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Title: Assessing the Design of International Water Supply and Hydropower Arrangements For Managing Certain Climate Change Scenarios

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Increased variability of rainfall and flow from climate change has the potential to stress existing transboundary water sharing agreements and make meeting the needs of all riparians difficult. Water treaties have been theorized as valuable tools for mitigating conflict in times of climate stress, but the relationship between the design of treaties and their impact has not been explored in depth.

In this study, a literature review extracts core concepts commonly used to explain the success of treaties in managing hydrologic stress. These are summarized as seven treaty mechanisms categories (specificity, uncertainty management, enforcement, communications, flexibility, integrativeness, and scale) and are hypothesized as important for shaping the institutional resiliency of a treaty. While recognizing that there is significant variability within basins and treaties, this project uses a comprehensive, quantitative approach with multiple basins (n=52) and treaties (n=146), to empirically examine the effectiveness of the seven treaty mechanisms for deterring conflict and complaints that occur due to hydrologic stress. Contrary to expectations, the most robust treaties with more mechanisms have a higher instance of both climate and general conflict. Coefficients obtained from regression analysis indicate that an increase in flexibility, scale, and enforcement within a treaty are an indicator of less conflict or

complaints and the negative coefficients for communications, specificity, and integrativeness tend to indicate more conflict.

The general mechanism results are used to evaluate specific treaties and their capability to manage projected changes in climate in five case study basins: the Nile, Jordan, Tigris/Euphrates, Indus, and Helmand. The case studies illustrate the difficulties in pinpointing the importance and impact of each mechanism, and the overall treaty design, on water relations. Treaty mechanisms certainly play an important role in de-escalating tensions when stresses occurred within each basin. However, conflict de-escalation is not a direct cause and effect relationship between the capabilities of the water institutions and the amount of stress to the system. Instead, there is a complex relationship between change to the system and management efforts that involves a series of feedback loops and influence from non-water related sectors.

Analysis of the seven mechanisms and the five case studies provides several summary explanatory concepts that include: treaty design and mechanisms exert an influence not just on the management capability (institutional resilience) aspect of relations, but also help to shape the political context of the problem; complaints are not necessarily an indicator of decreased institutional resiliency, weak, or ill-designed treaties, but in some cases illustrate that a treaty is functioning properly; and ambient poor relations are important for shaping many complaints. What is better understood through this research is how treaty design has a relevant and important role in shaping basin management so that nations may better achieve their goals in a changing climate.

Assessing the Design of International Water Supply and Hydropower Arrangements For Managing Certain Climate Change Scenarios

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

Matthew A. Zentner, Author

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DEDICATION

This dissertation is dedicated to my family: Stephanie, Izzy, Maggie, Eli, and Aila. Thank you for coming along to pursue the other Daruma eye. And to my parents, for being everything I always wanted to become.

Assessing the Design of International Water Supply and Hydropower Arrangements For Managing Certain Climate Change Scenarios

1 Introduction

Projecting the changes to water supplies, and our ability to manage those changes, is a worthwhile endeavor given recent data on climate change. The exacerbation of seasonal rainfall variability in a changing climate, as outlined by the Intergovernmental Panel on Climate Change (IPCC), will likely have considerable effects on freshwater systems and aggravate other existing stresses to water supplies. Based on projected increases in water variability, current management practices may not be robust enough to cope with the impacts of climate change on water supply, flood risk, ecosystems, health, energy supply, and agriculture (Bates et al., 2008). Transboundary rivers, where water resource management is already a delicate and complicated balance of myriad needs and decision processes, will be especially challenged.

Increased variability of rainfall and flow from climate change has the potential to stress existing transboundary water sharing agreements and make meeting the needs of all riparians difficult.[1] For some shared international rivers, a shift may occur from all needs being met and no history of disagreement to unfulfilled treaty requirements and, perhaps, an elevated potential for conflict (2008; M. Zeitoun & Allan, 2008). Basins with extreme changes in climate will certainly have the resiliency of any relevant treaty tested.[2] Some authors have predicted that treaties will fail, with potentially extreme political-economic consequences (Amery, 2002; Gleick, 2010; Homer-Dixon & Blitt, 1998).[3]

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[1] Water sharing agreements are defined synonymously with institutions as binding arrangements, typically called treaties or conventions.
[2] Resiliency is defined as the ability to mitigate conflict or adapt to stress (in particular, hydrologic) or changing circumstances.
[3] Failure in this study is defined as the measurable exhibition of conflict, especially when directly attributed to climate-related stress within a system.

> “Climate changes will inevitably affect water resources around the world, altering water availability, quality, and the management of infrastructure. New disputes are already arising in transboundary watersheds and are likely to become more common. The existing agreements and international principles for sharing water will not adequately handle the strain of future pressures, particularly those caused by climate change” (Gleick, 2010).

Will treaties indeed fail and conflict ensue due to growing stresses, including those from climate change? Perhaps. Unless institutions and agreements have mechanisms robust enough to respond to changing local and global situations (including hydrologic), the stresses associated with climate change may outpace the capacity of the agreement to manage the changes (M. Giordano, Giordano, & Wolf, 2005).

Most transboundary treaties are uniform in their ostensible goal to enable countries to manage shared waters without conflict. However, international water law does not provide explicit rules and procedures, but rather suggests guiding principles based on legal precedence. Consequently, nations are often left on their own in determining how to best design and implement an agreement.

While recognizing that water treaties are non-uniform and each institution is unique, some treaty designs may be better able to manage external stresses to the agreement, such as allocation of unforeseen inter-annual variability in river flows. However, empirically derived analyses that quantify the impact of specific mechanisms on mitigating conflict are lacking in general. An analysis of a large number of basins (n>5) that generalizes the extent to which many common and dissimilar institutional characteristics may influence the success or failure of a treaty has not been undertaken. Consequently, the general principles and conditions under which international river treaties are most effective are not well understood.

Using a comprehensive, quantitative approach with multiple basins (n=52) and treaties (n=146), this research suggests mechanisms and general treaty components which best explain why some water treaties have been more resilient to past hydrologic stress. The mechanisms are empirically tested with historical observations of hydrologic stress and response, made across multiple basins/treaties over time. The results show which types of mechanisms are most important for managing seasonal and interannual variability of flows. With an understanding of treaty mechanisms and their response to past water stresses, models of future hydrologic scenarios associated with climate change are used in several case studies to estimate the treaty's capability to manage the scenarios. The results are used to develop a model for considering strategies in transboundary water law formation, which can mitigate the negative impacts of variability on riparian relations.

The literature is first examined to determine a general set of principles that are most commonly cited as critical to effective water treaties. The literature review in Chapter 2 discusses how water scarcity and fluctuations in availability impacts national stability and security, which in turn determines the priority that nations place on the management of water. The projected impacts of climate change are discussed, as well as its potential to cause multiple, often indirect changes to water supplies that will affect internal stability as well as the relations between nations. The literature review identifies many of the principles most often cited as important for mitigating hydrologic stress related conflict.

In Chapter 3, seven treaty mechanisms are used to categorize and quantify the extent that treaties contain the literature principles. These mechanism categories are: *specificity*, *uncertainty management*, *enforcement*, *communications*, *flexibility*, *integrativeness*, and *scale*. Hydrologic fluctuations (drought/flooding) and differences in power (political, economic, internal stability) are also considered important for shaping the interactions between riparians. Three hypotheses are presented: 1) increased hydrologic stress increases the likelihood of complaints or state grievances involving a shared water resource; 2) water sharing agreements that have mechanisms in place will have less conflict and fewer grievances; and 3) all mechanisms have added benefit, but some mechanisms are more important to providing increased institutional capacity.

In Chapter 4, a methodology for observing and quantifying each of the seven treaty mechanisms is discussed. Treaty, drought, power, and conflict data is then used to estimate treaty strength, or institutional resiliency in four basic steps:

1) Treaties are are assessed for a total of 38 treaty measurements that are used to quantify the mechanisms that play a role in managing hydrologic stress. From this, a preliminary strength based on the number of mechanisms is estimated for each treaty (called the Literature Review strength).
2) The amount of hydrologic stress that treaties have managed in the past is quantified using the Palmer Drought Severity Index (PDSI) for the period 1950-2005.[4]
3) The presence and severity of conflict/complaints is used to measure the success of the treaty in managing hydrologic stress applied to the system. This study utilizes the Transboundary Freshwater Dispute Database (TFDD) Basins at Risk (BAR) dataset, which estimates intensity of conflict, as an indicator of the overall health of the system. A total of 388 complaints are segregated, based on their description, into climate related (85 total complaints) or non-climate related (303 total complaints).
4) The relative importance of each treaty mechanisms towards responding to hydrologic stress is quantified using a multiple linear regression (MLR) analysis.[5] From the coefficients for each mechanism, another treaty strength is calculated (called the MLR strength).

