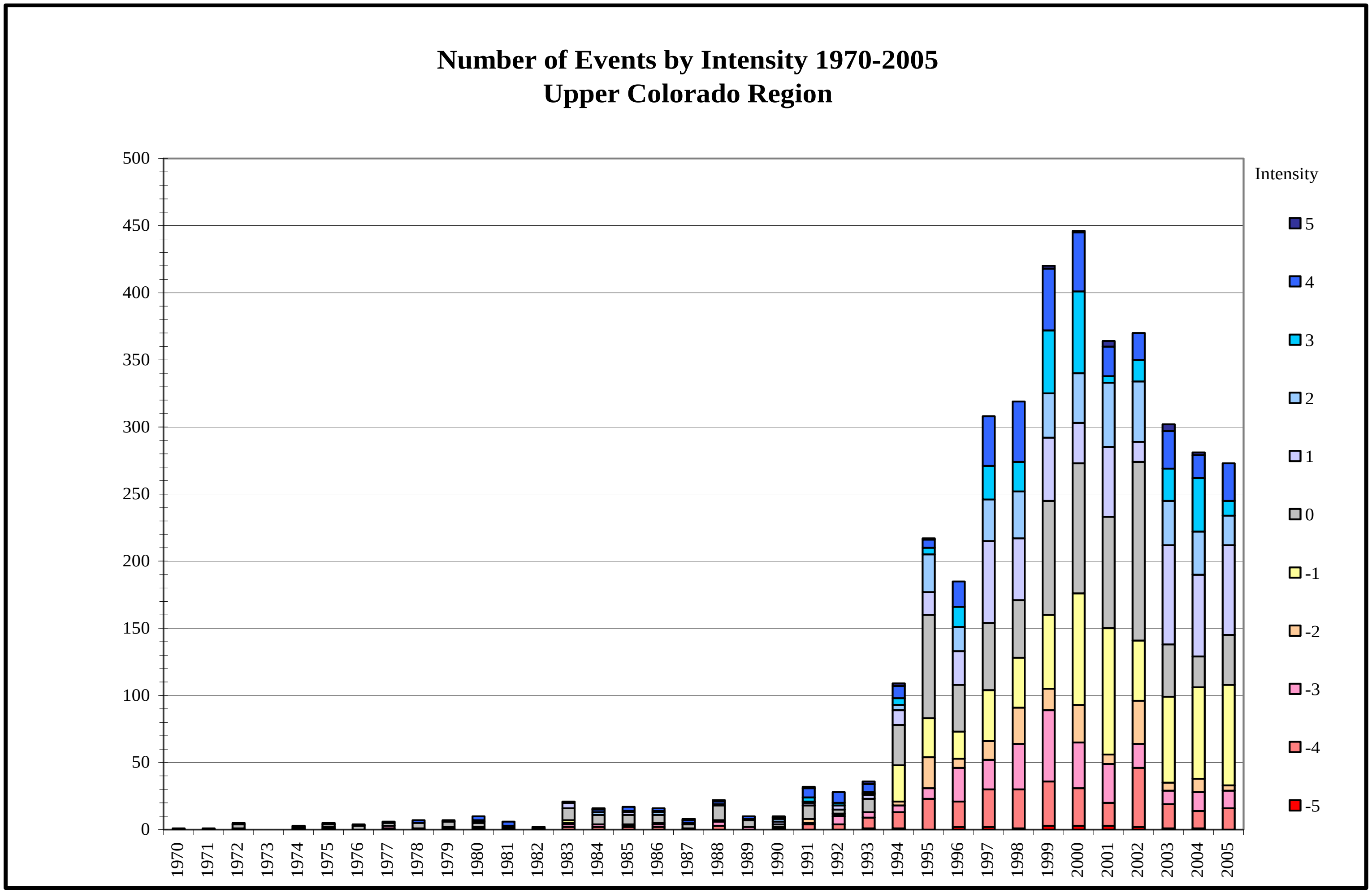

Figure 3. Total events per year categorized by event intensity.

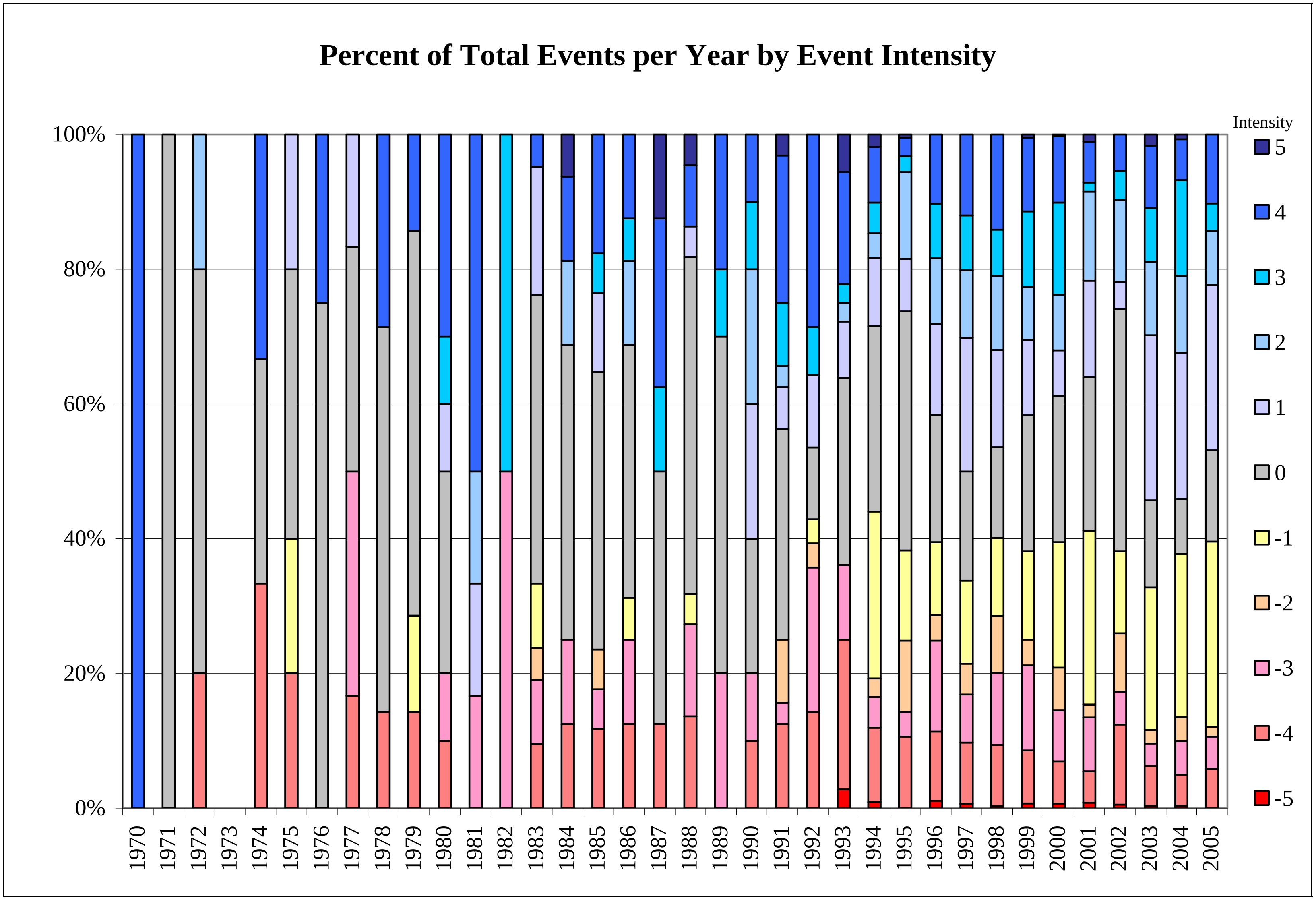

Figure 4 Percent of total events per year by event intensity.

3.2 Issue Type

In terms of frequency of occurrence, the following issue types topped the list: water rights, infrastructure, water quality, and intergovernmental (Table 5).

Table 5. Frequency of events for each issue type.

Issue Type	# Events	% Events
Water Rights	803	21
Infrastructure	780	20
Water Quality	664	17
Intergovernmental	616	16
Instream Use	302	8
Conservation	192	5
Groundwater	165	4
Drought	148	4
Transfer	95	2
Flooding	55	1
Fish Passage	35	1
Invasive Species	12	< 1
Total	**3,867**	

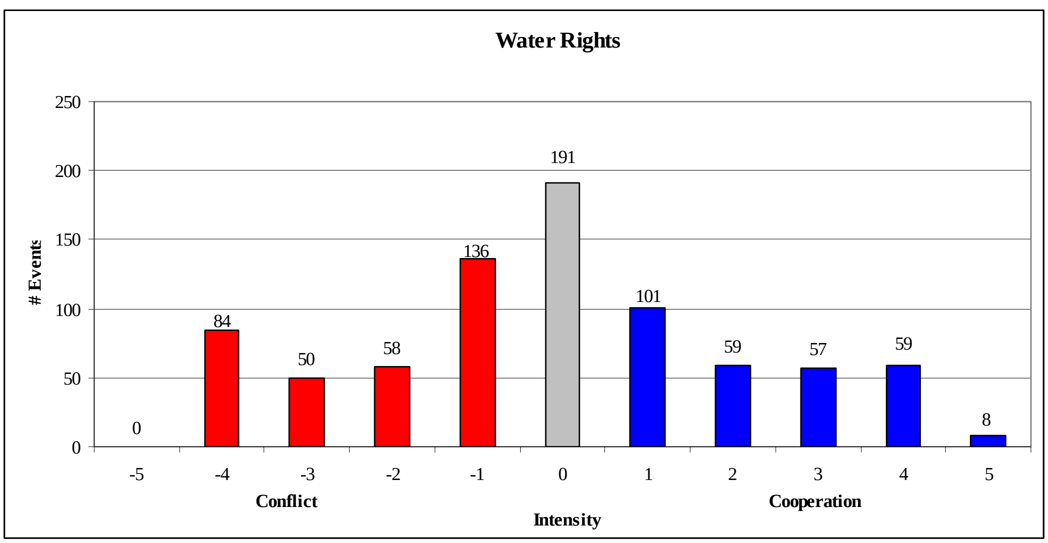

Figure 5. Distribution of water rights hydropolitical events.

Water rights events tended to be more conflictive (328, 41%) than cooperative (284, 35%) as illustrated in Figure 5. The cooperative to conflictive ratio was 0.87. 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.

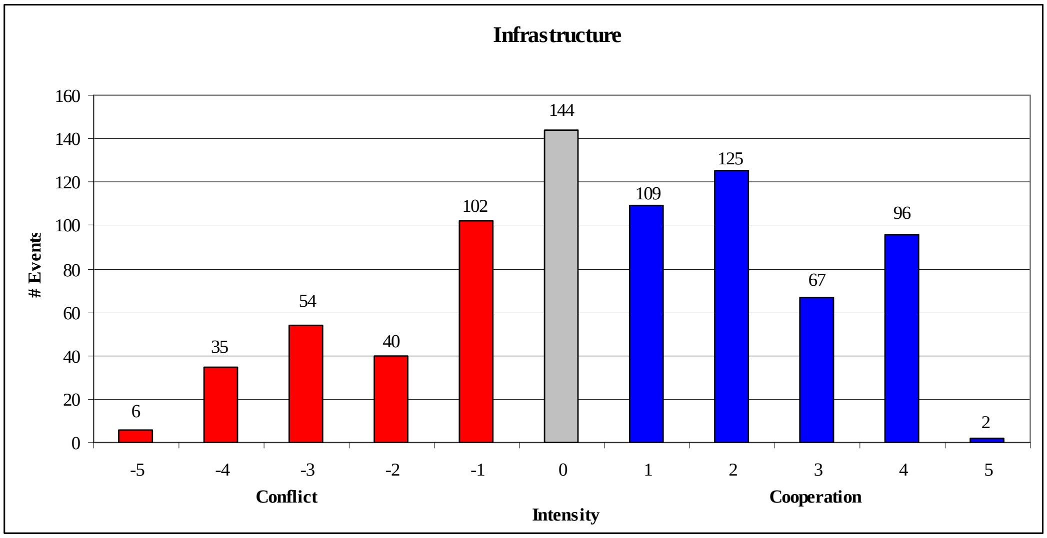

Figure 6. Distribution of infrastructure hydropolitical events.

Hydropolitical events relating to infrastructure tended to be more cooperative (399, 51%) than conflictive (237, 30%); with a cooperation to conflict ratio of 1.68. The high proportion of +2 and +4 events shows that people are willing to not only make proposals for collaboration, but also form collaborative groups when infrastructure is involved.

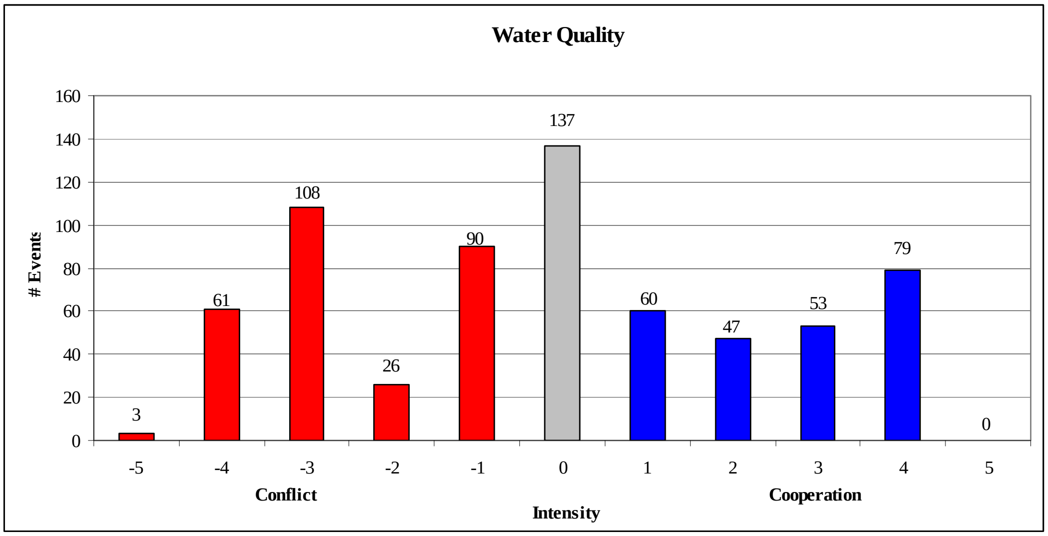

Figure 7. Distribution of water quality hydropolitical events.

Water quality events tended to be more conflictive (288, 43%) than cooperative (239, 36%), having a cooperation to conflict ratio of 0.83. The highest number of conflictive- water quality events were permit violations (-3). There were also a large number of +4 events, indicating a willingness to work together to manage water quality.

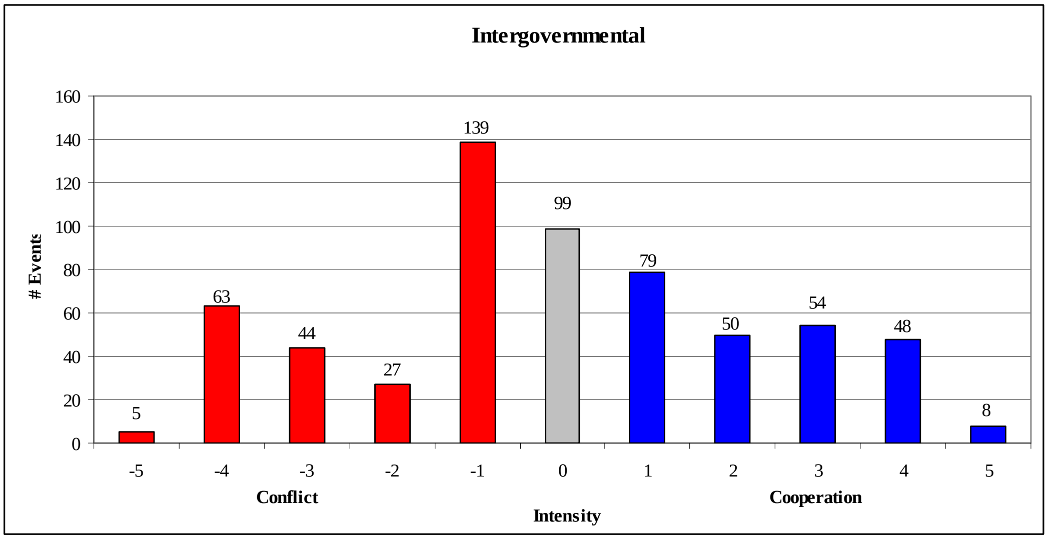

Figure 8. Distribution of intergovernmental hydropolitical events.

There were more events of intergovernmental conflict (278, 45%) than cooperation (239, 39%). The ratio of cooperation to conflict was 0.86. The largest number of both conflictive and cooperative events were mild verbal dissent (-1) and support (+1).

Table 6. The five most common issue types in the UC WWIS Events Database by decade.

Rank	1970s	1980s	1990s	2000s
1	Water Rights	Water Rights*	Infrastructure	Water Rights
2	Infrastructure	Intergovernmental*	Water Rights	Intergovernmental
3	Intergovernmental	Water Quality	Water Quality	Infrastructure
4	Water Quality	Infrastructure	Intergovernmental	Water Quality
5	Instream Use	Flooding	Instream Use	Instream Use
	* Same number of events.			

Of the twelve issue types coded, the four most common overall, water rights, infrastructure, intergovernmental, and water quality, were also the most common types in all decades (Table 6). Instream use is the fifth most reported in three of the decades.

Table 7. Top five 6-digit HUCS ranked by percentage of total events per HUC for each issue type (i.e. 12% of events in the Lower Bear were related to drought).