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[4] The PDSI was selected from three different modeling approaches (PDSI, remotely sensed surface wetness, and water balance) with the aim of simulating past hydrological time series. Each was analyzed for their suitability for this study, with the PDSI selected as the most appropriate.

[5] Several combinations of independent and dependent variables are used to extract regression coefficients. Generally, the dependent variable incorporates the conflictive events within the BAR, while the independent variables are formed from the seven treaty mechanisms, power differences between the signatories, and hydrologic stresses to the system.

Results of the above analysis are presented in Chapter 5. Surprisingly, drought does not occur any more frequently in basins that have reported climate related conflict than it does in other basins. However, for treaties that do have climate related conflict, complaints are shown to be much more likely during periods of greater drought and hydrologic stress, indicating that for a certain subset of treaties, climate fluctuations are a driver of conflict. It was also unexpected that the stronger treaties (based on the Literature Review strength that emphasizes the number of treaty components) have a higher instance of both climate and general conflict. A comparison of the quantity of mechanisms per treaty for treaties with climate complaints, any type of complaint, and no complaints indicates that treaties with more mechanisms had an increased likelihood of having complaints. The coefficients obtained from regression analysis indicate that an increase in *flexibility*, *scale*, and *enforcement* within a treaty result in less conflict. The MLR analysis also indicates that *communications, specificity*, and *integrativeness* are indicators of decreased likelihood of a complaint being filed.

In Chapter 6, case studies for the Nile, Indus, Tigris/Euphrates, Jordan, and Helmand Rivers show how the study's findings regarding general treaty mechanisms can be used to help explain and shape riparian relations within specific basins. The treaty mechanism results are combined with future climate projections to estimate whether specific treaties are likely resilient enough to manage hydrologic stresses from climate change. The case study results provide some confirmation of strengths/weakness as estimated by the MLR. The MLR results indicating that an increase in *scale, flexibility*, and *enforcement* within a treaty result in fewer or better managed complaints were confirmed in all case studies. MLR results for *communications* and *integrativeness* that indicate these mechanisms result in more conflict were not reflected in the cases studies.

The conclusion from the mechanism and case study analysis is that political, economic, and social influences and factors that are often only indirectly related to water are a key factor in determining the effectiveness of a treaty and the quantity and severity of water complaints. Complaints have typically occurred where water is important for national stability and where nations have placed extra emphasis on the treaty creation process resulting in treaties that are on average more robust (have more mechanisms) than treaties without complaints. Design elements can positively or negatively influence the treaty capabilities for managing stresses to the system. Complaints are not necessarily an indicator of decreased institutional resiliency, weak, or ill-designed treaties, but in some cases illustrates that a treaty is functioning properly.

This research does not use past treaty non-compliance as a predictor of future non-compliance. It also does not intend to predict conflict in any given basin nor to predict the specific impacts of climate change, many of which will be unprecedented and perhaps impossible to gauge. This research does use past treaty successes and failures in managing hydrologic stress as a means of determining the importance of treaty design parameters, which can then be used to estimate treaty capabilities for managing stresses, such as those from climate change. It also assumes that treaties in general improve resiliency and intends to provide direction for basins without a treaty or for those that wish to develop institutions to better account for climate change. The power of this analysis is that the results can be used to explain success across multiple basins and to guide the design of future basin agreements.

This dissertation is part of a larger project funded by the World Bank that includes several collaborators investigating basin and treaty vulnerability. While the author has been involved in all aspects, and data from the larger project is utilized, the primary focus of this research is on the treaty analysis.

2 Literature Review

2.1 Climate Change, Fluctuations in Water Availability, and Security

The focus of this review is to examine the relationships between international conflict and changes in climate (with shifts in water availability being a key factor in these changes). There is a vast amount of literature touching on the issues of climate and conflict, and by extension on environment and natural resources and their influence on societal and political stability (Brown, Hammill, & McLeman, 2007; Eckstein, 2010; 2007; p. 31; Swart, 1996). Global warming has raised concerns that changes to climate will pose unique challenges to many nations' security interests. Several studies have examined how already stressed systems that are vulnerable could be driven past a tipping point by shifts in climate (Barnett, 2003; Dabelko, 2008; Mabey, 2007).

The 2007 IPCC report summarizes the scientific understanding of climate change's impact on both air temperature and water resources, including far-reaching changes in the intensity and variability of precipitation and increases in the risk of flood and drought in many areas of the world (Bates, Kundzewicz, Wu, & Palutikof, 2008 ; IPCC, 2007).[6] The best models indicate that changes in climate will vary significantly in time and in space and, consequently, international river basins, and the stability of the treaties that govern them, will not be impacted uniformly. Those areas that are already vulnerable to drought may have its frequency and intensity increased. Likewise, areas that have floods may receive higher intensity flooding more often. For many locations, the IPCC projects that the changes in water resources are likely to be dramatic. Historically, long-term fluctuations in water supplies have typically occurred on a relatively limited scale, with usually only localized areas impacted. However, climate change will likely intensify the global hydrologic cycle, impacting multiple regions at the same time (Fowler, 2003). When stresses to a basin are severe or long-term (such as from shifts in climate patterns),

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[6] Such climate shifts are predicted with fairly good certainty at the global level, but this certainty is reduced as scales decrease to the national and local level.

sometimes second, third, and fourth order changes must develop before a new equilibrium is attained. Putting a finger on the causes and responses to change that are often indirect and at multiple scales requires an understanding of the social and physio-chemical dynamics within these ecosystems that is undoubtedly a daunting challenge.

Many of the impacts of climate change, both positive and negative, will coincide with fluctuations in water resources that in many areas are already scarce. Twenty-one countries fell below the threshold for water scarcity in 2000 and "another 14 will join them by 2030. This represents 55 percent of the world's population" that will have insufficient domestic water (Falkenmark, 1990; World Economic Forum Water Initiative, 2009).[7] Changes in precipitation and temperature from climate change create uncertainty regarding the timing, quality, and quantity of current water resources. A change in absolute water resources also has an impact on the relative wealth of countries and causes changes in relative power. Allan (2007) notes that contemporary conflict theory postulates that "conflict and social change originate from shifts in relative deprivation, from absolute deprivation, where the availability of even the lowest quality of life is uncertain, to a state of relative deprivation, which raises an awareness that others have more." Migration could result from both the increased appeal of areas with abundance or from shifts to scarcity that can make areas less habitable. Such rapid shifts have been proposed as causes of conflict in the past, especially in areas where governance structures are not robust and institutional resiliency is low (M. Giordano et al., 2005; Lee, 2010).

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[7] Although water requirements are highly variable depending on the demands of an individual country, 1,000m^3/capita/year water scarcity in this case is used as a measure of where water becomes a limitation to economic development (Falkenmark, 1990). Many countries exist and flourish on much less than this amount, while other countries lack the infrastructure or management capacity to utilize their abundant existing resources.

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Fluctuating or inadequate water resources, such as those predicted by the IPCC, have been cited by many scholars as a potential major factor in political conflict and even war (Starr, 1991). Despite a lack of historical precedent, some studies continue to revert to environmental determinism, with a linear relationship between climate change induced resource scarcity and resulting conflict (World Economic Forum Water Initiative, 2009). While recognizing that the relationship between resource scarcity and conflict is complex and non-linear, climate-related stresses can certainly complicate relations (UNEP, 2004).

Conflict over transboundary water resources, when it has occurred, has usually been associated with rapid change and the introduction of stress to a system such as from drought, dam construction, or shifting political boundaries, as well as negative overall political relations (A. Wolf, 2007). When such stresses to the status-quo are beyond the available water management capabilities of nations, often incorporated in institutions such as treaties, they have often struggled to find satisfactory solutions that fulfill both their own requirements and the needs of neighbors who share the water. The complexities of nations sharing a vital, valuable, and increasingly variable natural resource cause water management to blend more into international diplomacy and conflict management (Odom & Wolf, 2008).

Internal instability within states often carries over into the international realm and must also be considered. For example, the Darfur conflict at least partially stemmed from local pastoral and agricultural groups fighting over access to scarce resources that then grew to have international aspects. The current UN General Secretary Ban Ki-Moon has made such connections, stating that the Darfur crisis "grew at least in part from desertification, ecological degradation, and a scarcity of resources, foremost among them water" (UNEP, 2010).

The interaction between environmental stresses, responses at various scales, and state stability have been described by scholars through the lens of securitization (K. Allan, 2007). Buzan (2000) considers security from different scales to describe how people or societies construct or "securitize" threats. The three levels used to describe interactions at different scales are individuals, states, and international systems (Buzan & Waever, 2009). Starting at the individual level, security can be considered as a factor of "life, health, status, wealth, freedom" (Stone, 2009). While defining individual security can be complicated by personal differences, Maslow's Hierarchy type-requirements generally hold true (Maslow, 1943). However, the concept of security at the individual level does not directly translate and apply to national security (Stone, 2009). For the level of state security, Buzan (2000; 2009) considers that states are larger, more complicated entities with a constantly shifting hierarchy of requirements in often overlapping sectors of Political, Military, Economic, Societal, and Environmental. Each sector impacts security, but also is linked to all the other sectors in often intricate and complex ways so that a discussion of each sector on its own does not adequately address the issue of security (Stone, 2009). It is necessary to decipher where one sector ends and another begins to determine how each sector individually affects overall security.

Buzan's discussion of security and stability at different scales and for different sectors is especially useful in the context of climate change (Buzan, 2000, 2001). The impacts of climate change will be largely in the Environmental sector, but it will arguably be as much of a factor and influence in other sectors, with consequences that are largely unpredictable. As opposed to most problems, climate change is unique as an environmental stressor since it has the potential to have a varying degree of impact on the Political, Military, Economic, Societal, and Environmental sectors at the same time and at all three scales (individuals, states and international systems). Allan (2001) builds on Buzan's ideas and notes that contentious issues arising over shared freshwater resources occur when extreme circumstances temporarily elevate the 'normal' lower status of water to the 'high' level of 'security politics.' With climate change and added scarcity, this increased importance has the potential to become permanent.

Many of the impacts of climate change will have little to do with the actual, realized environmental shifts within their borders, but instead are based on responses to the perceptions of projected change and the international political and economic ramifications of change in other areas. Nations are taking notice of and are already planning for the security implications of climate change. Many countries' actions for mitigating or taking advantage of climate change are already having second and third order impacts on both national and international stability. In India, approximately 2.6 percent of the country's 2006-2007 GDP was spent on adaptation to climate variability, likely intended to protect the 18.6 percent of their GDP and 60 percent of their employment that originates from agriculture (Paskal, 2010). "All countries will need to attain a reasonable measure of water security to compete effectively in global markets" (World Economic Forum Water Initiative, 2009). Perhaps in response to climate change projections, water-scarce, developed countries seeking their own water solutions are causing changes in the geopolitical landscape by securing agricultural land overseas from less developed nations. Wild fluctuations in global food prices associated with the 2008 crisis coupled with forecasts for future water demand has led many countries that were previously willing to rely on 'virtual water' in the form of food and other imports to now believe that "rapidly industrializing economies across South Asia, the Middle East and North Africa" (supporting approximately 2.5 billion people) will need to acquire additional water resources, including in the form of water-rich agricultural land outside their borders (World Economic Forum Water Initiative, 2009).Countries with more natural water resources will become more attractive locations for investments, and instability could be exacerbated in less developed countries willing to mortgage long-term water scarcity for immediate financial gains (World Economic Forum Water Initiative, 2009). Many countries have already taken steps towards this.[8] In this way, the

[8] Saudi Arabia considered its options to continue growing sufficient wheat for the country. In 2008, they gave up being self-sufficient and instead chose to "set up an investment fund to acquire land overseas to grow crops, possibly in Pakistan or the Horn of Africa. China is acquiring agricultural land in Southern Africa for similar purposes" (World Economic Forum Water Initiative, 2009). South Korea was looking to lease land from the government of Madagascar to grow food until protests occurred, which may have had some influence on a regime change in 2009 (African Economic Outlook, 2010)

projections (and not the documented impacts) of physical scarcity from climate change are driving and influencing changes in geopolitical and socio-economic scarcity both between and within nations.

Conflict often has indirect and multiple causes, and similarly the path from changes in climate to conflict between nations, if it is to occur, will not be a direct one (Lee, 2010). Conflict is not a linear response to stresses and changes from a shifting climate. Lee (2010) proposes three pathways for climate change to lead to conflict: sustained trends, conflict triggers, and intervening variables. Sustained periods of divergent weather leads to decreased national management capabilities and increased vulnerability to any additional stress. Conflict triggers include events that spark conflict such as assassinations, extreme natural events, or acts of violence. Climate change can create conditions where the threshold is lowered in order for conflict triggers to incite international conflict. Intervening variables include a degradation in adaptive abilities originating from factors other than climate change such as poverty, inequities between groups, weapons availability, ethnic tension, and institutional resilience. From Lee's analysis we see that the institutional resilience that treaties help to engender is only one of a number of determining factors for climate change related conflict. Treaties may be especially important, though, from the international aspect of managing climate stress. Paskal (2010) states that treaties should be considered not only for their equity and legality, but also for their ability to adapt to changing environmental circumstances.

2.1.1 Environmental and Water Institutions

Institutions can take on a number of different appearances and designs, but are generally understood as agreements or procedures intended to establish a protocol for enhancing mutually beneficial political or technical interaction. Institutions can be formal or informal, and can be applied across a wide variety of scales from the individual to regional to global. Dombrowsky (2008) states that institutions make up international regimes which in turn are the "implicit and explicit principles, norms, rules and decision-making procedures around which actors' expectations converge in a given area of international relations."

Institutions are often regarded as an important explanatory variable with regard to conflict or cooperation, with most studies indicating that institutions have helped to prevent disputes over shared water resources and increased cooperation between riparian states (R. B. Mitchell, 2006; A. T. Wolf, 1997). Under regime theory, treaties act as tools intended to better manage and share natural resources, such as water (Daoudy, 2008; A. Jagerskog, 2003). Institutions repre sent a nation's means to manage environmental stress and the "will, wit or capacity to change (a) state of knowledge, social goals, cultural modes, and technological mixes, or form of economy" (Selby, 2006). Treaties can define acceptable behavior and direct political interactions, and thus enhance stability. Recognized rights that have been previously established in a treaty can limit the potential for conflict since the likelihood of conflict generally decreases with "explicitly stated rational goals; and when there are norms and legal channels available for resolving conflict" (K. Allan, 2007; p. 231). If all parties have agreed-upon limits, transgressions are easier to avoid and redress. Transgressions of a well-designed treaty with clear definitions can often be solved with simple objections or communication without broaching the larger, perhaps more volatile subjects that were tackled at the time of the treaty signing (Hamner, 2008; p. 40).

Mitchell (2006) notes that institutions can help with compliance and with conflict management through processes that include "facilitative intervention in the form of good offices, mediation, conciliation, and fact finding, and binding intervention in the form of arbitration or adjudication." Many bilateral and regional water sharing agreements incorporate the overarching principles or general concepts of international law, but do not include specific mechanisms designed to facilitate negotiations and interactions between nations. In other words, the means to "not only solve disputes between states, but facilitate negotiation and positive interaction to resolve minor points of disagreement before they become legal disputes" (Subedi, 2003; p.35).

While the establishment of a comprehensive regime is almost universally recognized as a positive, the effectiveness of specific principles (with the principles within the 1997 UN treaty most often cited) during the application of the treaty has not been empirically determined (Tanzi, 2001). Research concerning the impacts of institutional design on the management of international rivers remains limited and the mere creation of an international water regime “does not provide any guarantees that it will ultimately contribute towards problem solving” (Dombrowsky, 2008). With regards to environmental institutions in general, there have been many explanatory models/variables proposed in an effort to account for their success/failure (e.g., (Gerlak, 2004; Gerlak, 2007; Gerlak & Heikkila, 2006; Gerlak & Heikkila, 2007; Heikkila & Gerlak, 2005; O. Young, 2006; O. R. Young, 2002). Chasek et al (2006) discuss how regime effectiveness is tied most closely to three main factors: first, regime design, which includes enforcement, reporting, and monitoring; second, implementation, which includes the “extent to which actors adopt formal legislation and other regulations to enact the agreement.”; third, compliance, or how much actors actually observe the treaty and regulations. Chasek then notes several obstacles to implementing/complying with conventions. These include transition from regime laws to domestic laws, lack of capacity to implement laws, lack of respect for the law, compliance costs, and lack of funding.