Conservation	**%**	**#**	**Drought**	**%**	**#**	**Fish Passage**	**%**	**#**	**Flooding**	**%**	**#**
Upper Canadian	**13%**	**4**	Lower Bear	**12%**	**7**	Upper Green	**5%**	**4**	Escalante Desert-Sevier Lake	**11%**	**15**
Mimbres	**12%**	**6**	Upper Bear	**11%**	**6**	Upper Colorado-Dirty Devil	**4%**	**5**	Upper Colorado-Dolores	**3%**	**2**
Upper Rio Grande	**8%**	**69**	Upper San Juan	**9%**	**51**	Lower San Juan	**3%**	**4**	Weber	**3%**	**4**
Rio Grande-Elephant Butte	**8%**	**139**	Rio Grande-Elephant Butte	**7%**	**121**	Upper Canadian	**3%**	**1**	Great Salt Lake	**3%**	**6**
Rio Grande Closed Basins	**7%**	**17**	Upper Rio Grande	**7%**	**59**	White-Yampa	**3%**	**3**	Jordan	**2%**	**10**

Groundwater	**%**	**#**	**Infrastructure**	**%**	**#**	**Instream Use**	**%**	**#**	**Intergovernmental**	**%**	**#**
Rio Grande Closed Basins	**12%**	**28**	Upper Canadian	**33%**	**10**	Rio Grande-Fort Quitman	**54%**	**55**	Lower Pecos	**36%**	**34**
Upper Pecos	**10%**	**27**	Upper San Juan	**29%**	**158**	Rio Grande-Amistad	**51%**	**60**	Upper Pecos	**34%**	**92**
Rio Grande-Elephant Butte	**6%**	**103**	Upper Bear	**28%**	**16**	Rio Grande-Caballo	**34%**	**50**	Rio Grande-Caballo	**32%**	**48**
Escalante Desert-Sevier Lake	**6%**	**8**	Lower Green	**28%**	**40**	Rio Grande Headwaters	**26%**	**52**	White-Yampa	**27%**	**24**
Great Salt Lake	**5%**	**12**	Weber	**28%**	**36**	Lower Pecos	**26%**	**24**	Rio Grande-Amistad	**24%**	**28**

Invasive Species	**%**	**#**	**Transfer**	**%**	**#**	**Water Quality**	**%**	**#**	**Water Rights**	**%**	**#**
Lower Bear	**4%**	**2**	Lower Pecos	**15%**	**14**	Gunnison	**70%**	**229**	Upper Colorado-Dolores	**73%**	**46**
Mimbres	**2%**	**1**	Lower Bear	**7%**	**4**	Lower San Juan	**47%**	**56**	Mimbres	**50%**	**25**
Colorado Headwaters	**2%**	**5**	Upper Pecos	**7%**	**18**	Upper Colorado-Dirty Devil	**40%**	**53**	Great Salt Lake	**41%**	**91**
Escalante Desert-Sevier Lake	**1%**	**2**	Rio Grande-Amistad	**6%**	**7**	Lower Bear	**39%**	**22**	Jordan	**37%**	**152**
Lower Pecos	**1%**	**1**	Upper Bear	**5%**	**3**	Colorado Headwaters	**38%**	**99**	Upper Rio Grande	**31%**	**260**

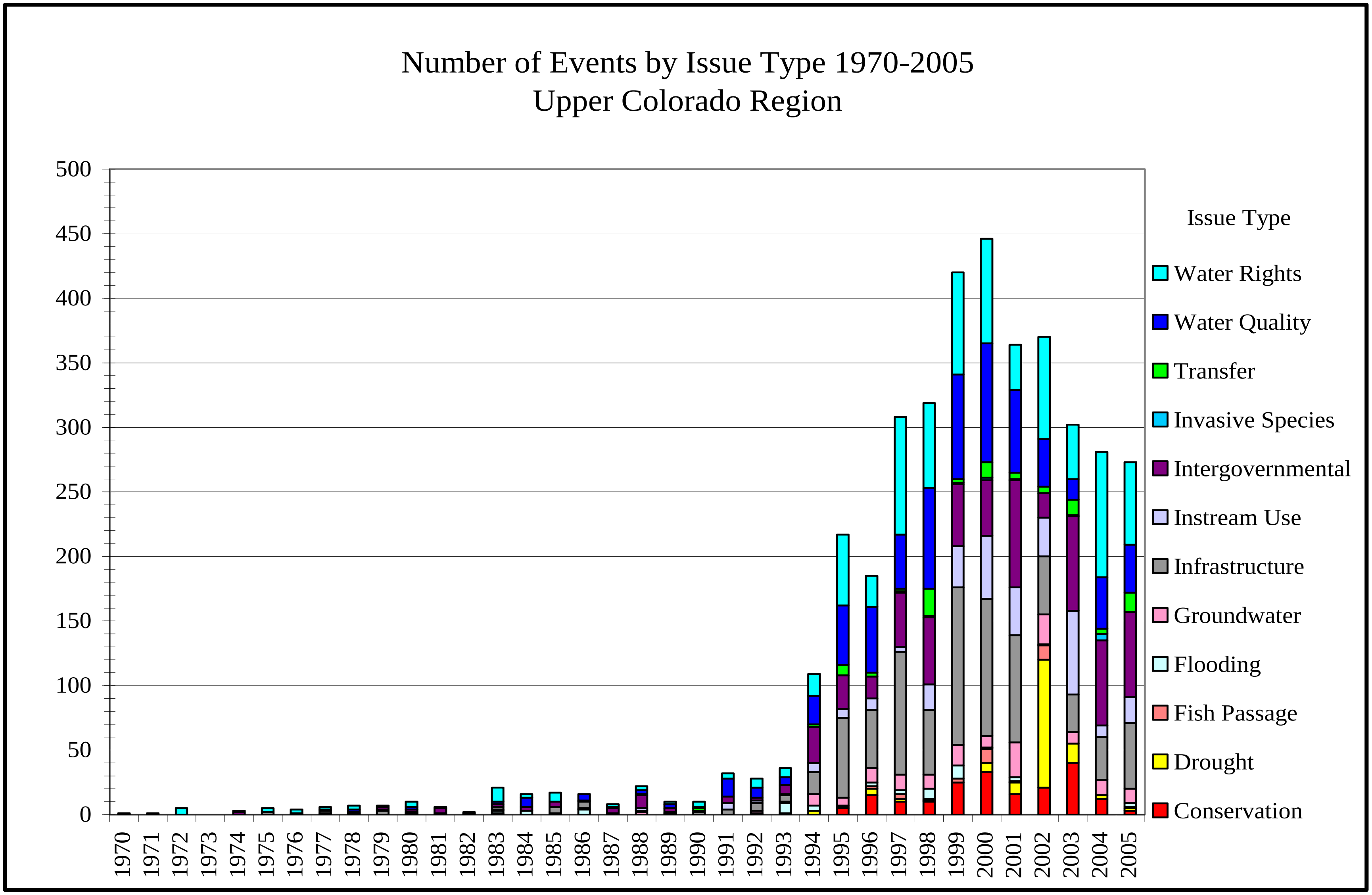

Figure 9 Total events per year categorized by issue type.

Looking at Figure 9, some trends in issue types emerge. From year to year, water rights is a major issue type. In 2001, there is a spike in the percentage of intergovernmental events. This corresponds to the Texas vs. New Mexico dispute over water deliveries. The year 2000 had the largest percentage of water quality events. This year saw agreements on the cleanup of the Moab tailings and Kennecott copper mine in Utah and agreements over water contamination caused by Los Alamos National Labs in New Mexico.

Another interesting pattern is the large percentage of drought related events in 2002, which was an extremely dry year, followed in 2003 by the largest percentage of conservation related events. The highest percentage of infrastructure related events was 1999, which saw several events relating to a proposed reservoir by the New Escalante Irrigation Company, including some violent threats.

3.3 Stakeholder Analysis

3.3a Event Intensity

Events were coded for the stakeholders involved. Eighteen categories of stakeholders were coded in the study (Table 8). Local governments were involved in the most events, followed by state governments and federal agencies. Of these different levels of government, only the state level had more involvement in conflictive events. This relates back to the intensity of water rights events. There were a large number of water rights litigations in the database, which falls in the lap of state government.

Railroads and environmental groups had the highest percentage involvement in conflictive events, while regional governments had the highest percentage in cooperative events. Railroads were involved in 23 events during the study period, 20 of which were related to water quality. Of these 23 events, 15 were conflictive, the largest number of which (11) were the issuance of citations for the spilling of pollutants into the water supply. The primary pollutant spilled was diesel fuel. Conservation districts and utilities had the highest percent of their total involvement in extremely conflictive and extremely cooperative events, respectively.

Table 8. The number and intensity of events by stakeholder group involved.

Stakeholder	Total	% Conflictive	% Cooperative	% Extremely Conflictive	% Extremely Cooperative
Local Government	1870	32%	44%	28%	23%
State Government	1276	41%	38%	24%	24%
Federal Government	1151	37%	42%	25%	26%
Private Citizens	824	47%	33%	23%	23%
Utilities	457	39%	40%	30%	33%
Water User Groups	392	38%	43%	29%	32%
Native American	379	40%	41%	27%	21%
Businesses	348	47%	35%	26%	26%
Environmental Groups	348	52%	32%	32%	19%
Developers	304	47%	35%	18%	27%
Agriculture Groups	230	39%	44%	18%	26%
Mining Interests	193	47%	34%	25%	26%
Conservation Districts	174	37%	47%	34%	20%
Other Interest Groups	156	29%	56%	26%	23%
Recreation Interests	115	40%	46%	33%	21%
Regional Governments	74	27%	62%	20%	17%
Railroads	23	65%	35%	13%	25%

3.3b Issue Type

Stakeholder groups were ranked for all issue types in the hydropolitical events database (Table 9). Environmental groups were primarily concerned with issues relating to endangered species and habitat in the category of instream use. Over half of the events involving Native Americans were in the category of water rights. The groups with the largest percentage of events in a single category were railroads and mining, 87% and 70% respectively, both in water quality. Thirty percent of recreation interests' events were over water rights. Private citizens too had a high percentage of events related to water rights. Although these groups didn't make the top five list, agriculture and water users had the highest percentage of their events over water rights.

The different levels of government were involved in different types of events. The largest percentage of events local governments were involved in related to infrastructure. Nearly one-third of the events state governments were involved in were focused on water rights. The federal government had the largest share of its events in water quality, 24%, followed by instream use, 17%. Regional governments were involved mostly in intergovernmental events.

Table 9. The top 5 stakeholder groups for each issue type by percentage of each group's total events (i.e. 87% of the events involving railroads are related to water quality.)

Conservation	**Drought**	**Fish Passage**	**Flooding**
Local Government (8%)	Business (11%)	Other Interest Group (3%)	Private Citizen (3%)
Private Citizen (8%)	Conservation District (6%)	Federal Government (2%)	Federal Government (2%)
Regional Government (7%)	Environment (6%)	Environment (2%)	Water Users (2%)
Business (5%)	Local Government (6%)	Regional Government (1%)	Environment (2%)
Agriculture (5%)	Agriculture (4%)	Recreation (1%)	Developer (2%)

Groundwater	**Infrastructure**	**Instream Use**	**Intergovernmental**
Agriculture (7%)	Developer (31%)	Environment (28%)	Regional Government (30%)
State Government (6%)	Other Interest Group (31%)	Regional Government (18%)	Utility (25%)
Private Citizen (5%)	Utility (30%)	Federal Government (17%)	Recreation (23%)
Local Government (5%)	Water Users (27%)	Conservation District (14%)	Conservation District (22%)
Developer (5%)	Local Government (24%)	Recreation (14%)	Water Users (21%)

Invasive Species	**Transfer**	**Water Quality**	**Water Rights**
Federal Government (1%)	Conservation District (10%)	Railroad (87%)	Native American (52%)
Other Interest Group (1%)	Regional Government (7%)	Mining (70%)	State Government (30%)
Environment (1%)	Agriculture (4%)	Business (46%)	Recreation (30%)
Business (< 1%)	Other Interest Group (4%)	Environment (26%)	Private Citizen (29%)
Native American (< 1%)	Water Users (3%)	Federal Government (24%)	Developer (29%)

3.4 Spatial Analysis

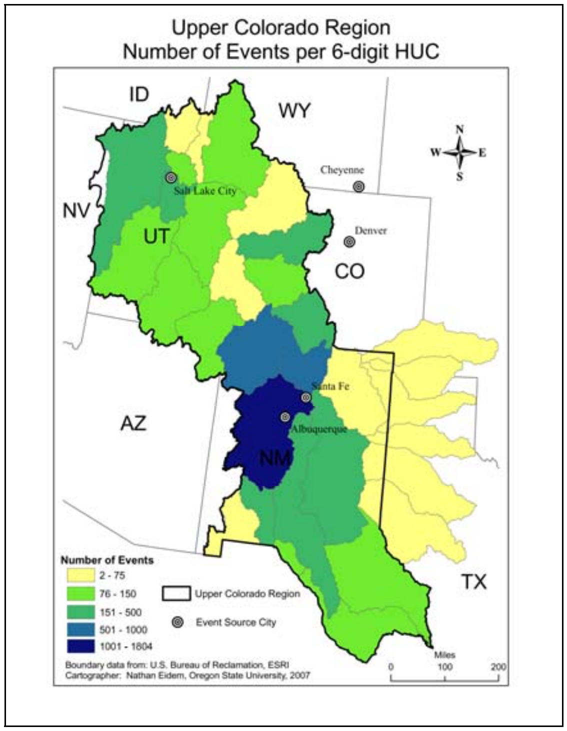

Figure 10. Number of news events per HUC. Locations of event sources shown.

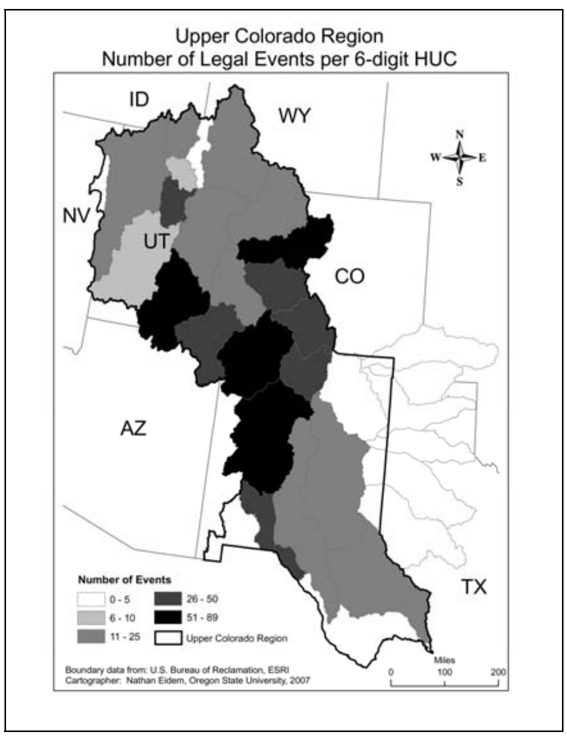

Figure 11. Number of legal events per HUC.

The distribution of events throughout the UC Region (Figure 10) follows the numbers in Table 1 relating to the number of events per source. The accounting units with the most events are in close proximity to the news sources. The largest percentage of both news and legal events (Figure 11) occurred in Rio Grande-Elephant Butte, the location of both Albuquerque and Santa Fe. The Upper Rio Grande and Upper San Juan accounting units also had high numbers of both news and legal events. The Colorado Headwaters and Upper Colorado-Dirty Devil accounting units were both subject to high numbers of legal events (Figure 11).

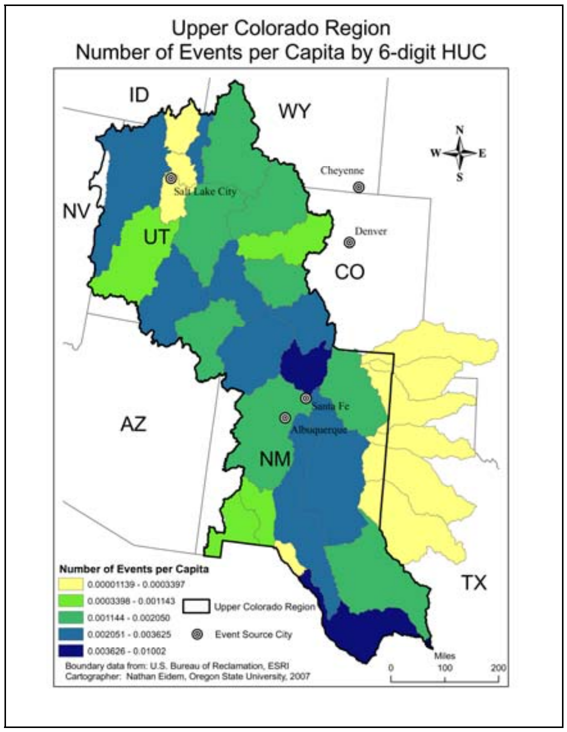

Figure 12. News events per capita. Locations of event sources shown.

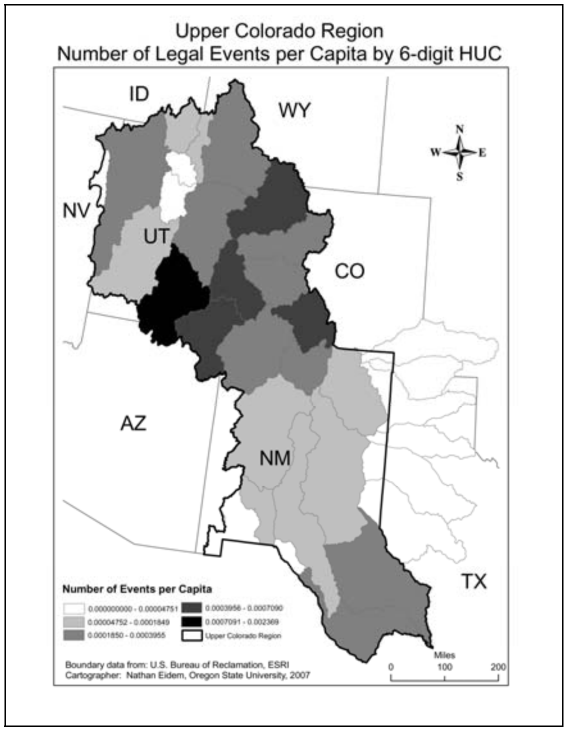

Figure 13. Legal events per capita.

Normalizing the events for population shows a different pattern. Data were normalized using 2000 Census data, as population data aggregated to 6-digit HUCS were not available for all years of the study. The assumption underlying this decision, is that those hydrologic units with high populations have had high populations relative to the other hydrologic units over the period of 1970-2005. The Upper Colorado-Dirty Devil accounting unit is the only watershed that has both a high number of legal events and a high number of legal events per capita (Figure 13). Looking at news events per capita (Figure 12), the pattern becomes more varied around the UC Region. Both Rio Grand-Amistad and Upper Rio Grande show a lot of activity per person, while Rio Grande-Elephant Butte drops to the middle range of events per capita. The Jordan accounting unit, which contains Salt Lake City and two news sources, shows the same two-category decline. The Upper San Juan accounting unit maintains its position in the second highest category in both number of news events and events per capita.