Treaties are often considered for their perceived impact without any knowledge of their inner workings. Blomquist (2004) notes that additional investigation of institutions is warranted to determine how they affect the outcome by prompting people to change their management practices, easing or hindering change, and shaping the management alternatives that water uses and organizations consider and adopt. The next step for treaty research is to go beyond a generic view of their positive nature towards an examination of the design and application that determines how and why they matter.

2.1.2 International Water Law

A review of international law reveals very few accepted general rules and guidelines for governing water resources. International water law is still in its formative state and nations have generally been solving their water sharing issues on an ad hoc basis with very few specific internationally recognized, overarching principles. An examination of the world's inter-state water agreements shows a wide array of mechanisms used to manage flow variability and minimize disagreement with varying degrees of effectiveness. According to the Oregon State University Transboundary Freshwater Dispute Database (TFDD, 2008), there are over 450 international treaties that govern river basins worldwide. Interpretations vary among the global community regarding which mechanisms are most important and the extent to which they have contributed to a successful agreement. Consequently, there is a lack of uniformity in the broad range of principles and prescriptions found within the world's water treaties.

Perhaps prompted by the limits of established international water law, nations have employed a wide variety of tools to facilitate compliance. The extent to which nations agree to enforce their treaties is sometimes described in terms of 'hard' or 'soft' law. Both terms have broad definitions that can refer to a number of processes, but the common thread generally used to segregate them is the binding nature of an agreement. Soft law sometimes refers to codes of conduct or is explained as 'customary law' that is not formally binding. There is not usually a set protocol for enforcing soft law; instead, the opinion and feedback from funding agencies, donors, and other nations is perhaps the greatest force for applying pressure.[9] Hard law includes some sort of obligation, sanctions, and/or an *enforcement* mechanism (Trubek, Cottrell, & Nance, 2005). International hard law provides the greatest leverage to enforce a state's or community's desired impact. Abbott (2000) describes the international use of hard and soft agreements, finding merit for both types of agreement. He states, "private actors generally seek hard

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[9] Soft, or customary law, enforcement tactics can include 'naming and shaming' those parties that are not in compliance with an agreement.

legal arrangements that reflect their particular interests and values." However, hard laws "often conflict with those of other private actors or of government." For this reason, "soft legalization helps balance competing considerations, offering techniques for compromise among states, among private actors, and between states and private actors."

International water law, which is shaped by and includes the treaties themselves, almost always falls under the category of soft or customary. The most comprehensive, widely referenced summary of customary law for international water management is in the United Nations 1997 Convention on the Law of the Non-Navigational Use of International Watercourses.[10] The convention states its intent is to lay a widely-applicable "codification and progressive development of rules of international law" and framework that "will ensure the utilization, development, conservation, management and protection of international watercourses" (U.N., 1997). The convention builds on the International Law Association's Helsinki Rules on the Uses of the Waters of International Rivers and summarizes many of the core concepts found in treaties at the time of its signing (McCaffrey, 2007).[11] Negotiations for the 1997 UN Convention began in 1981 and had participation from all UN member states. "Adopted by a large majority on May 21, 1997, the Convention has not entered into force since…35 countries are needed to make the UN Convention applicable to all parties" (Salman, 2007).[12] As of 1 July 2010, it has only been rati-

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[10] The convention was constructed by the International Law Commission, which is a "UN body composed of legal experts nominated by states, elected by the United Nations General Assembly, and tasked with the codification and progressive development of international law" (Salman ,2007).

[11] The 1997 Convention is based in large part on the Helsinki Rules. "Concepts such as equitable utilization and the consideration of all beneficial uses, as well as using the international basin as the primary unit of analysis, were laid out in the Helsinki Rules" (McCaffrey, 2007).

[12] 106 countries voted for the Convention, and three against (Burundi, China, and Turkey), with 26 abstentions (from personal communication with Ms. Flavia Loures, at the World Wildlife Fund).

fied or approved by 19 countries.[13] Wouters (2000) notes that the Convention did not require 35 ratifications by May 20, 2000 in order to come into force and that "as with many other global international treaties, the UN Watercourses Convention will come into force upon acquiring the necessary number of ratifications. This could occur at any time and, in fact, is a feasible possibility." Even if it does enter into force, only countries who have signed the convention will be party to it. States that initially voted for the convention are not obligated to then sign or abide by it.

The 1997 UN Convention presents baseline principles in order to provide a framework for managing international waters or dispute resolution. There are very few specifics; instead, common definitions and expectations are laid out with the intent that they be applied in a way that is appropriate for the specific basin. For example, broad terms such as "watercourse" are defined, but the specifics are left to those applying the definitions (Salman, 2007). There are four principles in the convention that are increasingly referenced by those managing international watercourses. They are:

- Article 5 is the "equitable and reasonable utilization and participation" obligation to utilize an international watercourse in an equitable and reasonable manner (often summarized as 'equitable utilization') (U.N., 1997);
- Article 7, which presents the "obligation not to cause significant harm" to other riparian states (the "significant harm" rule) (U.N., 1997);
- Article 12, entitled "notification concerning planned measures with possible adverse effects" discusses the notification of other riparians of water management and construction that could "have a significant adverse effect upon other watercourse States" (often summarized as "prior notification") (U.N., 1997);

[13] Finland, Germany, Hungary, Iraq, Jordan, Lebanon, Libya, Namibia, Netherlands, Norway, Portugal, Qatar, South Africa, Spain, Sweden, Syria, Tunisia, Uzbekistan, and, most recently, Guinea-Bissau have signed onto the Convention (from personal communication with Ms. Flavia Loures).

- Articles 20 to 26, entitled "Protection, Preservation and Management," these articles deal with obligations to protect the environment associated "with international watercourses, including protection and preservation of ecosystems; prevention, reduction and control of pollution; introduction of alien or new species; and protection and preservation of the marine environment" (Salman, 2007; U.N., 1997).

A twenty-year analysis of hundreds of treaties led to the establishment of the core principles found in the 1997 UN Convention (Conca, 2006b). The pendulum now swings in the other direction, with nations encouraged to take the general principles from the convention and apply them in the hundreds of specific agreements. While the convention may never get the necessary signatures to enter into force, it does influence nations regarding how they manage their agreements, especially new agreements or the diplomatic negotiations regarding their shared watercourses. For instance, Southern African Development Community Protocol on Shared Watercourses have rewritten the protocol to include the main provisions of the Convention (Loures, Rieu-Clarke, & Vercambre, 2010; Wouters & Salman, 2000). Unfortunately, the broad and vague language used in the convention can be interpreted in a variety of ways that can often be conflictive. There is no overarching management body to provide direction and it is left up to the parties involved to determine whether actions and principles conform to the convention. Application of the convention is further complicated by a lack of oversight or practical enforcement by the UN for situations that cannot be resolved independently.[14] The net effect is that abstract UN Convention principles, such as absolute territorial sovereignty and absolute territorial integrity, are usually not the basis for an agreement, but rather a compromise based on basin-specific water requirements (Odom & Wolf, 2008).

[14] The International Court of Justice will hear cases that may be in violation of the Convention, but only when both parties agree to it and only regarding specific issues (McCaffrey, 2007).

For practical application of the convention, interpretation of general principles such as 'equitable utilization' and 'no harm' is accomplished by looking at existing treaties and how they have already applied these terms. This is, in essence, the basis for all legal construct as established under 'Customary International Law.' The definitions of 'fair and equitable' and 'no harm' are determined by the widespread repetition of similar acts by States "out of the belief that the law required them to act that way" (UC Berkeley, 2007). In other words, "it is by looking back at previously established treaties that we can best understand how to go forward with these principles" (Dinar 2007). However, detecting and quantifying these principles is often difficult. From examination of the actual treaties, the "aforementioned principles of causing no significant harm, prior use and priority of use are not explicitly referred to in documents that allocate water" (Odom and Wolf 2008).