3.4a Issue Type by Accounting Unit

The next set of maps (Figures 14-21) show the spatial distribution of the four most frequently occurring issue types, water rights, infrastructure, water quality, and intergovernmental, as a percentage of total events per accounting unit. The Upper Green shows high percentages of both water rights related news and legal events (Figures 14 and 15). The Upper and Lower Pecos had high percentages of water rights related news events, but low percentages of legal events. The opposite is true of the White-Yampa accounting unit.

Utah accounting units experienced the most interaction over infrastructure (Figure 16). The state had several events relating to the Central Utah Project and the construction of flood control structures. The Upper Colorado-Dirty Devil accounting unit had the highest percentage of infrastructure related legal events (Figure 17).

The accounting units within the UC Region with the highest percentage of water quality events (Figure 18) were the Upper Colorado-Dolores and Mimbres HUCs. Additionally, five of six accounting units on the eastern edge of the region had high percentages of water quality events. These HUCs had very few events reported, and the majority of these units' areas is outside of the UC Region. In terms of legal events (Figure 19), the accounting units in western Utah had the highest percentage related to water quality, along with the Mimbres and Rio Grande-Amistad units. A large number of litigations in western Utah focused on the Tooele chemical agent disposal facility, Legacy Parkway, and on increased stream temperatures from pipelines.

The spatial distribution of intergovernmental news events is fairly evenly distributed across the UC Region (Figure 20), while the Upper and Lower Pecos had the highest percentage of intergovernmental legal events; again relating to the Texas vs. New Mexico lawsuit (Figure 21).

Interestingly, there is little similarity when comparing the distribution of news events with the distribution of legal events. This does make sense when considering the range of event intensities coded in the news event database. The legal event database only captures a portion of litigations, all the same intensity, which makes it a much smaller dataset. The news event database captures a wide range of intensities, including litigations. The news events database even captures some of the litigations left out of the legal database, as it doesn't discriminate against those in which an out-of-court settlement was reached.

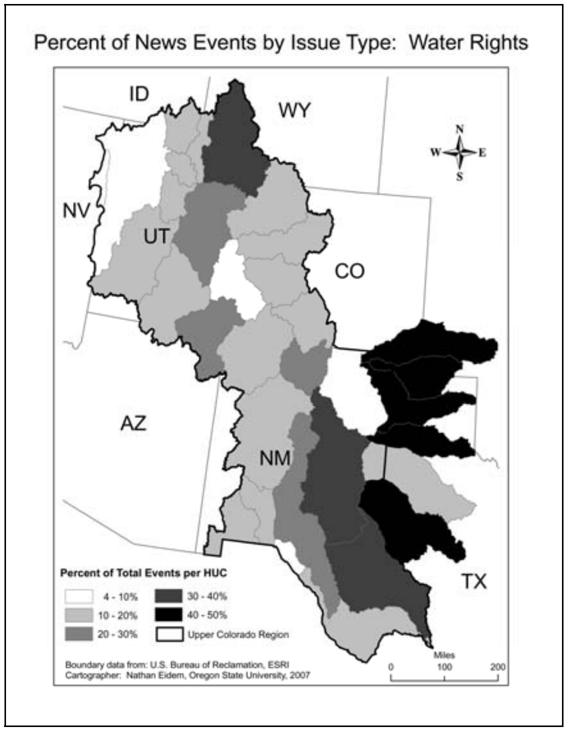

Figure 14. Percent of total news events per HUC that are water rights related.

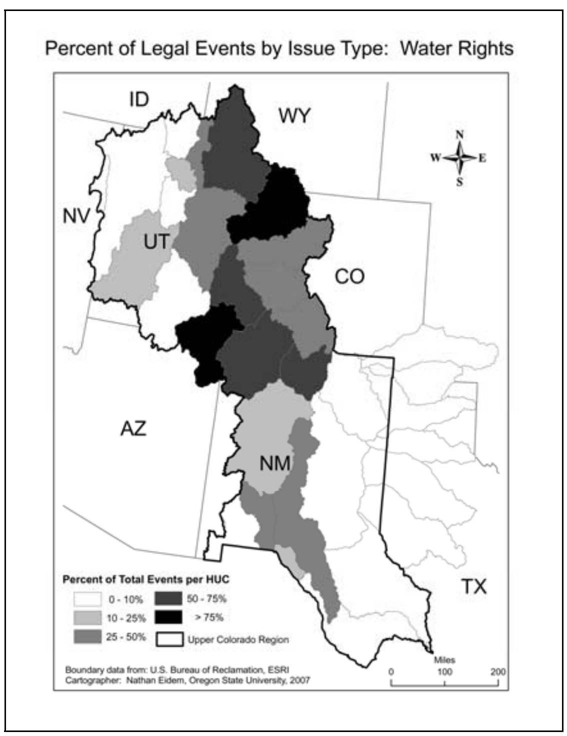

Figure 15. Percent of total legal events per HUC that are water rights related.

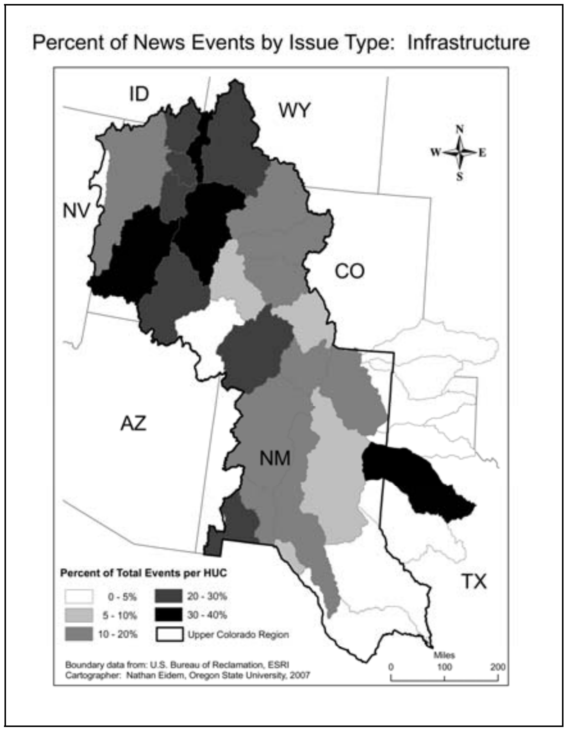

Figure 16. Percent of total news events per HUC that are infrastructure related.

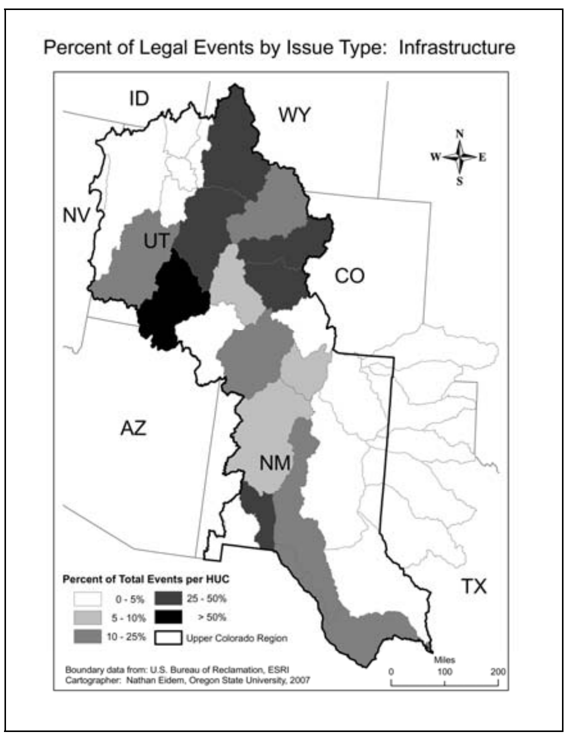

Figure 17. Percent of total legal events per HUC that are infrastructure related.

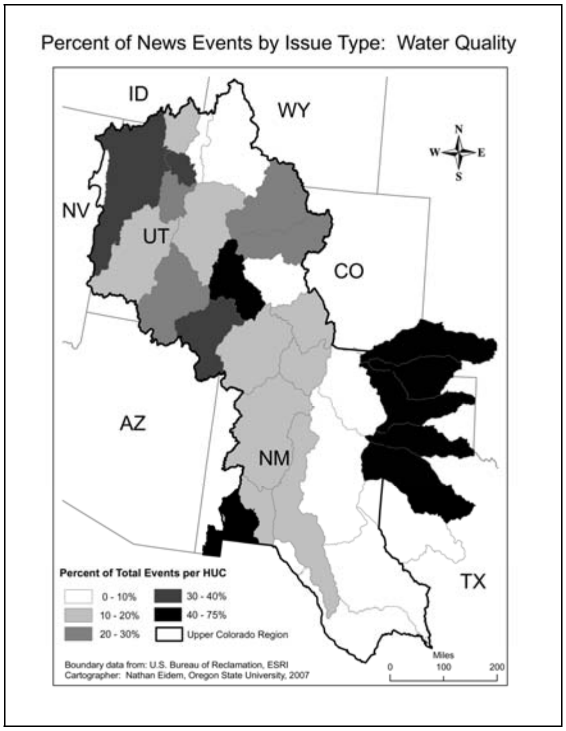

Figure 18. Percent of total news events per HUC that are water quality related.

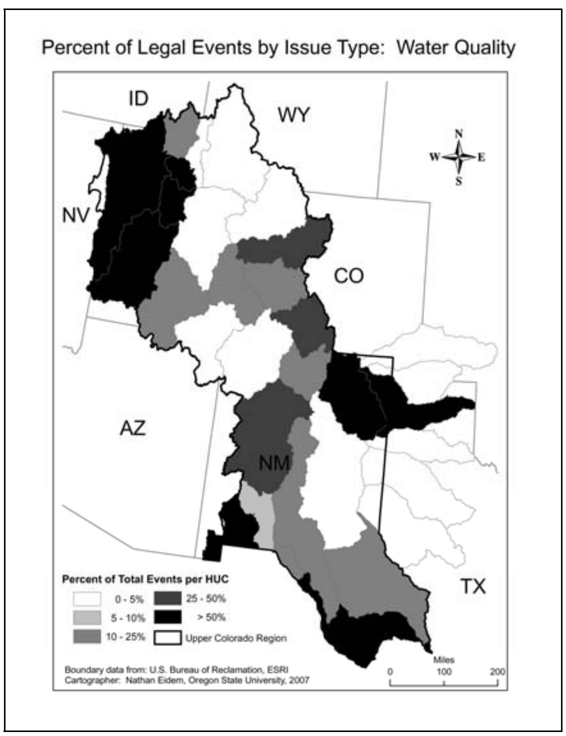

Figure 19. Percent of total legal events that are water quality related.

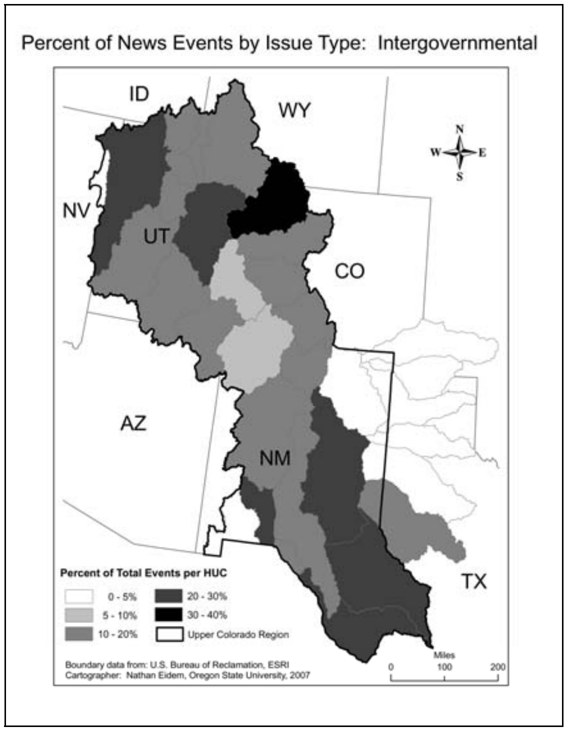

Figure 20. Percent of total news events per HUC that are intergovernmental related.

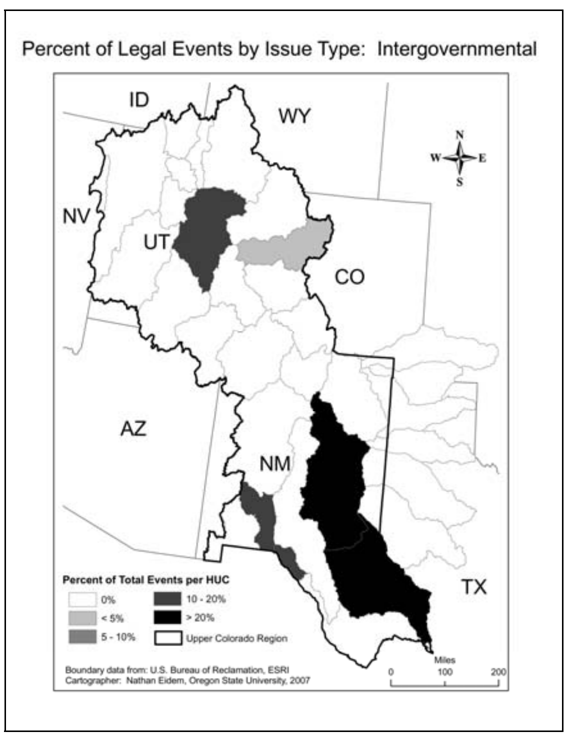

Figure 21. Percent of total legal events per HUC that are intergovernmental related.

3.4b Issue Type Across Space and Time

Figures 22 through 25 show the composition of issue types for each accounting unit by decade. Several patterns emerge when the maps are compared. Water rights events dominated the UC Region during the 1970s, and maintained a presence in all decades. In the 1980s, infrastructure events were prevalent in northern Utah. Utah also experienced a fair amount of intergovernmental related events. Instream use events began to appear in the headwater regions of both the Colorado River basin and Rio Grande river basin during this decade. In southern New Mexico and Texas, intergovernmental related events spread and increased in number. Events relating to water quality were spread throughout the UC Region.

The 1990s saw a decrease in the percentage of infrastructure events in northern Utah, but this issue type spread throughout the state and across the region. A lower percentage of water quality events occurred, but the issue type appears in nearly all accounting units. The percentage of intergovernmental events also declined, but this issue type too spread to most watersheds. This decade saw an increase in the number of instream use events, as they spread across the region.

In the current decade, infrastructure related events hold steady across the UC region. Intergovernmental events have declined as a percentage of total events in southern NM and Texas, where instream use has become the dominant issue type. Instream use has also re-emerged as the dominant issue type where it first appeared, the Upper Rio Grande and Gunnison accounting units. Intergovernmental events have become dominant in several basins in Colorado and Utah. Although it is a small percentage of total events, groundwater is becoming an issue across the Upper Colorado region. Together, these maps show how issue type composition changes across the region and through time.

It is important to keep in mind the limitations of the database when looking at these maps. As discussed in section 3.1, the majority of events captured occurred after 1994. Seemingly, there is an increase in the diversity of issue types over time. This can most likely be explained by the lack of electronic media reports prior to 1994. It does stand to reason, however, that the diversity of events would change over time, especially in basins experiencing population growth and those home to endangered species, as the water available in the system becomes fully allocated.

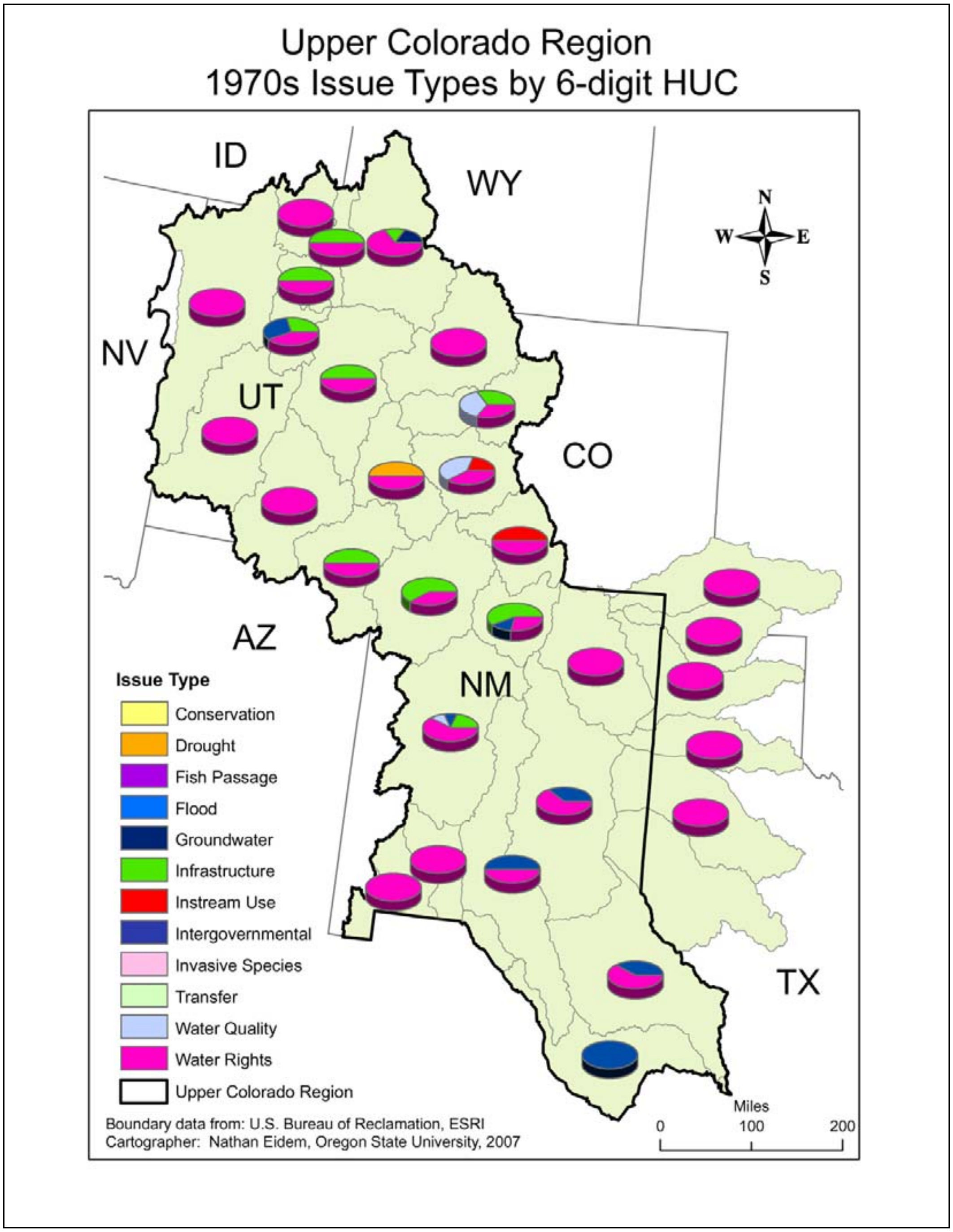

Figure 22. Events from the 1970s mapped by issue type. Each pie chart represents the total events that occurred in a 6-digit HUC.