International law has arguably not kept up with the shifting management requirements that stem from increased use and new applications of water. Many international problems from the expanding and myriad uses of water have yet to be solved. Thus far, "most attempts to manage the new suite of water sharing problems have simply mirrored the methods used for navigation" (McCaffrey, 2007). As McCaffrey (2007) states, "maintaining harmony between nations sharing freshwater resources and providing equitable allocation of those resources while protecting ecosystems and water quality is one of the great challenges facing international law and institutions in the twenty-first century."

2.1.3 Water Treaty Implementation and Application

The application and implementation phase of water treaties has largely gone unanalyzed. Some suggest that empirical research of the sort that catalogues representative observations is too limited for properly identifying critical factors and for creating regression equations that speak towards causality (USACE, 2006; p.13). Academic work has largely been focused on how water treaties were established (i.e. how to get parties to cooperate enough to sign and implement these agreements), rather than the impact of the treaty subsequent to its signing (T. Bernauer, 2002; Koundouri, 2006; Siegfried & Bernauer, 2007). Research examining the impact and effectiveness of treaties has generally been limited to individual basin case studies, which have been conducted for several specific basins around the world (Alam, 2002; Eyal Benvenisti, 2003; A. Jagerskog, 2003; Mimi, 2003; Williams, 2007). These case studies often examine the effectiveness of treaty design features in order to provide answers to when and why each treaty fails or succeeds. While a strong institutional influence is almost universally acknowledged by these studies as a positive causal factor for successful management of trans-boundary waters, the construction and performance of the different institutions is highly variable.

Since a comparison with other treaties and locations is often not pursued, the applicability of these results is usually limited to a specific study basin. Very few researchers have empirically examined the relative strengths and weaknesses of institutions across multiple basins (Marty, 1999; Shira Yoffe, 2003; S. Yoffe, Wolf, & Giordano, 2003). A quantitative study across a large number of basins that generalizes the extent to which common and dissimilar institutional characteristics may influence the success or failure of a treaty has not been undertaken.

2.1.4 Water Treaty Design

Most international organizations limit their prescriptions for modifying old treaties and creating new ones to general guidelines such as those in the UN Watercourses Agreement. For example, UNDP Water Governance Facility at SIWI acknowledges that there is no blueprint for how transboundary water cooperation should be accomplished, but instead gives general guidelines such as:

- "The respective riparian feel an ownership of, and a political commitment to, processes of promoting cooperation";
- "The respective riparian shifts focus and moves from challenges and constraints to opportunities"; and

- "Trust and personal relations are developed among riparian delegations from countries and between domestic water user groups" (U.N.D.P. Water Governance Facility, 2010).

Overarching principles such as these are indeed needed to provide goals and a vision from which all parties can agree to base their negotiations. However, what is often lost in the generalities is a blueprint of how to best implement such nebulous ideas as 'promoting cooperation' and developing 'trust and personal relations'. In other words, what are the 'nuts and bolts' that can be applied to mold these principles into a workable agreement? This section examines the academic literature and provides a summary analysis of the treaty parameters that are most often cited as essential to successful treaty implementation.

Treaty parameters and principles that have theoretically been important, but are not shown empirically across a large number of treaties, have been put forth by multiple authors. Recent work (S. Dinar, Odom, & McNally, 2008; Drieschova, Giordano, & Fischhendler, 2008; Itay Fischhendler, 2007; Itay Fischhendler, 2008b; Stahl, McNally, De Stefano, Zentner, & Wolf, 2010) has shown that some water allocation mechanisms are better able to cope with climate-uncertainty, based on their ability to manage hydrologic changes and subsequent reductions in the number of interstate grievances associated with changes in runoff. Drieschova (2008) and Fishendler (2005) found that specific allocation mechanisms resulting from negotiations vary and that many that had been agreed upon by all involved parties were not ideal due to technical or political barriers.[15] Dinar et al. (2008) describes eight allocation methods that include "fixed quantities that vary according to water availability, fixed quantities recouped in the following period, by percentage available, prior approval (e.g. by joint management commission), geographic distribution/allocation of entire rivers, consultation, and prioritization of uses." Using this classification, Dinar et al. (2008) identified 137 treaties and associated grievances that pertained to water quantity, hydropower and flood control.

[15] In that case, 'ideal' meaning flexible in the face of change but still enforceable and binding.

Statistical analyses were conducted on a subset of 74 treaties (basins with only two riparians) to infer how precipitation variability affected the frequency and intensity of complaints and found that "various mechanisms are statistically different in their resiliency to complaints and grievances" (De Stefano, Duncan, Dinar, Stahl, & Wolf, 2009; S. Dinar et al., 2008).

Overall, the works by Marty (1999) and Drieschova (2008) have perhaps best framed the terms for water institutional effectiveness/resiliency, and supported the hypothesis with some empirical data across multiple basins. Marty provides a solid foundation for proceeding to a larger-scale research (with a larger number of basins) using social and political theory as explanatory mechanisms. Marty proposes that treaties that are detailed and have exact guidelines are more successful. The more specific the expectations, the more behavior can be influenced since the parties know how they should behave to comply with the regime specifications. He contends that increased clarity inherently resulting from most treaties prevents future confusion or conflict and simplifies the implementation and operation of the basin management plan. However, while *specificity* in treaties may be an indicator of strength, the mere presence of a mutually agreed upon thresholds could also be superficial in its importance. Institutions that go beyond metrics and also define outcomes and strategies for successfully achieving those outcomes, including specific goals and thresholds, may be inherently more focused and resilient.

Drieschova et al (2008) look at treaty mechanisms for addressing flow variability. They propose several mechanisms that are likely to aid in managing variability. They then examine large numbers of treaties and calculate the percent of treaties that contain those mechanisms. While they propose that each mechanism could play a role in management, they do not attempt to empirically quantify or evaluate the role of each mechanism in treaty resiliency. While some treaties include mechanisms that are explicit in their intention to manage flow variability, the majority use broad, non-specific mechanisms that "deviate from an 'ideal' state of being both flexible in the face of change but binding in enforcement" that rather "reflect trade-offs between flexibility and enforcement."

3 Hypotheses, Definitions, and Explanatory Mechanisms

This research uses past treaty successes and failures in managing hydrologic stress as a means of determining the importance of treaty design parameters. These parameters can then be used more broadly across other treaties to estimate capabilities for managing stresses, such as those from climate change. It assumes that treaties in general improve resiliency and hopes to provide direction for basins without a treaty or those that wish to develop institutions to better account for climate change.

It is likely impossible to consider what makes a robust and resilient treaty without also considering what makes an effective treaty. Draper (2006) considers an effective treaty as one that facilitates adequate planning, conservation, and management of a water basin in a manner that causes no significant harm to most other parties. Effectiveness, or success, in this study is defined simply as the avoidance of conflict, as manifested by the public and official expression of dissatisfaction by a party.

Part of the question regarding the assessment of the design and application of institutions is “what makes a treaty effective?” Secondary to that is “how well does (and what makes) a treaty remain effective even when the system is changed/stressed?” Together these two questions help us to better answer what makes a treaty resilient. While this study uses hydrologic stress and response, the “resilient” traits that the treaties either have or don’t have are not specific to water treaties. In other words, while this study uses water treaties as the lens with which to view treaty resilience, the principles researched here can apply to all treaties, especially within the environmental realm.

3.1 Hypotheses

While recognizing that there is significant variability between basins and treaties, this project uses a large treaty and conflict dataset to examine the hypothesis that some treaty mechanisms are more important to deterring conflict and complaints that may occur due to hydrologic stress. In turn, treaties can perhaps be better evaluated to determine their capacity to manage projected changes in climate. Specifically, there are seven treaty characteristics, or mechanisms, that are expected to elicit less conflict and fewer complaints when they are implemented in an agreement. It is expected that these mechanisms should make the agreement more stable in the face of increased variability and decreased flows and run-off. In addition to the treaty mechanisms, the importance of both the magnitude of hydrologic stress and the difference in economic and political strength between the riparians is investigated.

In this dissertation three hypotheses are tested, which are:

Hypothesis 1: A state experiencing a period of increased hydrologic stress in the form of drought or additional variability will have an increased likelihood of complaints or state grievances involving a shared water resource, compared to a state that is not experiencing hydrologic stress.