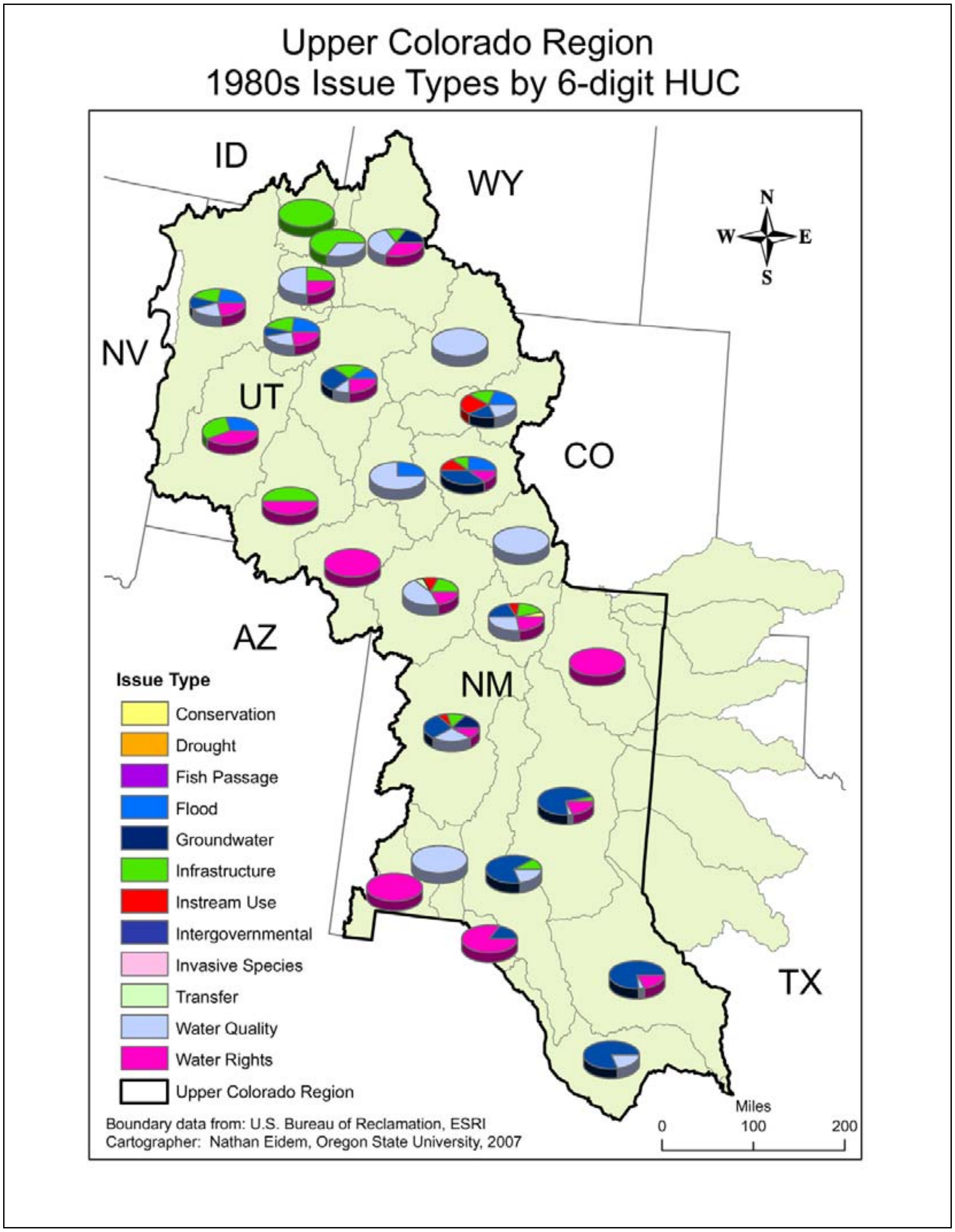

Figure 23. Events from the 1980s mapped by issue type. Each pie chart represents the total events that occurred in a 6-digit HUC.

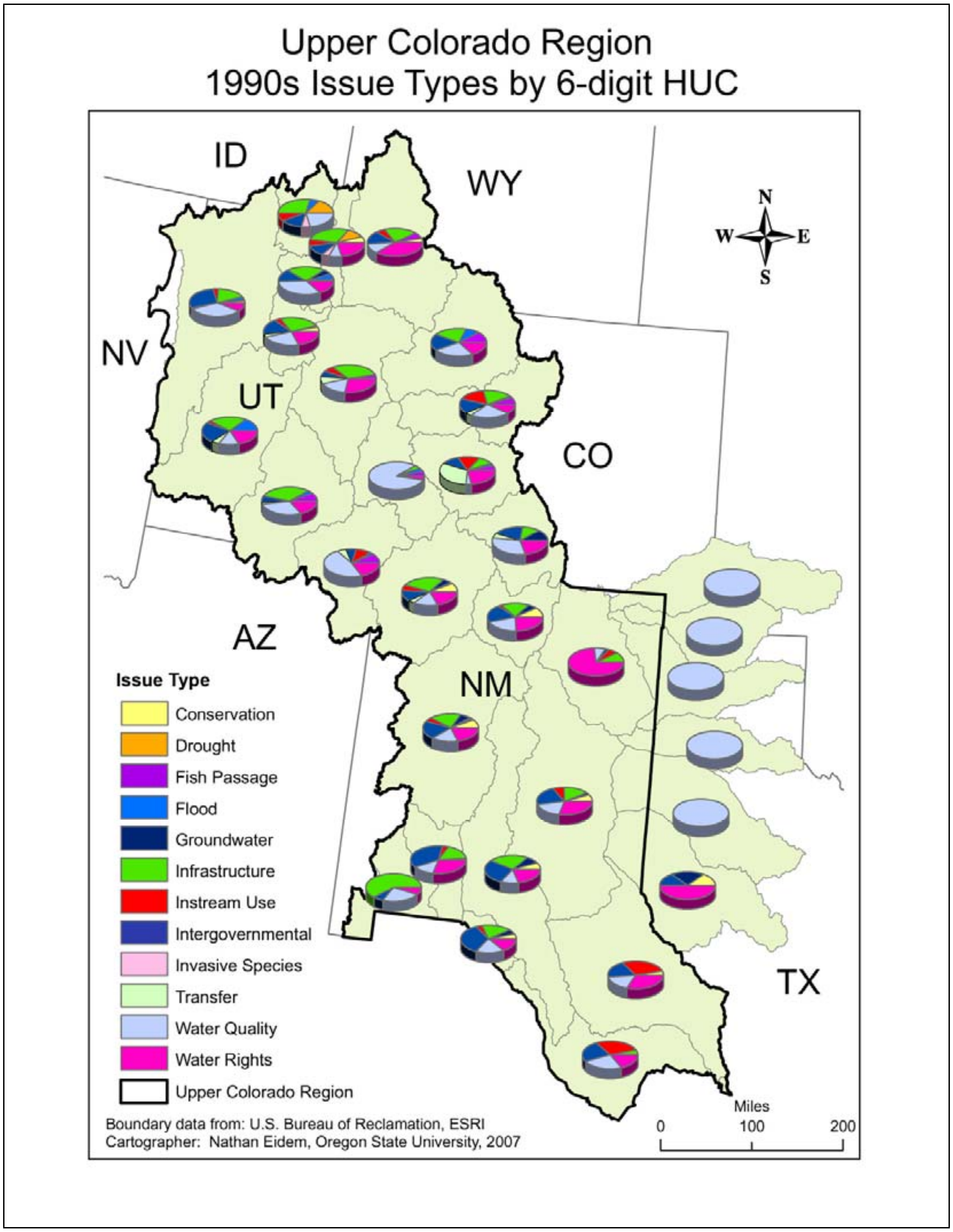

Figure 24. Events from the 1990s mapped by issue type. Each pie chart represents the total events that occurred in a 6-digit HUC.

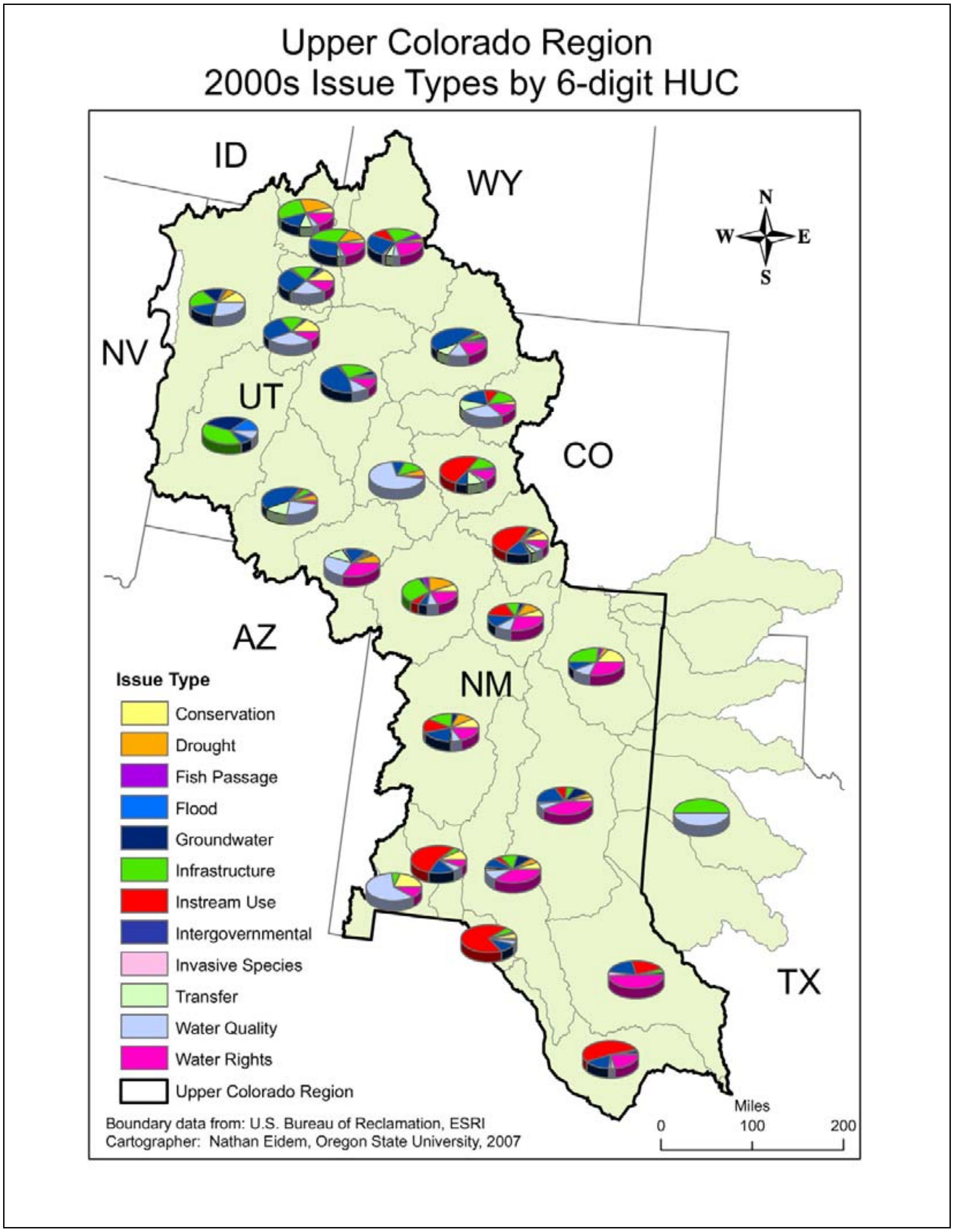

Figure 25. Events from the 2000s mapped by issue type. Each pie chart represents the total events that occurred in a 6-digit HUC.

3.4c Intensity Across Space and Time

The following sets of maps compare weighted average intensities across the UC Region by decade. Looking at total average intensity, few spatial patterns emerge (Figure 26a-d). The Upper Green, Lower Green, and Upper Colorado-Dirty Devil do become more conflictive over time.

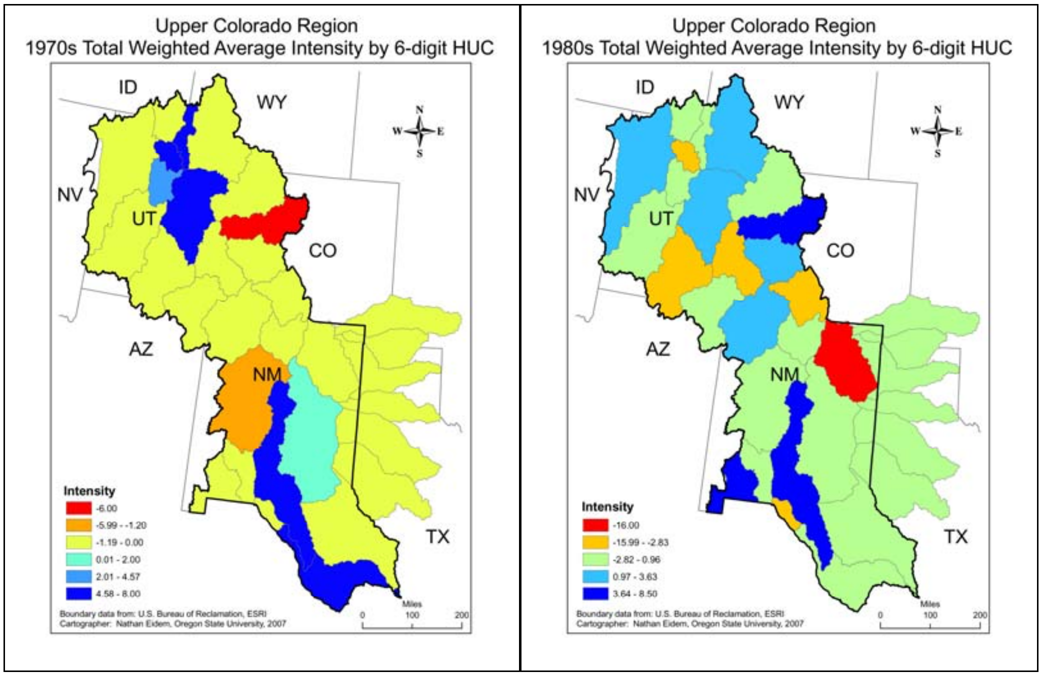

Figure 26 a,b. Total weighted average intensity by decade.

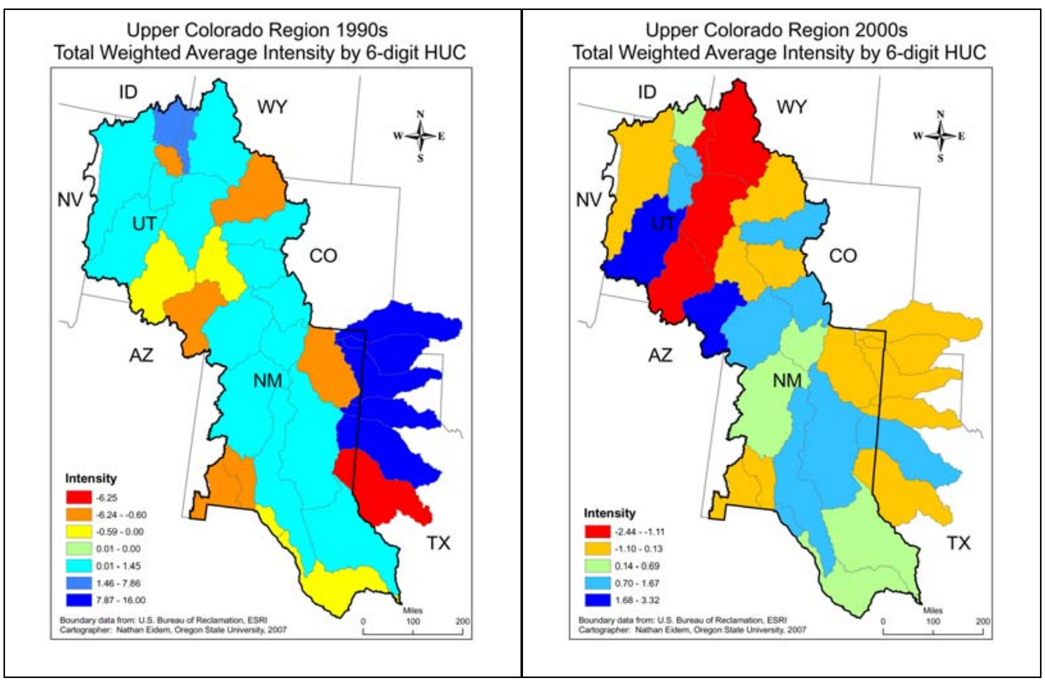

Figure 26 c,d. Total weighted average intensity by decade**.**

Hydropolitical intensity varies across space and time. All accounting units experience shifts in the intensity of interaction. Additionally, the range of intensities across the UC Region changes over time. There are no discernable patterns of change, however.

Weighted average conflictive intensities were mapped by decade (Figures 27a-d). The Upper and Lower Pecos had high conflictive intensities in the 1970s, relating to the Texas vs. New Mexico lawsuit. There were high conflictive intensities across Utah during the 1980s. The Gunnison accounting unit shows a high conflictive intensity in all decades except the 1990s. Here, a majority of the major conflictive events were related to Black Canyon and the Union Park diversion. The Upper Green basin was consistently among the basins with the highest conflictive averages, but did see a decline in conflict in the current decade.