Hypothesis 2: Water sharing agreements that have mechanisms in place, namely *specificity, uncertainty management, enforcement*, *communications*, *flexibility, integrativeness*, and *scale*, will have less conflict and fewer grievances, including those that are climate related. Each mechanism contributes equally to the treaty's utility in managing hydrologic stress, and the overall institutional resiliency of a treaty can be summarized by adding the number of mechanisms included in the treaty.

Hypothesis 3: All mechanisms have added benefit, but some mechanisms are more important to providing increased institutional capacity to manage drivers of conflict such as hydrologic stress, as well as stress from differences in political power, national stability, and economics that, if left unmitigated, could otherwise lead to conflict.

The basis for these hypotheses is laid out in this section and tested and discussed further in Chapter 4 (methodology), Chapter 5 (results), Chapter 6 (case studies), and Chapter 7 (conclusions). The definitions used to frame the analysis and testing of the hypotheses are presented below, including the physical and theoretical extent of the system, the parameters for hydrologic stress, explanations of what a successful treaty entails, and the interpretation of institution in this study.

3.1.1 Defining the System

In order to understand how to best measure and monitor parameters, the theoretical, spatial, and temporal extent of the system needs to be clearly defined. This is a global study, but our analysis begins with the scale that the treaty covers. Therefore, the unit of analysis is the treaty and the system is defined as the spatial, political, and, topical areas that are included in the treaty.[16] Most international water treaties are directed primarily at a specific basin or water body. The spatial delineation of the basins considered are identified by the TFDD. [17] All agreements used in the study originated between 1945 and 2008 and included the topics of flood-control, water quantity and/or hydropower. Some cases were not included since they did not contain the mechanisms and independent variables of interest due to missing data or a lack of foreign language translation. After taking these restrictions into consideration, a total of 146 agreements were used in this analysis.

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[16] Scale differences in the typical unit of analysis political and physical scientists use to delineate and describe a basin-or in other words, the way to define the scope of the problem- complicates the integration of data and discussions from both disciplines. Political scientists typically follow the accepted country, region, and local boundaries when defining their areas of consideration. Physical scientists tend to use the basin itself to define the area. The two different definitions would not be an issue if the river basins area coincided with the political boundaries. Unfortunately, rivers often do not follow political boundaries.

[17] Gleditsch (2004) defines a river basin as "a topographically delineated area drained by a stream system – that is, the total land area above some point on a stream or river that drains past that point. This means that it encompasses all of the fresh and ground water in a large geographical area. Often encompassing a unique ecosystem, it is frequently used as a spatial unit for socio-economic management."

A broader view beyond the flows of a specific river is necessary to understand the stress and management challenges that a basin is undergoing. Gleditsch (2004) notes that this “could include the standard upstream/downstream conflict scenario, but also broader concerns about watershed management, pollution, and a more subjective notion of scarcity.” The degree that a treaty remains effective is influenced by things at scales both greater and smaller than those outlined in the treaty. Impacts and interactions are not limited to one scale. For example, a local area might dissent with national policies, but in may unite with the rest of the nation when faced with a common international disagreement. Accordingly, it is not always possible to know which unit of analysis we are working with. When analyzing our system, impacts (social, political, economic, biophysical) of the institution across multiple scales (international and national) as well as the dynamic interaction with interrelated issues are considered. In order for this research to be effective, however, multiple comparable data sets are necessary. In this study, the sampling design/data sets are primarily at the national or regional scale, where we have information on treaties, events, responses, and biophysical data. Therefore, the analysis of impacts to the system will primarily be at the nation-state level. In the case study analysis, national stresses and response to social, political, economic, and biophysical parameters, including those that at first may appear only tangentially related, are considered to determine to what extent they have a relationship with treaty functionality.

3.1.2 Defining Institution

Institutions come under the guise of many different names and definitions. For simplicity, in this study institutions are defined as a binding agreement, typically called treaties or conventions.[18] Chasek (2006) places institutions under the broader definition for “regime,” which is defined as either a set of “norms, rules, operating procedures, or

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[18] Treaty, convention, and institution are used synonymously in this study.

institutions that actors create or accept to regulate action." Young (2006; 2002) emphasizes the behavioral impact that the arrangement produces and his definition makes the distinction between "thick" and "thin" institutions. Thin institutions are "systems of rules, decision making procedures, and programs as articulated in constructive documents (e.g. treaties)." Thick institutions are defined as "social practices that are based on constructive documents, but also include "common discourses in terms of which to address the issues at stake, informal understandings regarding appropriate behavior on the part of participants, and routine activities that grow up in conjunction with efforts to implement the rules." Chasek's definition of "regime" and Young's definition for "thick institutions" seem to be similar, with an emphasis on the behavioral impact that the arrangement produces.

Hardin (1968) explained that both individuals and societies act in an unsustainable manner towards common resources, ultimately overexploiting and depleting the resource. The solution to this "Tragedy of the Commons," was for institutions to provide "mutual coercion, mutually agreed upon by the majority of the people affected." Hardin's ideas have been influential in examining institutional arrangements and management regimes which are generally considered important factors in shaping the actions of the constituents (Dietz, Ostrom, & Stern, 2003). However, there is much variability in the purpose and characteristics of the institution.

3.1.3 Defining Institutional Success

What constitutes success and failure of a treaty remains a matter of interpretation among scholars (as well as those designing and applying the treaty). Bernauer (2002) provides an excellent review of two measurements for success and failure employed by social scientists (compliance and problem solving). Mere compliance to a treaty, he argues, is a poor indicator of success since it does not accurately reflect the extent to which an international river management problem was dealt with. Compliance with a poorly designed and ineffective treaty has no real meaning. Another measurement of success is the extent of problem-solving that the treaty facilitates. Problem-solving essentially seeks to measure the extent to which institutions change behavior towards solving specific environmental problems.

A robust and resilient treaty is often defined as one that continues to function as intended even when the system changes or is stressed in some way. Gerlak and Heikkila (2007) note that in addition to persistence, it is also important to consider the functionality of the institution. Young (2002) similarly considers the sustainability of institutions, but calls this “robustness” and defines it as “a measure of the capacity of an institution to survive various pressures intact in the sense of withstanding the impact of destabilizing forces without suffering collapse or experiencing transformative change.” Giordano (2005) notes that institutions may not be sustainable where “rapid changes in resource environments outpace the capacity of institutions to deal with the change.” These pressures can be either internal or external to the issue at hand, and can be either immediate or grow gradually; the institutional capacity to deal with the stress is often dependent on the type and timing of the stress.

Our measurement of success in this paper leans more toward the problem-solving philosophy, with resiliency used as a measure of problem-solving capability. Resilience is defined by Nelson (2007) as the amount of change (or stress) a system can undergo and still retain the same function and structure while maintaining options to develop. Treaties are designed to lessen the impact and minimize the overall stress on a system, thereby increasing system resiliency. Our measurement of institutional success then becomes how well the treaty buffers the system from stress. Or, put another way, institutional strength/resiliency/success is defined synonymously as the ability of an institution to aid the system in mitigating or adapting to stress (in particular, hydrologic) or changing circumstances. The measurable exhibition of this success is the presence or absence of complaints, especially those that can be directly attributed to the climate-related stress being applied to the system.

3.1.4 Defining Hydrologic Stress

In several international basins, water allocation rules agreed upon in water sharing agreements or treaties have been challenged due to uncommon hydrological conditions (e.g. prolonged droughts or severe floods). Such flood and drought events may become more frequent due to climate change effects. Identifying the hydrological conditions associated with past water treaty challenges and then estimating the probability of having similar (or more severe) conditions in the future based on climate change projections will contribute to the understanding of how climate change might increase stresses on international water sharing agreements.

International water-sharing treaties often express water allocation rules between the riparian countries as a minimum in-stream flow to be maintained at any time or as a volume of water (accumulated flow) to be delivered within a specific timeframe (e.g. year, season). However, the clear quantification and location of the allocation, although essential for monitoring treaty compliance, can be ambiguously expressed in the treaty texts (Itay Fischhendler, 2008a). Moreover, data about past difficulties to meet the allocations specified in treaties can be vague, misconstrued, or absent. The analysis of gauged streamflow data available at the Global Runoff Data Centre for international basins shows that flow records are not always available or of sufficient quality in river stretches where treaty compliance is to be monitored (Stahl, 2007). Hence, in many cases historical records cannot be used for identifying hydrological conditions associated with treaty allocations or disagreements related to compliance with these allocations.