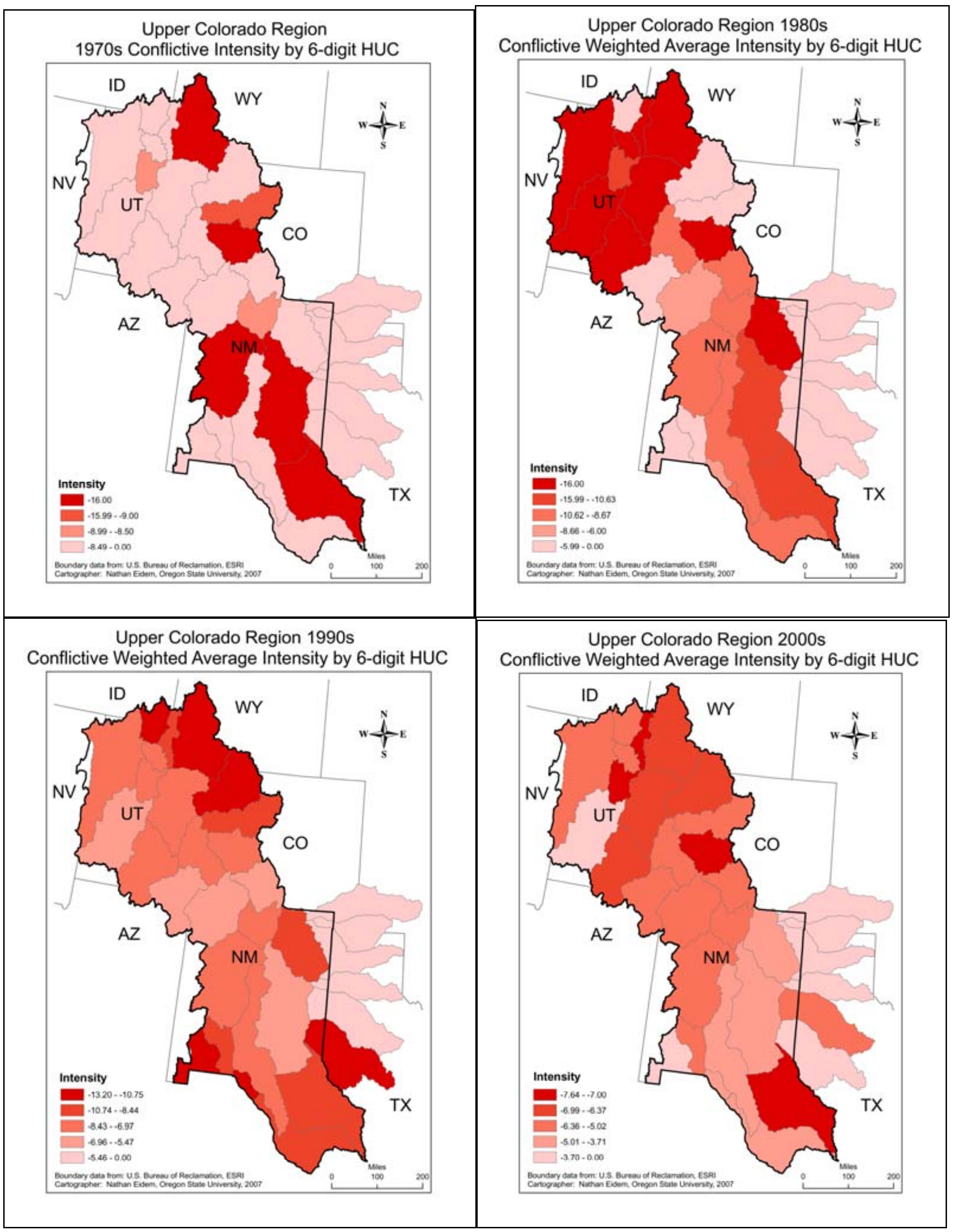

Figure 27 a,b,c,d Total weighted average conflictive intensity by decade.

Some interesting trends emerge when looking at the spatial distribution of weighted average cooperative intensities (Figures 28a-d). The regions that showed the highest conflictive intensities also have the highest cooperative intensities. There is also an increasing trend toward cooperation across the UC Region from the 1990s to 2000s.

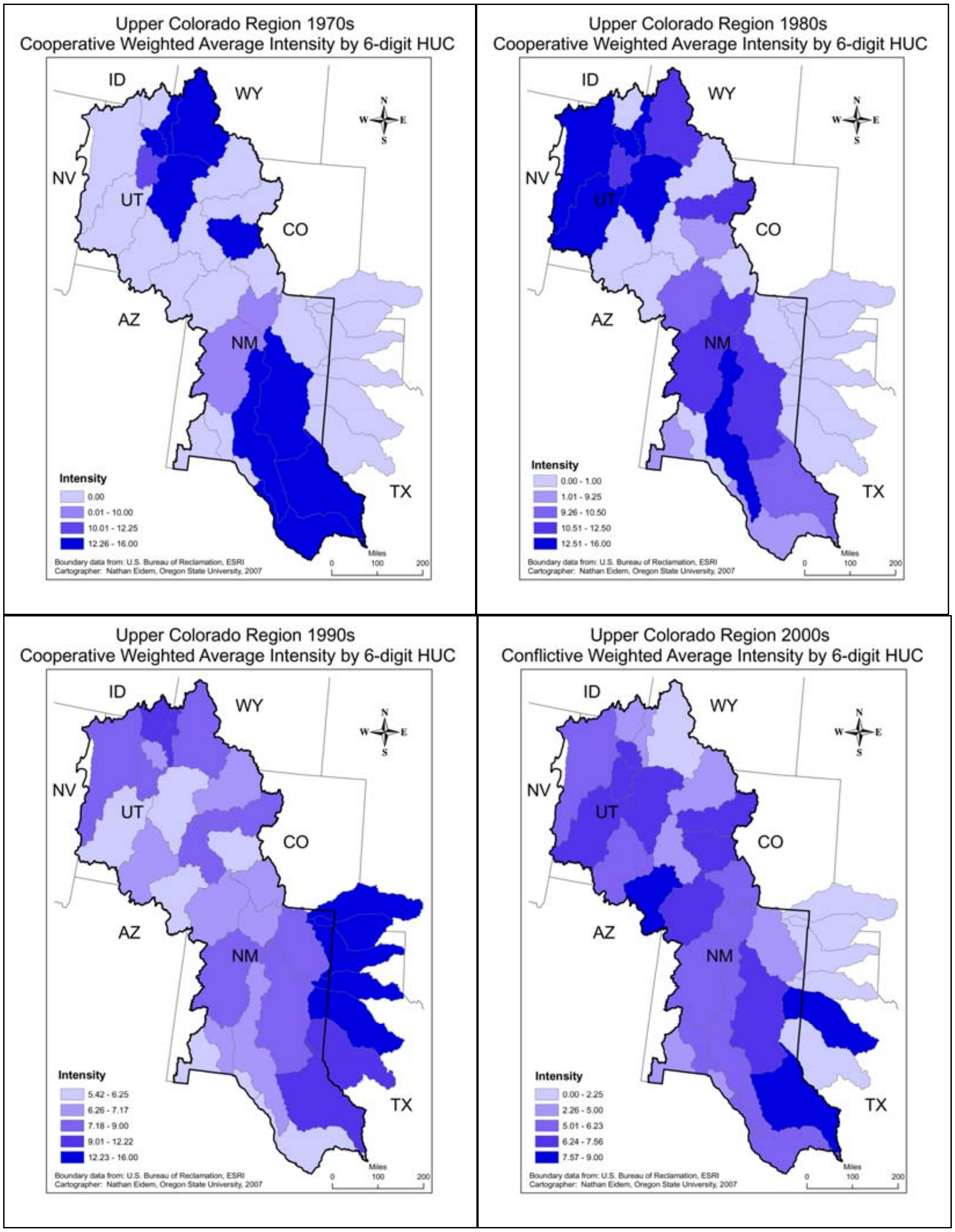

Figure 28 a, b, c, d. Total weighted average cooperative intensity by decade.

3.5 Non-Parametric Multiplicative Regression Analysis

Previous research on hydropolitical events (Yoffe 2001; Fesler 2007) employed simple ordinary least squares regression to identify relationships between intensity and various predictor variables. Neither of these studies yielded any statistically significant results. The use of ordinary least squares regression to analyze event data is common [See Goldstien 1992, Schrodt 1993, Yoffe 2001, Shellman 2004, and Fesler 2007 for examples.], however event data do not meet the requirements of independence and random sampling for this type of analysis (Abdi 2003). Schrodt (1994, p. 2) provides a good discussion of the statistical nature of event data:

> *"Despite their prevalence in contemporary quantitative studies, event data are odd statistical objects: they are nominal random variables occurring at irregular intervals over time subject to non-random selection bias. The conventional statistical repertoire has almost no techniques explicitly designed for such data and, ... virtually no original statistical work has been undertaken to fill these gaps. As a consequence, event data are commonly aggregated and then analyzed using interval level statistical techniques."*

Both Yoffe (2001) and Fesler (2007) employed simple linear regression to look for relationships between hydropolitical intensity and various independent variables. Given the nature of water resources, and the inter-relatedness of its uses, users, and issues surrounding its use, it was deemed more appropriate to use a multiple regression approach in an attempt to identify predictors of conflict or cooperation in this study. Here again, the issue of appropriate statistical analysis method arises. Rather than continue to try and fit a square peg, hydropolitical event data, into a round hole, ordinary least squares regression, a nonparametric approach was employed. Rather than applying a global, straight line relationship to the entire dataset at once, as is the case with ordinary least squares regression, nonparametric regression uses the opposite approach. This approach starts with a local model, a relationship fit to each data point, and using a kernel function, weights each point in relation to the target point. No global model is specified, and in the end, it can take any form (McCune 2006).

Nonparametric multiplicative regression (NPMR) was used in this study, as it provides a means of analyzing multiple predictor variables to a single response variable without the assumptions required by multiple ordinary least squares regression. NPMR was developed by ecologists for habitat modeling (McCune 2006). As is the case with modeling habitats, modeling hydropolitcal intensity involves non-linear relationships between several, potentially inter-related variables (Yoffe 2001; Fesler 2007). Advantages of using NPMR include: its allowance for both categorical and quantitative predictors; its use of multiplicative, as opposed to additive, weighting; and its use of cross-validation in variable selection, which reduces the chance of overfitting. NPMR also allows for small sample sizes, which is a problem in multiple linear regression, as the number of predictors included in a model is dependent on the size of the sample. NPMR allows for the use of many predictor variables, without regard for sample size. For a more thorough discussion of multiplicative nonparametric regression, see McCune 2006.

Using the local mean model available in the HyperNiche software package, the variables discussed in section 2.2b were used as predictor variables, while the three weighted intensities were used as response variables. Predictor and response variables were calculated for all 6-digit accounting units in the study area. Initially, there were 32 cases to use in the statistical analysis, however, the number of cases was reduced to 26, as outlying accounting units were removed (Upper Cimarron, Upper Beaver, Middle Canadian, Prairie Dog Town Fork Red, Brazos Headwaters, and Upper Colorado). These accounting units all had fewer than ten events coded for the entire period of study, and the majority of the area of all of these units is outside the UC Region.

HyperNiche performed an exhaustive search of all possible combinations of predictor and response variables, producing more than 4,400 potential models. The best model produced had an R2 value of 0.511. This model incorporated the following predictor variables: groundwater withdrawals, impaired waters, and drought frequency. Drought frequency and groundwater withdrawals had the highest coefficients in the model, 0.36 and 0.39 respectively. This software allows for the creation of 3-D surfaces of a single response versus two predictor variables from the model selected. Surfaces were produced for all combinations of predictor variables in the best model. Only the combination of groundwater withdrawals and drought frequency versus weighted average intensity produced a continuous surface (Figure 29).

Although the model is not a good fit, some interesting relationships in the data can be seen in this surface. Weighted average intensity increases the most (becomes more cooperative) in accounting units in which 50% of the HUC experiences a Palmer Drought Index score of -3 more than 10.12% of the time, and has less than the median of groundwater withdrawals for the 26 HUCs in the UC Region. In other words, cooperation is higher when intense drought is more frequent and ground water withdrawals are low. Weighted average intensity decreases (becomes more conflictive) when intense drought occurs less frequently and groundwater withdrawals are low. When groundwater withdrawals are above the median, the level of intensity is approximately the same regardless of the frequency of intense droughts, although they are slightly higher when intense droughts occur more frequently.

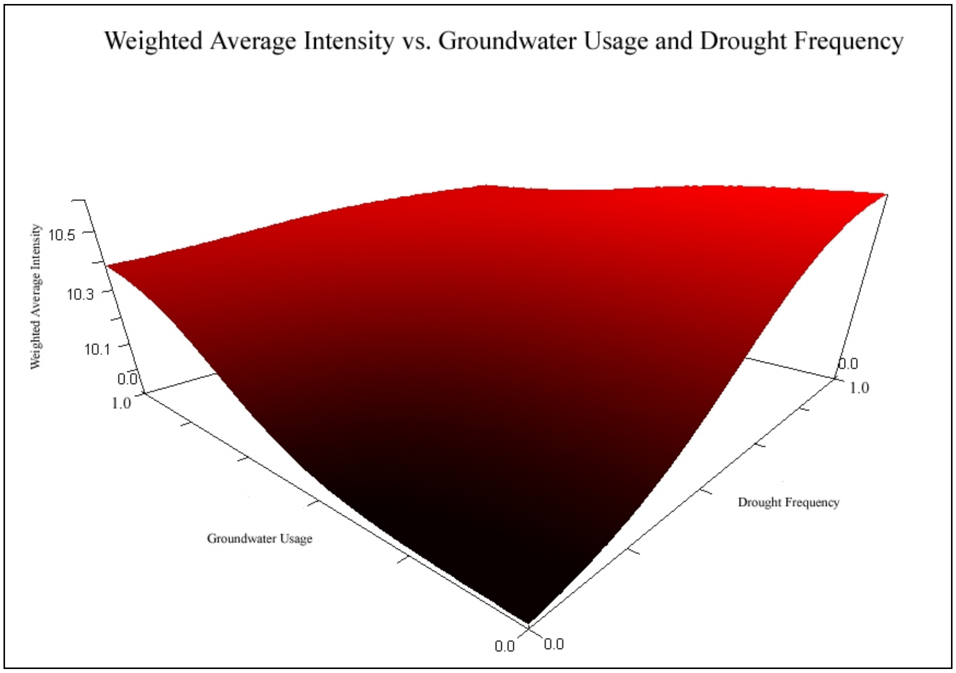

Figure 29. 3-D graph showing the relationship between weighted average intensity, drought frequency, and groundwater usage.

The nonparametric approach utilized in this study is a step in the right direction for the analysis of event data, however, both the predictor and response variables are very course and need to be refined for future statistical analyses. It would be best to try and correlate the intensities of individual events with predictor variables from the specific point in time when these events occurred. The data most likely do not exist for such a statistical analysis. Further, future attempts to predict conflict or cooperation through statistical analysis may likely be fruitless. The seeds of conflict may be planted many years before the actual event occurs. As one water manager said, "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."

3.6 Trend Analysis

In order to understand how cooperation and conflict changed in the UC Region over time, timelines of weighted average intensities were created. Timelines are in a sense the heart monitors of the region, effectively keeping the pulse of interactions between stakeholders. Other variables can be graphed along with intensity values for qualitative comparison. As discussed in section 3.1, 90% of events in the UC events database occurred after 1994, which influenced the variation seen in the trend lines (Figure32). The result of low numbers of events is high variability in the timelines. The high percentage of low intensity events (+/- 1, +/- 2) causes the trend lines to converge toward the x-axis by 'watering' down extreme events (Figure 17). Convergence toward the trendline means that the value is approaching zero, or neutrality. In order to limit the potential bias caused by this lack of data in the early years of the study, timelines only include events from the years 1995 through 2005.

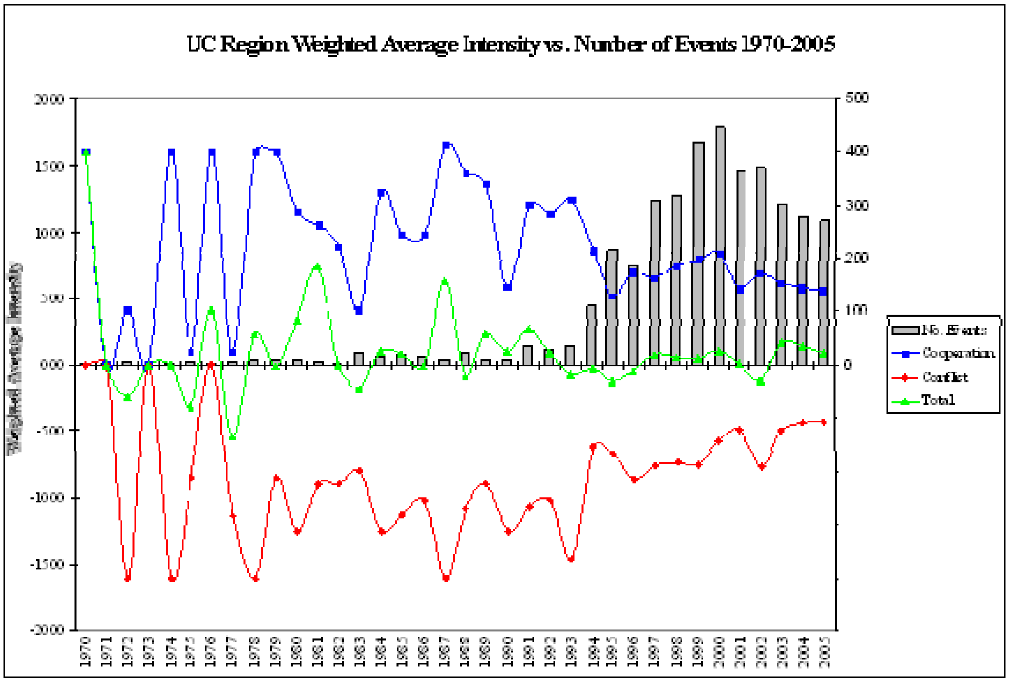

Figure 30. Weighted average intensities compared to the number of events per year.

3.6a Hydropolitical Intensity vs. Palmer drought index

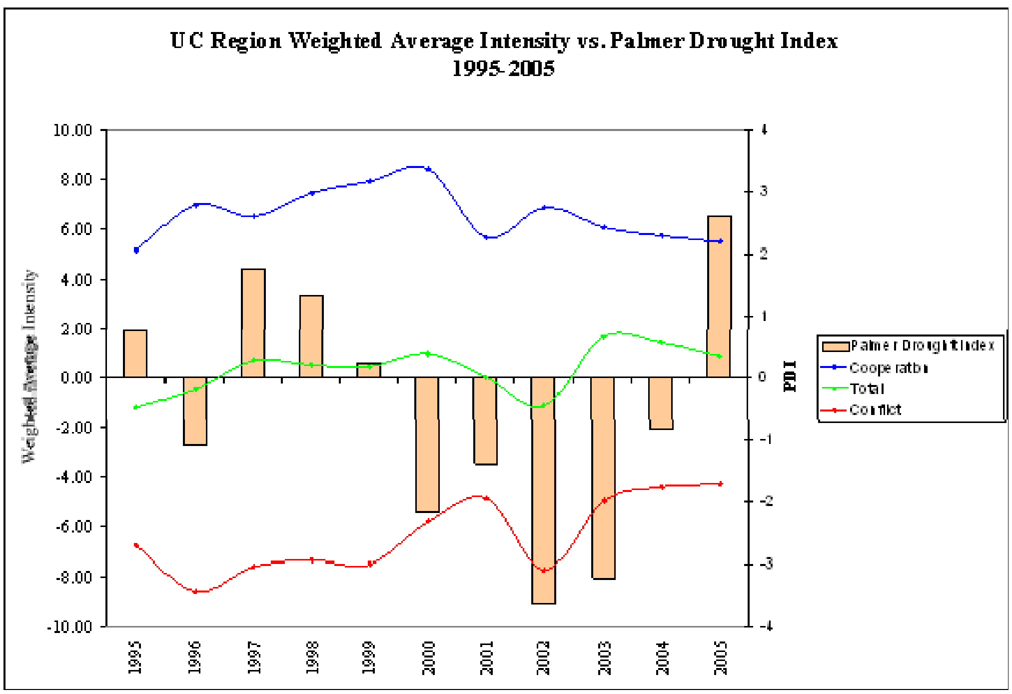

Figure 31. Weighted average intensities compared to the Palmer drought index.

Trend lines were compared to annual drought intensity for the entire UC Region and all hydrologic units. Drought is frequently cited as the source of conflict over freshwater. The Palmer drought index was compared to weighted average intensities for the UC Region (Figure 31). Drought data were aggregated to 6-digit accounting units from National Climatic Data Center climate regions. The Modified Palmer Drought Severity Index (PMDI) incorporates a weighted average of temperature and precipitation to form wet and dry index terms, which are weighted using probabilities. Extremely wet years have values greater than 4.0, near normal is between 1.49 and -1.49 and extreme drought has a value of less than -4.0 (NCDC 1994). Despite the potential relationship observed between drought frequency and weighted average intensity in the multiple regression analysis, there is no consistent relationship between weighted average intensity and the severity of drought by year at the UC Regional scale. Trend analysis shows that there is no apparent relation between what we thought caused conflict and the rate or intensity of conflict. The comparison is continued at the 6-digit accounting unit level.

Timelines were created for selected accounting units based on the ratio of extreme cooperative events to extreme conflictive events (Figures 32-39). Extreme events are those with an intensity value of +5, +4, -4, and -5, and represent the most conflictive and cooperative interactions at the intranational scale. Here again, weighted average intensities are compared to Palmer drought index values for the years 1995 through 2005. As was seen at the regional scale, there is no relationship between annual Palmer drought index intensity and weighted average intensity. The results are the same for both cooperative and conflictive accounting units. Spikes in conflict occur during both wet and dry years, and many peaks in cooperation occur during times of drought and times of surplus.

3.6a.1 High Cooperation Ratio Accounting Units

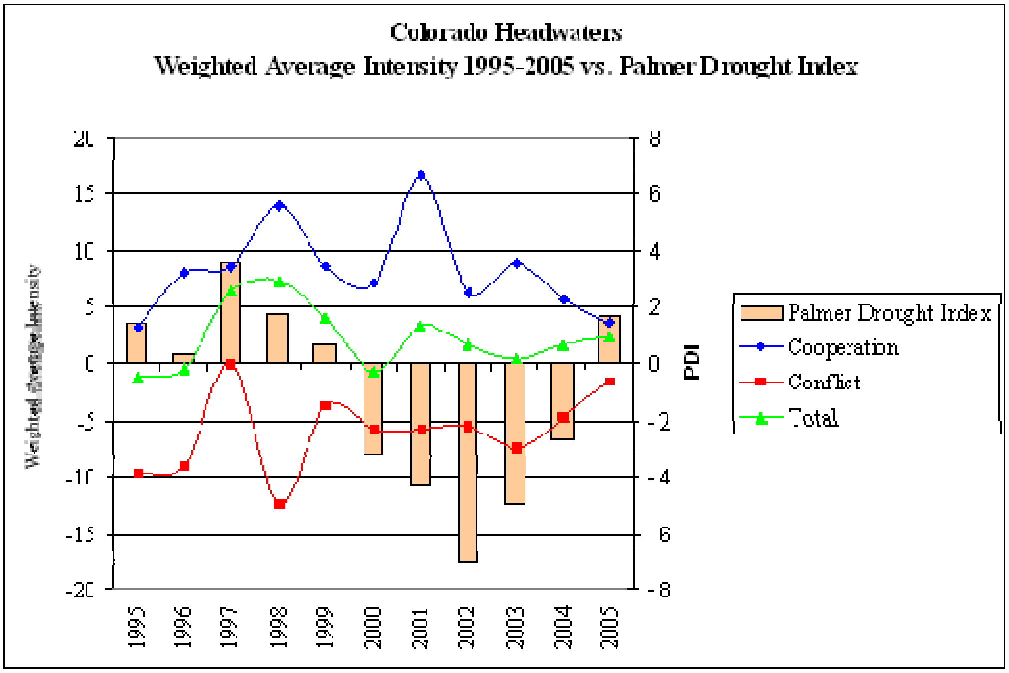

Figure 32. Weighted average intensity compared to the Palmer drought index for the Colorado Headwaters accounting unit. The HUC had an extreme cooperation to conflict ratio of 2.33.

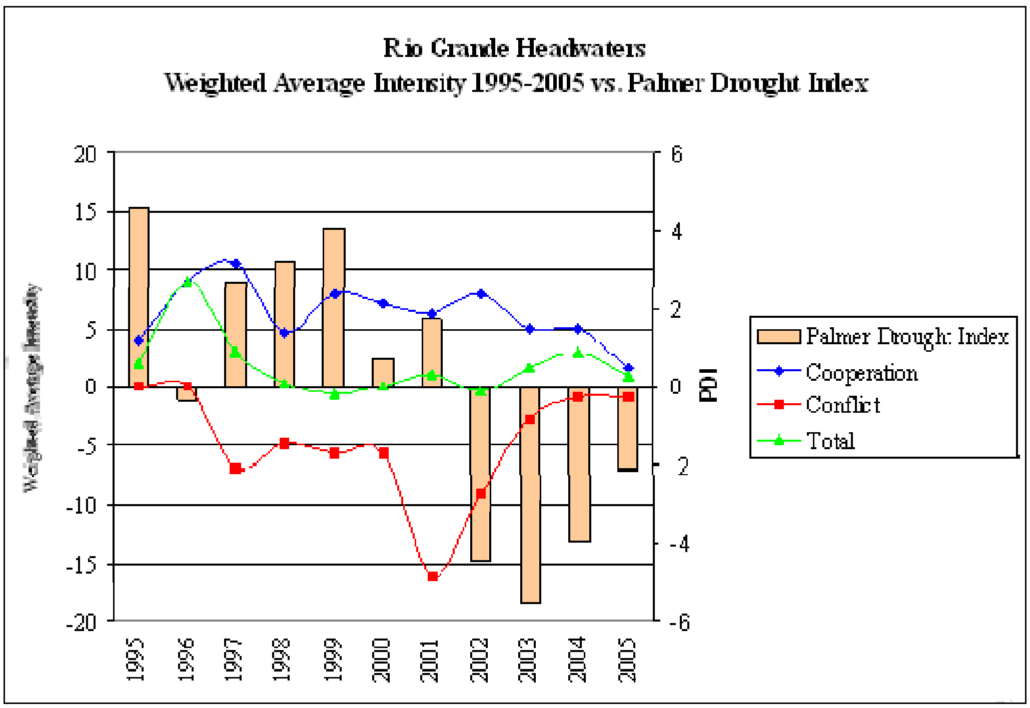

Figure 33. Weighted average intensity compared to the Palmer drought index for the Rio Grande Headwaters accounting unit. The HUC had an extreme cooperation to conflict ratio of 1.75.

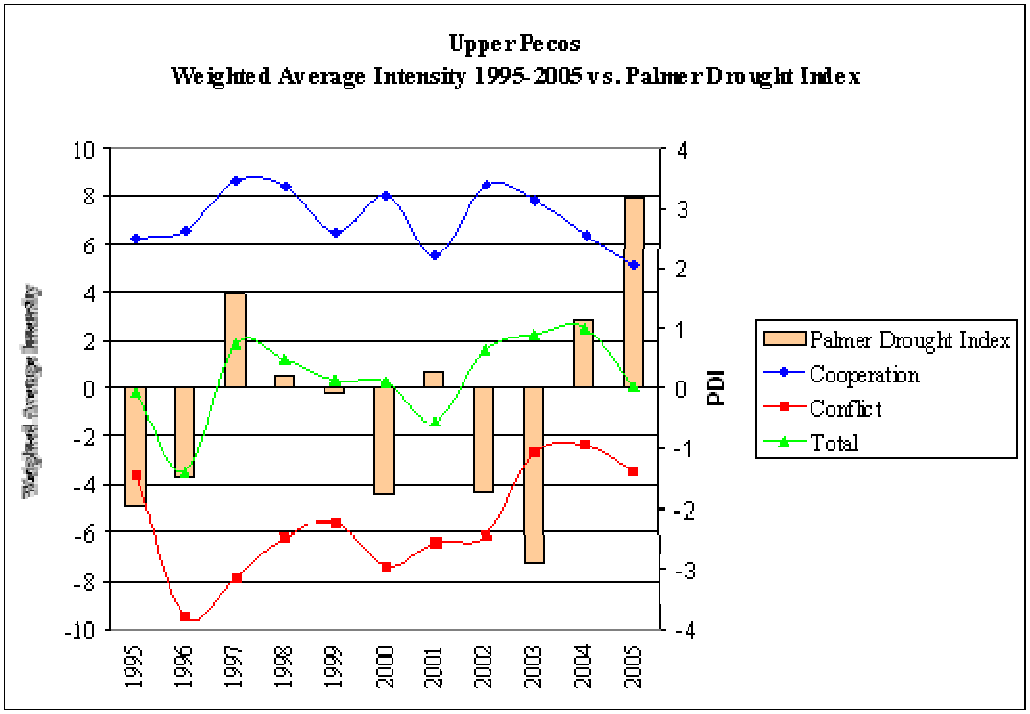

Figure 34. Weighted average intensity compared to the Palmer drought index for the Upper Pecos accounting unit. The HUC had an extreme cooperation to conflict ratio of 1.85.

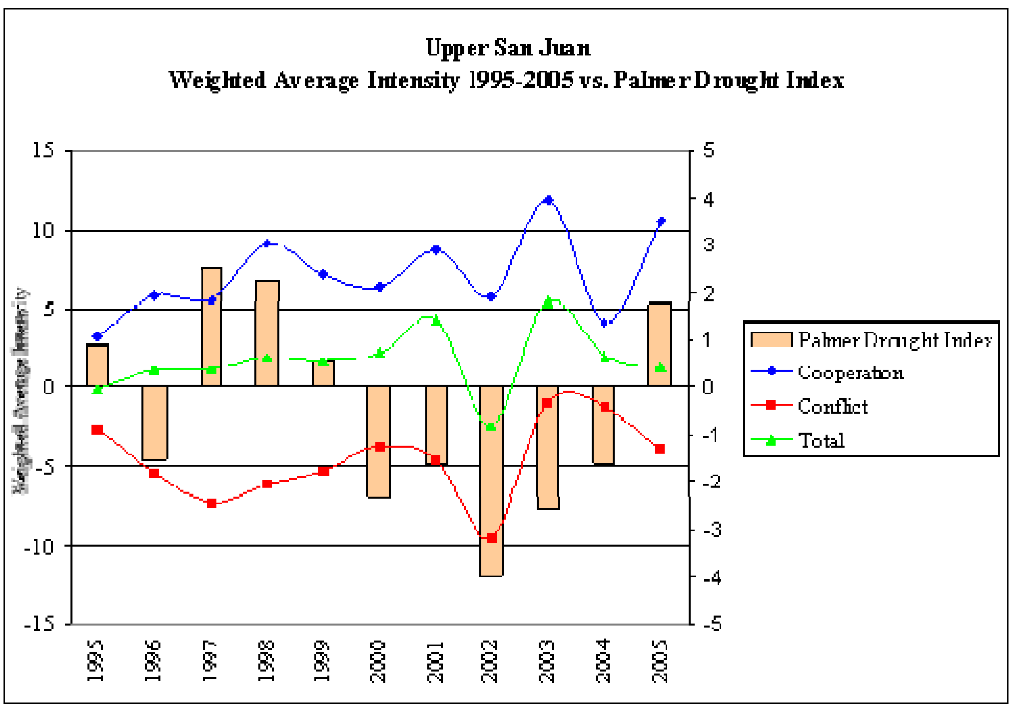

Figure 35. Weighted average intensity compared to the Palmer drought index for the Upper San Juan accounting unit. The HUC had an extreme cooperation to conflict ratio of 2.33.

3.6a.2 High Conflict Ratio Accounting Units

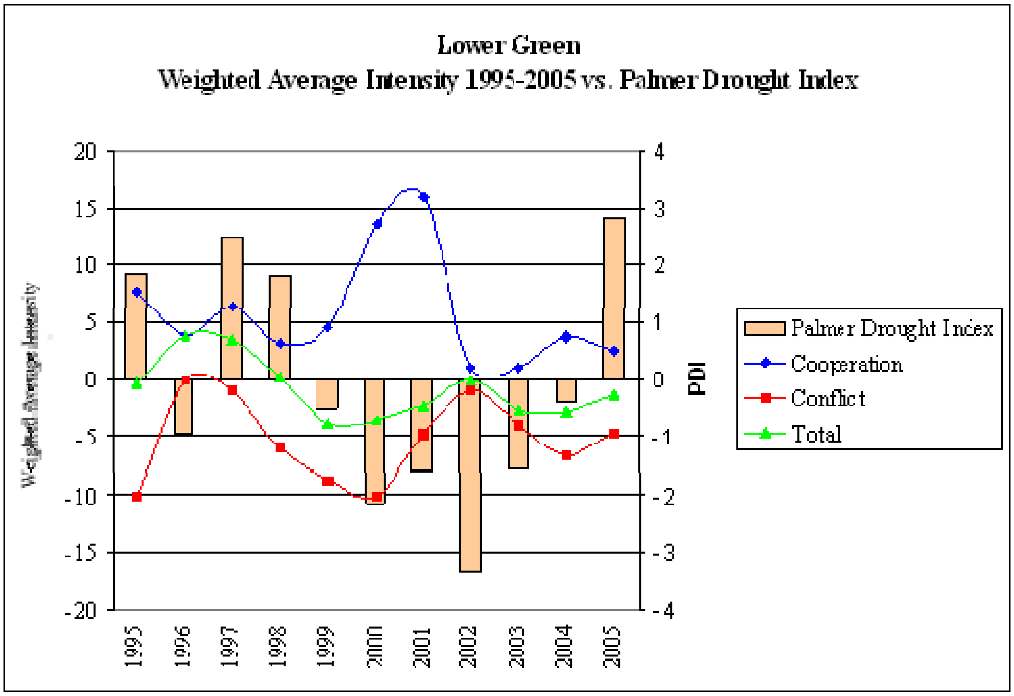

Figure 36. Weighted average intensity compared to the Palmer drought index for the Lower Green accounting unit. The HUC had an extreme conflict to cooperation ratio of 1.50.

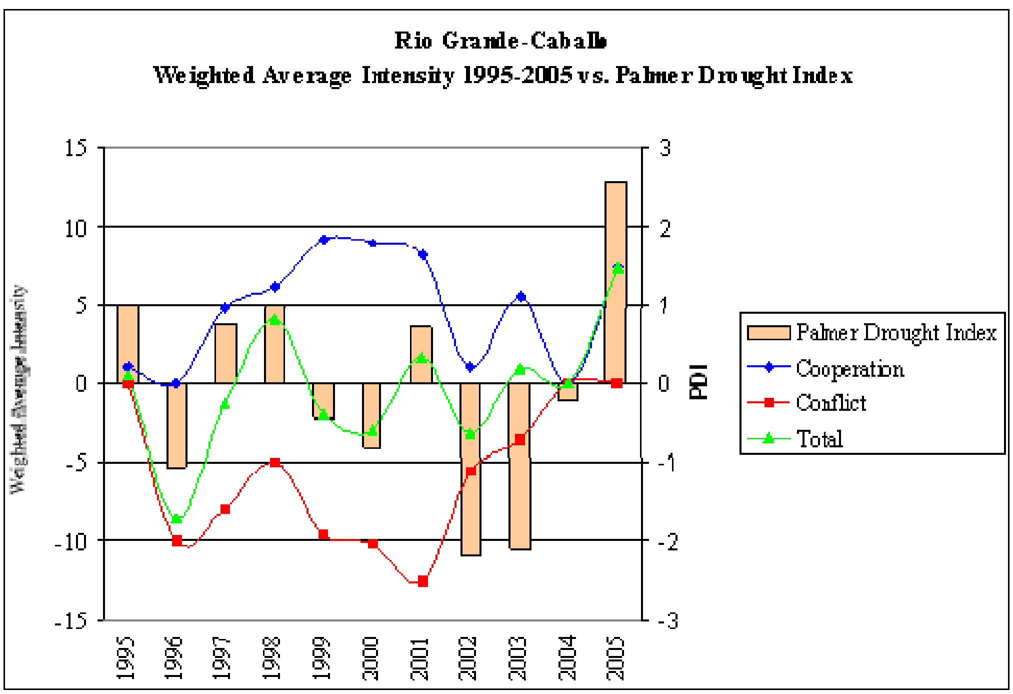

Figure 37. Weighted average intensity compared to the Palmer drought index for the Rio Grande-Caballo accounting unit. The HUC had an extreme conflict to cooperation ratio of 1.33.