This project is interested in thresholds of flow (stream, river) or water body levels as stated within the water treaty. When flows/levels are pushed below these thresholds, a signatory is in non-compliance. Non-compliance thresholds can be used as an indicator of where higher political or social stress could result, unless treaty mechanisms are able to manage the non-compliance. Due to the great variety in data availability and the inherent problems with flow and water level modeling, both quantitative and qualitative techniques (water balance, soil moisture, and drought index) were considered and are presented in Appendix B.[19] For this study, the more qualitative drought index and the term ‘drought’ is used to describe the state when a basin has experienced hydrologic stress that might have challenged allocation agreements.

Drought is often used loosely to describe any situation where water is deficient, but there is a lack of consensus within academia on how to define and quantify drought. Droughts have received over 150 definitions over time and, in most cases, thresholds for declaring drought are arbitrary (Smakhtin & Schipper, 2008). This analysis is interested in *meteorological drought*, or a deviation from the average precipitation pattern (Burke & Brown, 2006).[20] For this study, the Palmer Drought Severity Index (PDSI) for the period 1950-2005 is used as a quantifier of meteorological drought. Using this dataset as a baseline, two study-appropriate definitions were used to classify the extent that a basin is experiencing hydrologic stress. The first definition used is *absolute drought*, or a point on the PDSI defined by Palmer where conditions are severe enough to be universally classified as drought regardless of the location. The second definition is *relative drought* that uses the average PDSI for each basin to define a numerical threshold below which a situation can be considered to be a drought. Each of these definitions is discussed in greater detail in the methodology Chapter 4.2.5.

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[19] An in depth study was conducted to determine the best way to reconstruct past hydrologic conditions and river flows, especially in poorly gauged or ungauged rivers. A detailed summary of the merits and limitations of three different methods is presented in Appendix B.

[20] Burke (2006) provides the following drought definitions: “*meteorological drought* relates actual precipitation departure to average amounts on monthly, seasonal, water year, or annual time scales; *agricultural drought* focus on precipitation shortages, differences between actual and potential evapotranspiration, and soil water deficits (for specific crop activities); *hydrological drought* focus on the effects of periods of precipitation shortfall on surface or subsurface water supply (i.e. streamflow, reservoir and lake levels, groundwater) rather than with precipitation shortfalls; and *socioeconomic drought* associates the supply and demand of some economic good or service (e.g. water, hydroelectric power) affected by precipitation shortages.”

The hydrologic stress definitions used in this study are spatially and temporally broad. This is a direct result of a lack of data and modeling approaches with the spatial detail relevant to determining water availability at the location where the treaty stipulates water is to be delivered or monitored. Both of the definitions used for drought are serviceable, but do not provide an ideal indicator of when a treaty's allocation thresholds may have been challenged by decreased flows. However, they can be universally applied and enable comparison across multiple basins. Ideally, each basin would be considered individually and a definition created that incorporates the area-specific consequences of hydrological drought that depend on regional/local circumstances such as soil type, water storage capabilities, agriculture production, availability and depth of groundwater (Bresser, van Schaik, & Kabat, 2006). As discussed in the method investigation in Appendix B, unfortunately data are too sparse and non-uniform to be applied across a large number of basins.

Future hydrologic stress is defined differently than historical drought as described above. Climate change causes variability in precipitation and evapotranspiration, which in turn are related to the variability of drought. This study uses modeled variability of precipitation and subsequent runoff, rather than the PDSI, to define future hydrologic stress. Modeled data are used to establish a coefficient of variation (CV) for these two variables, which is defined as the standard deviation divided by the mean of all annual values within a given time period (De Stefano et al., 2009). The methodology for evaluating projected climate is discussed in Chapter 4.3.1.4.

3.2 Importance of Treaty Design and Institutional Mechanisms

As discussed in the literature review, significant research at the basin level has resulted in many theories regarding treaty design that postulate different criteria that make the most impact on institutional performance. In addition, the success or failure of environmental institutions in general has been studied and many explanatory variables have been proposed. The theoretical basis for this project is that certain of the institutional mechanisms discussed above are of more significance to the effectiveness of the treaty than other mechanisms: in other words, the design of the treaty has a large impact on the capacity of a treaty to manage water stress (either from variability or from changes in requirements). Of the three measures of treaty effectiveness explained by Chasek previously (design, implementation, and compliance), we are thus primarily focused on its design.

3.3 Explanatory Mechanisms

This study uses seven explanatory mechanisms that are common to the literature review and most often cited for being of primary importance to resiliency. These criteria are a means to collapse treaties into their basic components to better explain successful treaties. A broad set of case studies, academic articles, reports, and books regarding water treaties and their application was utilized as part of the literature review. Each article was reviewed and the concepts proposed as key to the success or failure of a treaty for managing stress, particularly hydrologic, were recorded. While far from exhaustive, a quantitative analysis of 45 academic publications revealed a large number of principles and concepts that were mentioned as critical to effective water treaties (Appendix A). While the principles proposed by each article were unique in many ways, commonalities were apparent regarding the overall emphasis or intent of the principle. Based on these commonalities, the author grouped and segregated the principles into seven summary categories, which are: *specificity, uncertainty management, enforcement, communications, flexibility, integrativeness,* and *scale*. In Table 1, the mechanisms are ranked according to their estimated importance (based on the number of times mentioned as a factor in treaty success in the literature review). Each of the mechanism categories is defined and discussed in greater detail below. The methodology for measuring each mechanism is presented in Chapter 4.2.2.

Table 1 Summary of the purpose, function, and relative importance of mechanisms. Treaty variables that are most often cited as being instrumental to successful management of relational stress are segregated into seven categories, or mechanisms.

Mechanism	Purpose	Practical Application/ Components	Number of times mentioned in litera-ture	Ranking of relative importance
Communications	Increase the contact and data sharing between parties to increase compliance and cooperation	Information exchange Establish meetings schedule/protocol Data validation	25	1
Flexibility	Manage changes in the water flow/availability or in the existing political framework.	Treaty amendment mechanisms that can be applied in times of rapid change Managerial tools to recognize and plan for variability Communications mechanisms for observing and relaying change	20	2
Specificity	Provide precise rules and procedures to structure the participant's actions	Guidance for implementation of the treaty; Crisis response to and mitigation of drought/flood Confirm locations and measurement methods for increased data accuracy Illustrates benefits/requirements outside of water (hydropower, etc)	13	3
Integrativeness	Increase the cross-scale and cross-topic cooperation the treaty addresses	Non-water exchanges or concessions linked to water issues Integrated view of total environmental sphere Requirements of larger political issues	12	4
Enforcement	Provide leverage and proto-cols to influence adherence to the treaty	Resolution mechanism and procedures for disputes Communication requirements for alterations to basin Equitable joint management bodies that can exert influence.	12	4
Scale	Provide policy direction for regional, national, and local management	Enhance public participation Include needs of all stakeholders/non-signatory riparians Incorporate national programs	11	6
Uncertainty Management	Recognize and plan for the possibility that available data may not accurately reflect current conditions or that the future may be very different from the current environment	Alternative scenarios to increase preparedness Application of prediction models Variability management for periods of flood/drought	4	7

3.3.1 Communications

Communication networks and provisions can help address uncertainty, adaptability, and capacity issues that can hinder compliance and cooperation. Drieschova (2008; p.9) proposes that developing communication networks can “overcome the rigidity of water treaties and serve as a venue for solving water conflicts.” Subedi (2003) states that creative “win-win” solutions to most problems are possible, but may be hindered by a lack of regular communication. Brett (2001) notes that the key to making a sustainable integrative agreement is an understanding of the underlying interests and values of each group, achieved thorough effective communication. Much of the work of successfully implementing and managing institutions is laying a proper communications framework, and a treaty that has those mechanisms already in place avoids confusion and potential conflict over an inability to share timely and accurate data. Communication networks can be established by multiple means, including via some of the other mechanisms discussed in this section (e.g. *flexibility*, *uncertainty management*) that have integrated communication elements.