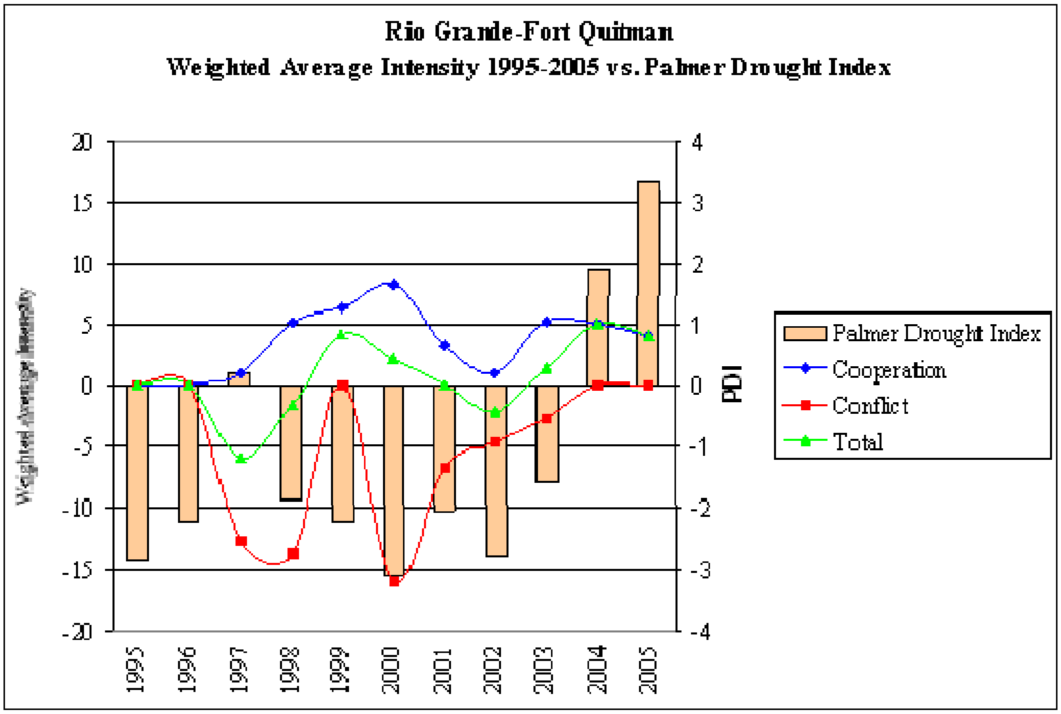

Figure 38. Weighted average intensity compared to the Palmer drought index for the Rio Grande-Fort Quitman accounting unit. The HUC had an extreme conflict to cooperation ratio of 1.17.

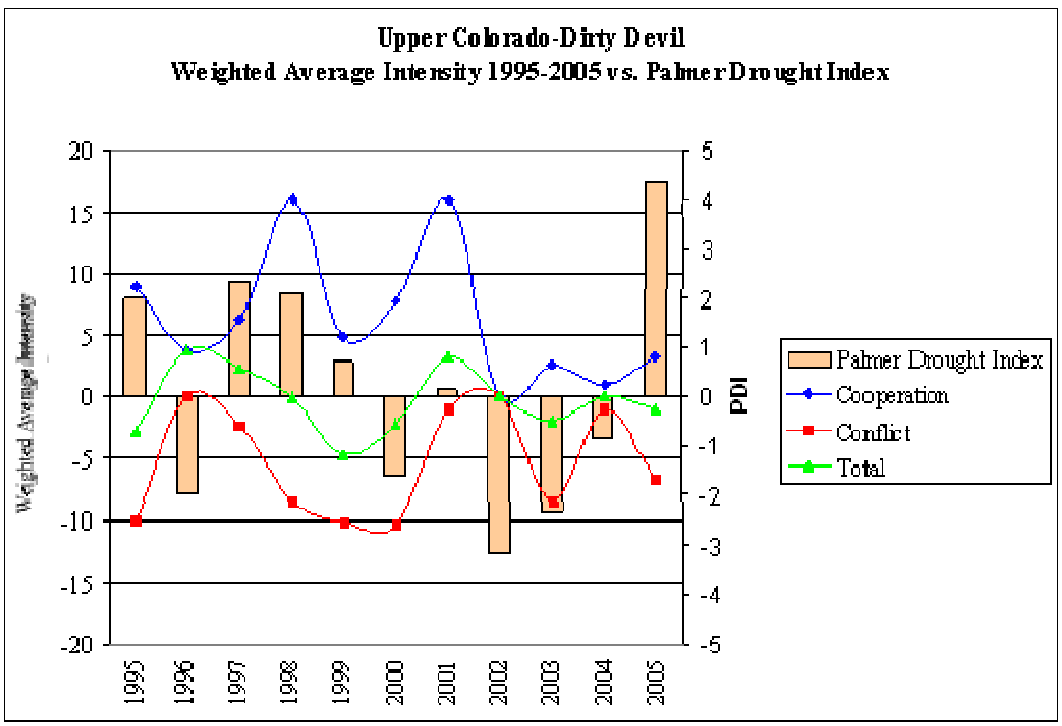

Figure 39. Weighted average intensity compared to the Palmer drought index for the Upper Colorado-Dirty Devil accounting unit. The HUC had an extreme conflict to cooperation ratio of 1.83.

3.6b Hydropolitical Intensity vs. Biological Opinions

The following timelines show the years in which a biological opinion was issued by a federal agency as compared to the weighted average intensities of 6-digit accounting units (Figures40-42). Biological opinion dates were found online at the UC Region and U.S. Fish and Wildlife Service websites as well as a paper by Gosnell (2001). As can be seen, there is no relationship between the timing of a biological opinion and the intensity of events in the accounting units, even when multiple opinions are issued.

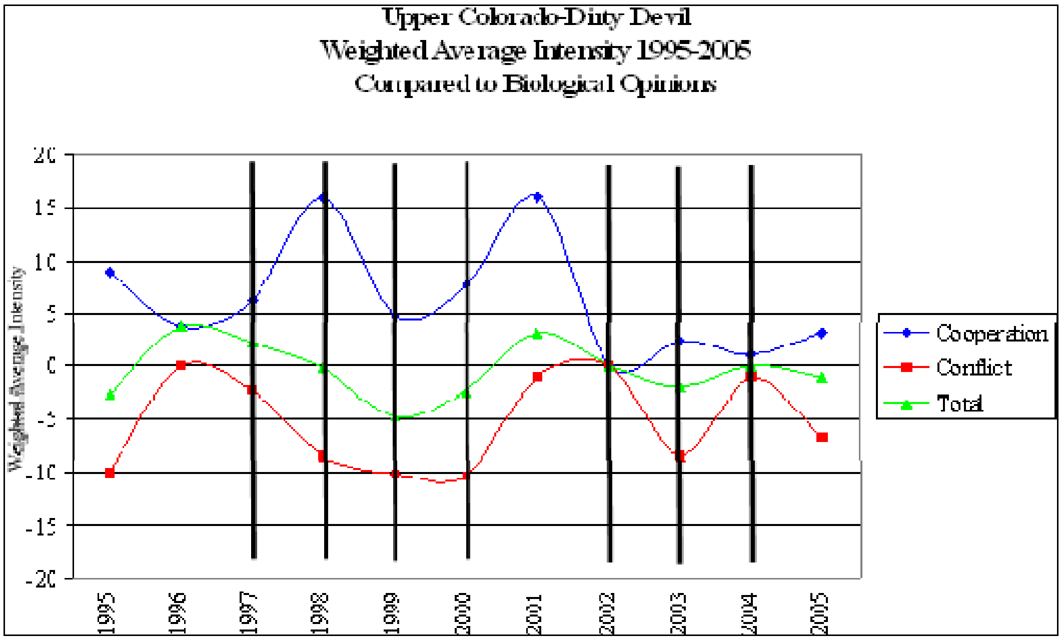

Figure 40. Weighted average intensity in the Upper Colorado-Dirty Devil HUC. Vertical bars represent biological opinions. Multiple opinions were issued in 2002 (4), 2003 (2), and 2004 (4).

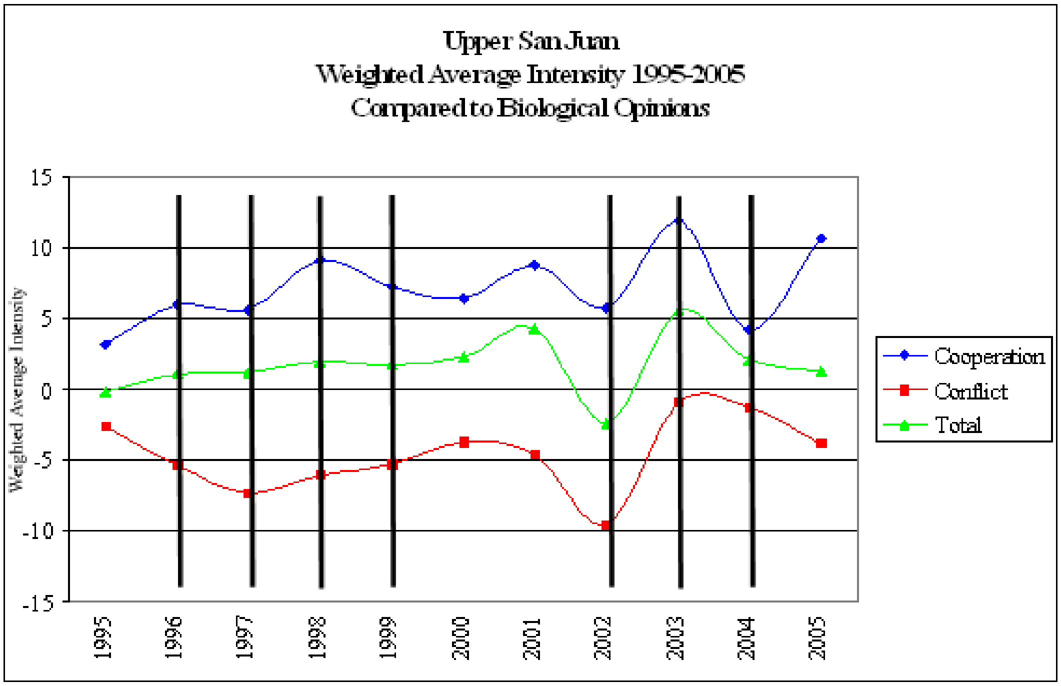

Figure 41. Weighted average intensity in the Upper San Juan HUC. Vertical bars represent biological opinions. Multiple opinions were issued in 2002 (2), 2003 (2), and 2004 (2).

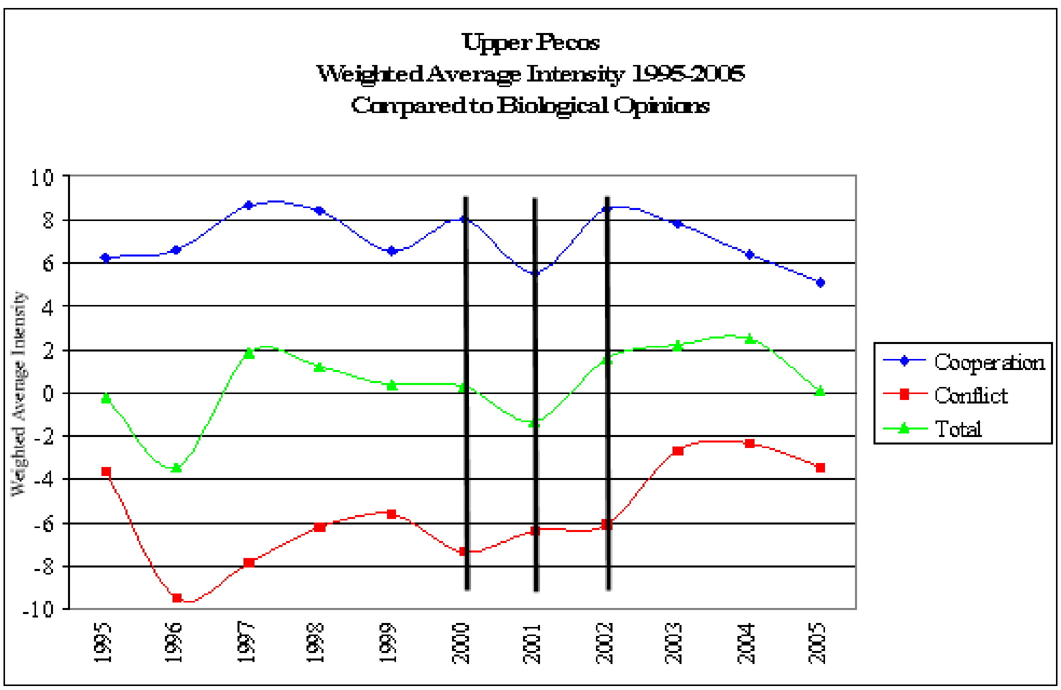

Figure 42. Weighted average intensity in the Upper San Juan HUC. Vertical bars represent biological opinions.

4 Institutional Capacity and Change

Sherk (2000) discusses three options for the resolution of interstate water conflicts: 1) the litigation option, 2) the legislative option, and 3) the compact option. The legislative and compact options represent cooperative solutions in this framework, while the litigation option represents conflict. Examples of all three options can be found in the USBR Upper Colorado Region (Table 10).

Table 10. Interstate water resolution in the USBR UC Region. Source: Sherk 2000; TFDD, U.S. Interstate Compacts.

Litigation Option	Texas v. New Mexico	Pecos River	1983
	Colorado v. New Mexico	Vermejo River	1982, 1984
	Oklahoma and Texas v. New Mexico	Canadian River	1993
Legislative Option	Boulder Canyon Project Act	Colorado River	1928
Compact Option	Animas-La Plata Compact	Colorado and New Mexico	1969
	Bear River Compact	Idaho, Utah, and Wyoming	1978
	Canadian River Compact	New Mexico, Texas, and Oklahoma	1950
	Colorado River Compact	Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming	1922
	Costilla Creek Compact	Colorado and New Mexico	1963
	La Plata River Compact	Colorado and New Mexico	1922
	Pecos River Compact	New Mexico and Texas	1948
	Rio Grande Compact	Colorado, New Mexico, and Texas	1938
	Upper Colorado River Basin Compact	Arizona, Colorado, New Mexico, Utah, and Wyoming	1948

These compacts, settlements, and acts represent different forms of institutions. There are nine interstate compacts governing the waters of the UC Region. Within the UC Region, accounting units fall under the jurisdiction of none of more than one of these compacts (Figure 43). Only one compact influencing the UC Region was signed between 1970 and 2005. In 1978, the Bear River Compact was signed by representatives of Idaho, Utah, and Wyoming. A notable compact, the Animas-La Plata Project Compact, was signed in 1969. The number of compacts per hydrologic unit was compared to hydropolitical intensity. No apparent relationship exists in the UC Region between the number of treaties present and the intensity of stakeholder interactions.

Institutional capacity is the ability of institutions to adapt to change, or in other words system resilience. 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). "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, p. 398).

Institutional capacity varies from place to place, depending on the characteristics of both the biophysical and geopolitical settings. The following are institutional arrangements that may be indicators of institutional capacity:

- Water management organizations
- International treaties
- Interstate compacts
- Regional plans
- Drought and flood mitigation plans
- Conflict resolution mechanisms
- Communication channels between agencies and stakeholders
- Meaningful public participation programs

Institutional change occurs when any of the previously listed comes in or out of existence, or is altered from its original state.

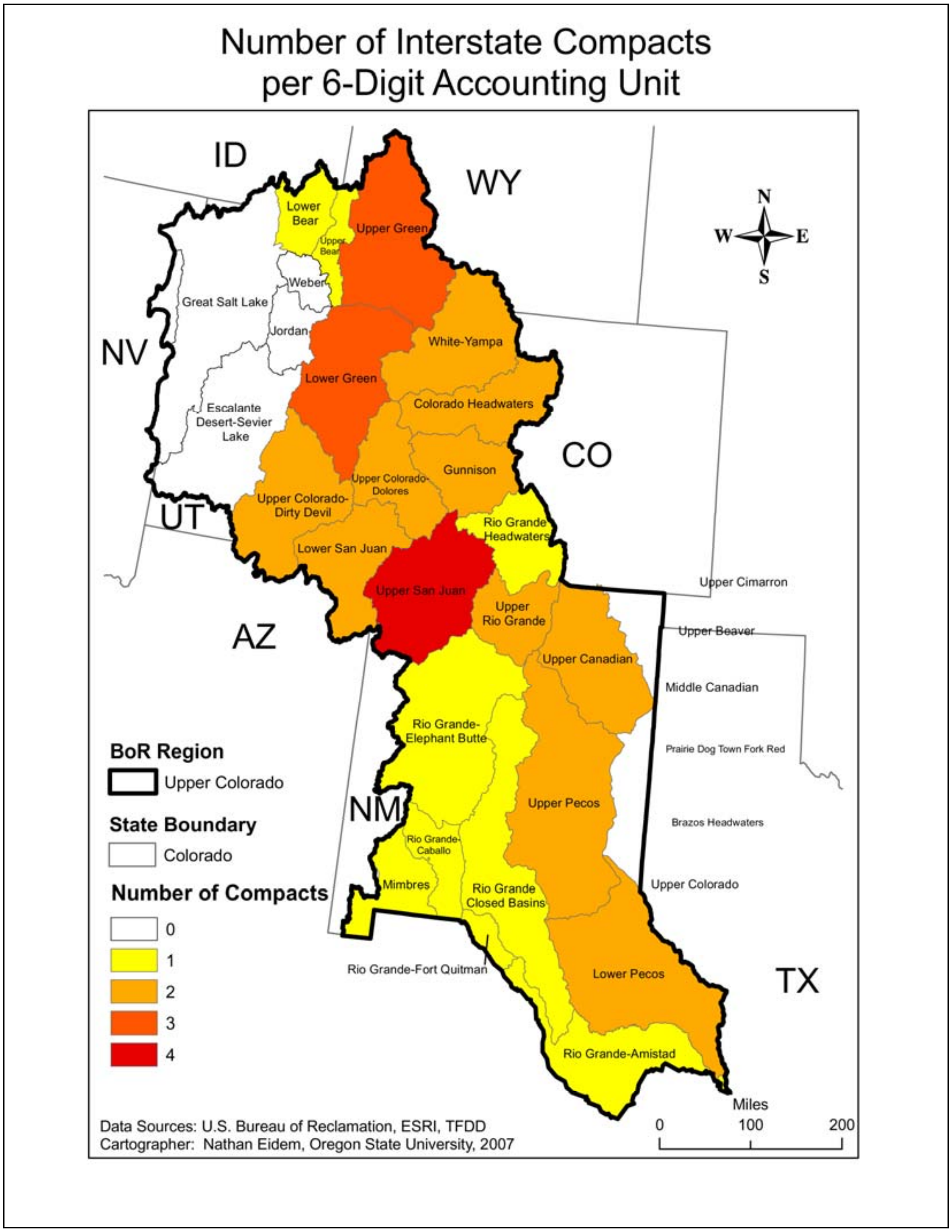

Figure 43. The number of interstate compacts per 6-digit accounting unit.

4.1 Institutional Change and Intensity: The Case of the Silvery Minnow

The following timelines compare weighted average intensities and Palmer drought index values over time to significant events related to the silvery minnow. Events are represented by vertical dashed lines. Figure 44 shows these values for the entire UC Region, while Figures 45 and 46 represent the Rio Grande Headwaters and Upper San Juan, respectively.

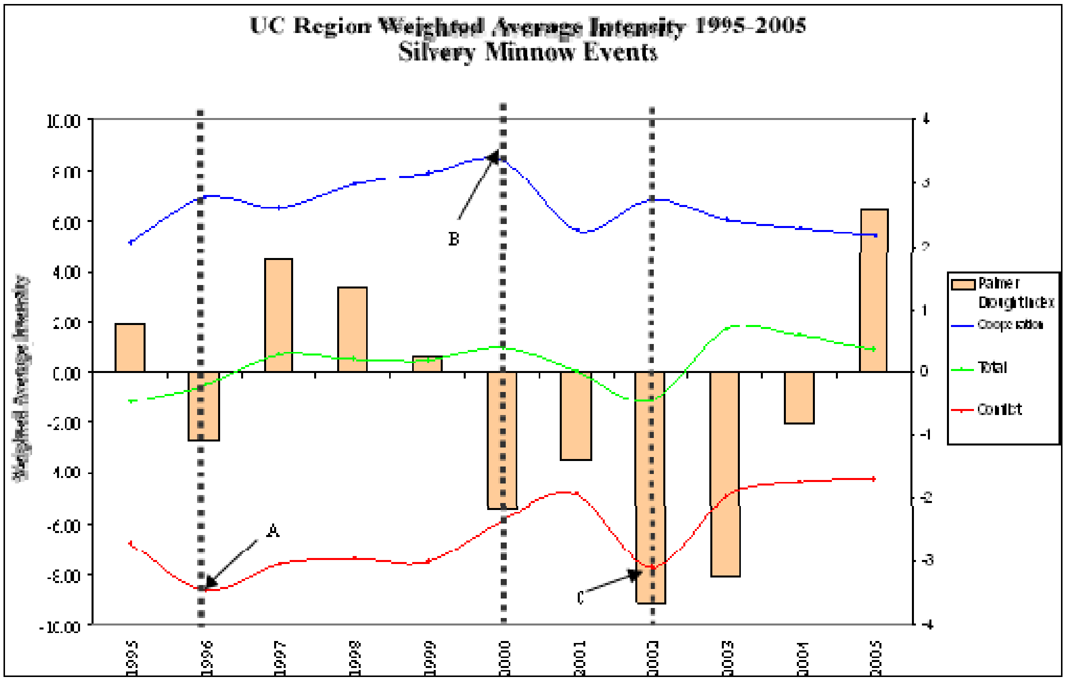

Figure 44. Significant events over the silvery minnow captured in the WWIS UC database. In 1996, thousands of silvery minnows died in a dried up reach of the river below the Middle Rio Grande Conservancy District's San Acacia Diversion Dam after water was diverted for irrigation (A). District officials insisted federal river managers were responsible for the catastrophe by not releasing enough of reservoir water, which the managers said was reserved for other users. No charges were filed. The conservancy district and Fish and Wildlife Service later reconciled in a settlement in which the district agreed to cooperate to protect the minnow but did not admit responsibility for the fish kill. In 2000, the Bureau of Reclamation and other stakeholders signed a memorandum of understanding to find a solution for preserving the silvery minnow (B). In 2002, a New Mexico U.S. District Court ruled that instream flows for fish supercede the rights of cities and farmers (C).

There is a spike in conflictive intensity in the UC Region in 1996 following the death of thousands of silvery minnows, which was caused by the drying up of a river channel due to irrigation diversions. Conflictive intensity remained high until 2000, when the Bureau of Reclamation, Army Corps of Engineers, New Mexico State Officials, City Officials, and other stakeholders signed an agreement to collaboratively solve the silvery minnow issue. Later in the year, an agreement was signed that gave water to both farmers and fish. Conflictive intensity spikes again in 2002. This increase corresponds to a U.S. District Court ruling that gave the silvery minnow water rights superior to both farmers and Albuquerque. Both conflictive spikes happen during times of drought, as does the peak in cooperation.

Moving down in scale to the Rio Grande Headwaters (Figure 47), we see that the largest spike in conflict corresponds to a suit brought against the federal government by environmentalists over the silvery minnow. Several appeals over the issue were also filed in 2001. It is important to note that the peak in conflict occurs during a time of water surplus. Also, there is a decreasing trend in conflict intensity after 2001, years characterized by severe drought.

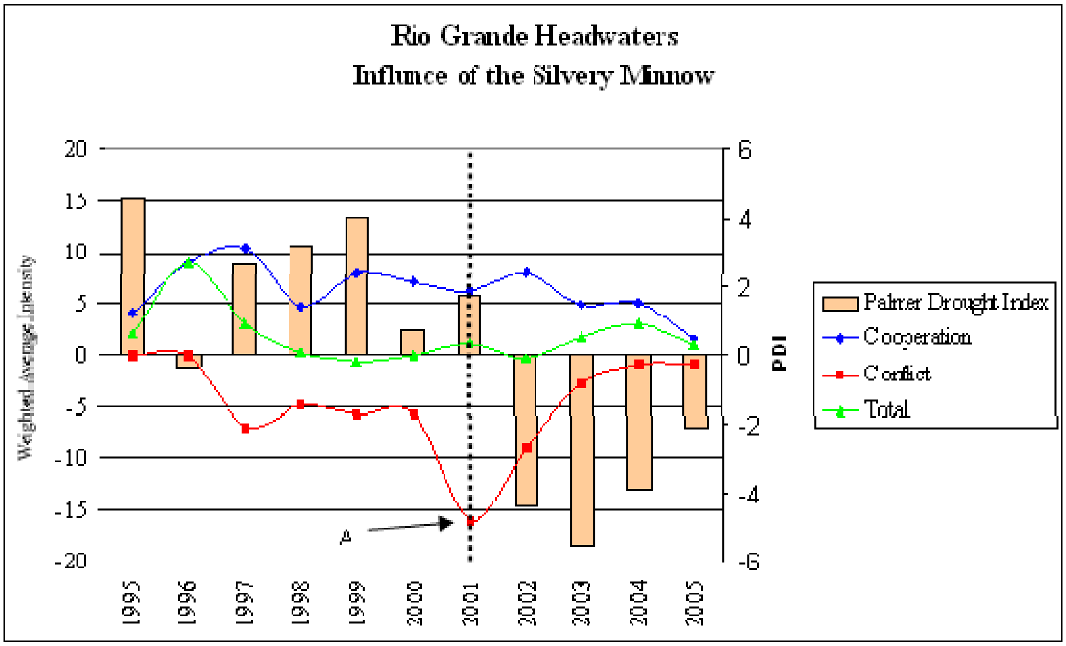

Figure 45. Significant events over the silvery minnow captured in the WWIS UC database. In 2001, Environmentalists sue the federal government, claiming it is not doing enough to protect the minnow (**A**).

The Upper San Juan provides an good example of the interrelation of events across boundaries. What is most interesting about this accounting unit with regards to the silvery minnow is that the fish does not live in the Upper San Juan. Despite the lack of the endangered species, the biggest spikes in both conflict and cooperation correspond to major events relating to the silvery minnow. The Upper San Juan is connected to the Rio Grande system through the San Juan-Chama project. A ruling was made in 2002, the most conflictive time in the accounting unit, stating that water from the San Juan-Chama project could be used for the silvery minnow. The largest spike in cooperation occurred in 2003, when a federal bill was passed that stated water could not be diverted from the San Juan-Chama project, ultimately reversing the previous ruling. Another spike in cooperation occurred in 2005, when an agreement to end litigation over the San Juan-Chama and silvery minnow was signed. This case shows that issues can travel through time, intensity, and space.

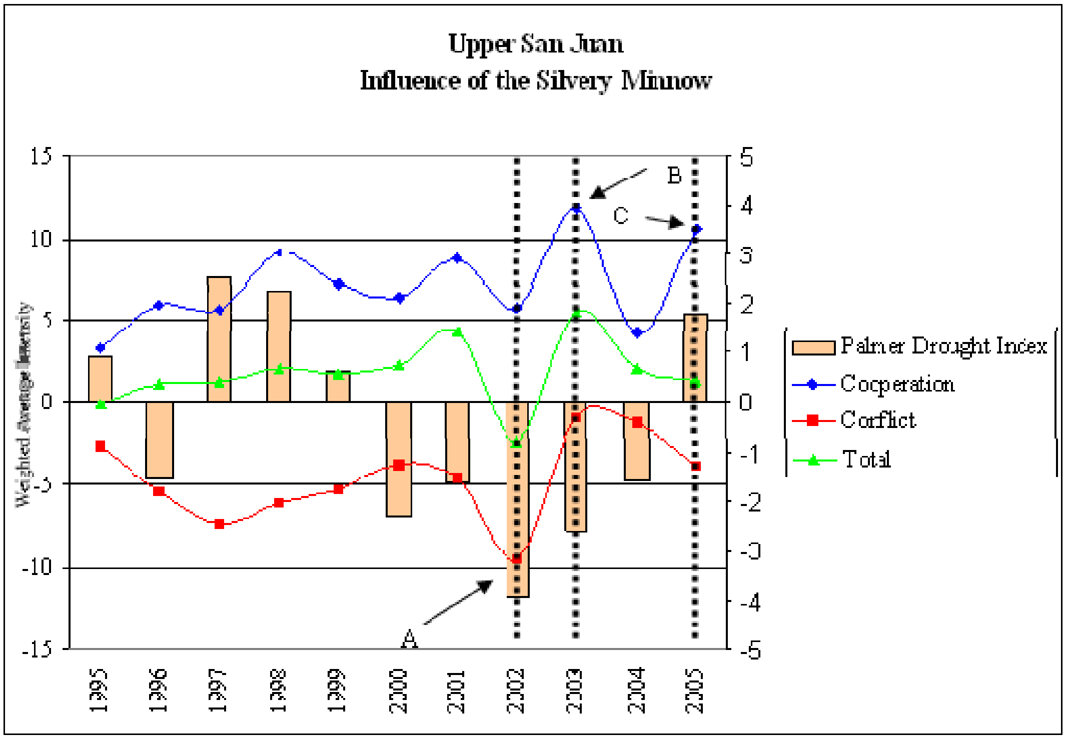

Figure 46. Significant events over the silvery minnow captured in the WWIS UC database. In 2002, a federal judge ruled that water from the San Juan-Chama project could be used to protect the silvery minnow(**A**). The signing of a federal energy appropriations bill into law states that water cannot be diverted from the San Juan-Chama Project for the silvery minnow (**B**). Stakeholders sign an agreement, promising to end litigation over the San Juan-Chama and silvery minnow (**C**).

The rapid shift from extreme conflict to extreme cooperation during times of extreme drought in both the Upper Rio Grande and Upper San Juan indicates that sufficient institutional capacity may exist in these accounting units to deal with major changes. Further study is required to map the institutional network within the UC Region and to determine the capacity and resilience of these institutions.

The WWIS UC events database captured 171 events relating to the silvery minnow case. This case provides a good example of how the database can be used to track events over time and space. If a similar situation were to arise in another portion of the region, water managers could use the database to see what events took place in the past in order to understand what they might encounter in their area in the future. Because the events are coded not only for intensity and location, but also which stakeholders are involved, managers can gain insight into how different parties behave in various situations.

5 Conclusions and Recommendations

This analysis has covered a large area, both in spatial and topical terms. Overall, interactions over freshwater tend to be cooperative. These results correspond with the findings of similar studies conducted at different scales, within international river basins (Yoffe 2001) and within the state of Oregon (Fesler 2007). This trend at multiple scales goes against traditional thinking about freshwater interactions, that conflict is the norm. Water is essential to human civilization, and people work together to manage it.

This study set out to answer the following questions:

1. How did the intensity of cooperation and conflict change USBR's UC Region from 1970 to 2005?

2. Did the spatial distribution of cooperation and conflict in the region change between 1970 and 2005?

3. Over what water resources issues were people interacting, and how did these issue types change across space and time?

4. Are there indicators of conflict and mechanisms that foster cooperation within the UC Region?

With regard to questions one, two, and three, hydropolitical intensities change over time and vary across space. Issue type of the events is as variable as intensity. Hydrologic units experienced different levels of collaboration and conflict at different times, in no certain pattern. Issue types followed the same pattern and no apparent pattern. As for question four, there are no significant indicators of conflict or cooperation based on statistical analysis. Drought frequency and groundwater withdrawals appear to play a role in overall hydropolitical intensity. Even so, the best statistical model produced had an R2 value of 0.511. Further study is required to uncover institutional capacity within the UC Region.

The intensity of interactions over freshwater is the result of many compounding factors. Individual variables may trigger a conflict, but only in a setting that is conducive to conflict. The accounting unit scale analysis provides a good starting point to look for case studies of institutional capacity. Accounting units that have experienced rapid swings in hydropolitical intensity might be able to provide valuable lessons. This ability to handle these spikes, especially spikes in conflictive intensity, is institutional capacity. As was shown in the case of the silvery minnow, the highest levels of conflict can be shifted to extreme cooperation in a short amount of time, even in times of extreme drought. The regional scale provides a birds-eye view of the situation, while investigations into the smaller scale provide insight into institutional capacity.

This project provides a general snapshot of stakeholder interactions in the UC Region. Future studies should incorporate a code for who initiated a conflictive or cooperative action. Additionally, stakeholders were grouped into broad categories in this study. It is recommended that future work identify stakeholders by specific agency, organization, tribe, etc. These measures would require more time, however, they would allow for more in depth studies of the motives of and relationships between various players in the region. Grouping in to general categories might mask the missions of different federal agencies or non-governmental organizations.

5.1 Limitations and Future Work

The biggest limitation to this study is the lack of event data prior to 1994. To fill in this gap would require a great deal of time and effort from human coders. Events would have to be coded from archives of non-digital sources. Such and effort is neither practical nor economically feasible. The coding of events for the UC study took several years, even when sources were limited to those available in digital format. To repeat the study using archival sources would require multiple teams in multiple cities. A more realistic approach would be to think of this study as the beginning of a long-term data collection and analysis project.

The WWIS UC Region project is the first step in creating a conflict monitoring system. It provides a method for quantifying the intensity of conflict and cooperation, allows for spatial comparisons of these intensities to be made, and allows for comparisons to be made between the intensity levels and various biophysical, socioeconomic, and political variables. The method can be refined as it is applied to other regions, and relationships between multiple regions can be uncovered. While this project provides a good understanding of how conflict and cooperation have changed in the region historically, it does not give a real-time or near-real-time picture. Technology exists to create this near-real-time system.

The first requirement of such a system is an automated event coding system. Currently, events of conflict and cooperation are coded by trained human coders. This is a time-intensive process, and is the largest limiting factor for a near-real-time system. Software packages are available that can code events with the same accuracy as human coders, in a fraction of the time (Gerner et al. 1994; Schrodt 2001; King and Lowe 2003). The next requirement is indicator data. Indicator data need to be current in order to make near-real-time comparisons. The WWIN provides a large database to be utilized by such a system. Real-time data such as stream flow, reservoir level, temperature, etc. would complement the WWIN data, and provide the most current information. The final requirement is an internet mapping system. This technology allows for non-technical GIS users to access and manipulate spatial data online. It also allows users to focus on the region(s) in which they are interested, and create their own maps and tables. Once such a system is created, water managers will be able to access it over the internet and monitor the status of their areas.

Such a large dataset could also provide valuable for input into agent based models currently being developed for the USBR. Agents could be trained with the thousands of events coded by the automated system, allowing for them to incorporate the most current information into their interactions. Along these same lines, these data could be analyzed using a multi-strategy data mining algorithm. This method has been successfully employed to predict when the price of airfare will increase or decrease, thus saving consumers money. Etzioni and others (2003) used this approach to analyze 12,000 airfare price observations over a 41-day period. They were able to save 341 simulated customers nearly $200,000 in total by telling them when to buy or not to buy. This research is now being utilized to predict, with different confidence levels, whether the price of airfare will likely increase or decrease, and whether or not to buy (www.farecast.com).

As with the monitoring system, this would require a more complete set of predictor variable data. If a robust usable model were produced, this approach could allow managers to get a head-start on potentially conflictive situations. Probably the most important study to follow this analysis is an in-depth study of institutional capacity and resilience. Previous TFDD studies have found relationships between institutional change and hydropolitical intensity. This relationship was not uncovered in this study. In order to conduct such a study, it is recommended that events be coded to correspond to management boundaries within the UC Region as opposed to hydrologic units. The 6-digit accounting unit provides an ideal scale for analyzing patterns across the UC Region, but is not appropriate for analyzing institutional capacity. Institutions do not generally correspond to hydrologic unit boundaries.

In order to study institutional resilience, a steady state for the area of interest would need to be calculated. Perturbations would be identified and compared to a calculated level of institutional capacity. Potential components of an institutional capacity value might include the amount of public involvement, the amount of inter-organization collaboration, the presence of mitigation plans or compacts, the amount of education and training of managers, the amount of funding, and organizational transparency to name a few.

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