Communication mechanisms increase the contact between parties. Such interaction and sharing of accurate information helps to build relationships of trust. Where data are iteratively shared, perceptions of inequality and unilateral action can be minimized. Successful communication is about sharing information, and disclosure often requires and foments trust between both parties, providing the institutional framework for improving cooperation.

Effective communication between local, national, and international levels allows policymakers to quickly respond to what are often dynamic and highly variable end-user requirements. Many treaties and governance mechanisms “emphasize centralized institutions with little local participation, resulting in stymied multi-level communication” and limiting the effectiveness of governance apparatus that are often built on the assumption that there is a constant flow of information and feedback (Michel, 2009; p.9). Conversely, information overload can occur, resulting in complex and often cumbersome decision-making, without proper filters that limit the type or source of information flow, information management.

Communication can be hampered by a lack of data and collection mechanisms. A lack of clear precipitation and flow data on the Euphrates has complicated Syria's agreement with Iraq; "Evidence is lacking to draw a definitive conclusion, but indications are that there has been only minimal and periodic compliance" (N. Zawahri, 2006; p. 1048). While the effects of drought and other biophysical stresses would not be completely overcome with better communication and reporting, the effects might be assuaged by better timed releases of water. Many of the negative impacts from drought and other biophysical stresses in the basin have stemmed from a lack of an effective monitoring and reporting framework, and several other mechanisms have communications components as their keystone. Communications can improve and facilitate *uncertainty management* and *flexibility* through the "early identification of future trends , and (offset) the problem of asymmetrical information between riparians" (Drieschova et al., 2008). In addition, *enforcement* confusion and unfounded perceptions of non-compliance can be minimized, and problems of *scale* and implementation can be assuaged.

3.3.2 Flexibility

Flexibility is defined as the ability to implement changes to an agreement to better manage changes in the water flow/availability or in the existing political framework. The availability and intended uses of water, once described in a treaty, is not static. Environmental fluctuations and economic changes shift the regional value and priority of water. A nation or region that is experiencing drought may place much greater value on water than during periods of plenty. Technological innovations may decrease the extent of agriculture, increasing supply and lowering demand/value. Decreased flexibility is "likely to lead to reduced regime effectiveness since the existing problem solving strategy may prove inadequate to cope with changing circumstances" (Lindemann, 2005).

During periods of drought, the hard numbers in place in the agreements may need to be modified to accommodate the biophysical conditions. Kibaroglu (2008) states, “the flexibility of decision-making procedures to respond to water stress conditions becomes crucial. Flexibility is defined as the ability to manage changes in the water flow/availability.”

In general, specific allocations within treaties have not been readjusted despite a constant flux in requirements, uses, and availability over time. Odom and Wolf (2008) raise the example of the Johnston Accord which based its allocations on existing irrigated agriculture within the Jordan basin. In practice, however, Israel applied most of its allocation “to other uses entirely, many of them outside of the basin.” Although both Jordan and Israel continue to adhere to the Johnston allocations, the basis for the allotments no longer reflects current needs. The end-users are required to shift their water applications to meet the inalterable mold of the agreement rather than the agreement changing to meet the needs of the users.

Haas (1992) discusses the need for flexibility in his recommendations for improving international institutions that deal with environmental issues, stating that the institution must be able to learn (i.e. adapt). He defines learning as receiving and applying new information to improve or initiate new program directives. This adaptability he ties to several features, including an ability to “act independently of the direct control of member governments” and an ability to “influence other actors' willingness to change their behavior and the capacity of these actors to absorb lessons.”

Flexibility is often tied to and enhanced by other mechanisms. Lyster (1985) notes that one of the key elements in the success of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) involves communication mechanisms that enable flexibility. The parties meet every two years, resulting in a constant evaluation/reimplementation process. Sand (1997) also notes flexibility is of primary importance in CITES, with many of its mechanisms having completely evolved over the last two decades.

Flexibility is important in dispute resolution mechanisms in order to allow states to choose from a number of diplomatic and judicial options to settle their disputes. The UN Watercourses Convention recognizes this and in Article 33 recommends several diplomatic options to be used depending on the situation, such as negotiation or mediation through the involvement of a third party, followed by arbitration if necessary (Subedi, 2003). Jagerskog (2003) notes that one way to handle variability, both for those issues that have been incorporated into an agreement and those that have been left out, is to establish a flexible joint conflict management or conflict resolution mechanism that can subsequently deal with situations of variability as they evolve.

Because of the complexity of the issues and the constantly shifting knowledge base surrounding the management of water, there is a need for expertise across a broad range of disciplines (such as engineers, lawyers, and geographers). Increased flexibility built into a treaty allows various experts and institutions to offer their capabilities to the states involved in the treaty. Smooth and established mechanisms to integrate input from experts into existing treaty parameters allows for water managers to grasp and respond to rapid shifts in the politics and hydrology of the basin. As Gerlak (2004) suggests that while "many of the factors that bring actors together in the first place are also those that keep them together," he also notes that "the role of learning and adaptation also play(s) a critical role." Giordano (2005) echoes these ideas, stating, "for institutions to be effective in the long run, then, they must be able to adapt not only to variations in the resources themselves, but also to the changing knowledge base and social systems of the resource users."

3.3.3 Specificity

Specificity is defined as how detailed and exact the institutional framework is. Precise rules and procedures structure the participant's actions; without precise rules and procedures, there is “scope for interpretation and rule avoidance” which could negatively impact regime effectiveness (Lindemann, 2005). Marty (1999; p.45) proposes that if “behavioral guidelines are not detailed and exact, they are unlikely to be operational.” Dreieschova (2008; p.13) uses the terms “direct” and “indirect” to describe treaties, where direct allocation “explicitly divide waters between co-riparians” and indirect allocation mechanisms are used to “establish the processes through which allocation will be determined, but without codifying the specific quantities or proportions to be shared.”

There is certainly a relationship between *specificity* and *enforcement*—the more specific the details regarding flow, the more easily non-compliance can be determined and the more likely enforcement options can be applied. A commonly noted weakness in international treaties is that intentional ambiguous language makes treaties more difficult to enforce. Fischhendler (2008a, 2008b) notes that ambiguity, while often intentional and desirable to getting a treaty signed, may have detrimental implications for monitoring, later dispute resolution, or when conditions change. For example, Zeitoun hypothesizes Israel included ambiguity and minimal enforcement in the 1995 Oslo II Agreement with Palestine to hinder its impact and to allow for asymmetric outcomes (Mark Zeitoun, 2008). This issue is common within international law and is not unique to water treaties. Jagerskog (2003) has pointed out that various issues might be left out of an agreement both on purpose and because the people involved were not able to identify them, leaving those applying the treaty to navigate without a specific roadmap. He notes that in some cases states negotiating a transboundary issue might choose a solution that involved a technical risk rather than one that involved a political risk in order to ensure that the treaty was signed. This potentially could lead to a situation where the treaty may be politically viable, but either difficult or impossible to implement based on the hydrology.

Specificity is usually thought of as a positive mechanism, but typically with a flexibility aspect that allows for changes in requirements and natural variability. Water availability is not static and thus while the agreement may have been feasible at the time of signing, changes in hydrology may increase the challenges of meeting specific flow requirements.

Especially with projected changes in climate, many treaties have flow thresholds and volume requirements based on hydrological records that may now, or in the near future, no longer be accurate hydrologic baselines. IPCC climate models predict alterations to the spatial and temporal hydrologic norms on which such agreements are predicated (Milly et al., 2008). In addition to changes in baseline flows, extreme hydrologic events, such as drought, that previously would have been expected to occur once in a hundred years may now arrive every 50, 20, or 10 years. In other words, the water management and climate challenges that treaties are meant to manage may soon be far removed from reality.

In the past, treaties with high *specificity* that were based on faulty or unrealistic flow data have led to disagreement or have been untenable. The negotiation of the Colorado River Compact took place in 1922 using the Reclamation Service's estimated average flow of 17.5 million acre-feet (maf). Unfortunately, the treaty was based on data from the unseasonably wet five previous years. The actual average flow over the last hundred years was nowhere near this number, averaging about 13 maf and with high variability ranging from 4.4 maf to over 22 maf. As a result, over-allocation and water scarcity has been at the root of most of the disputes and problems that have subsequently arisen over the compact (Gelt, 1997; Reisner, 1986).

A distinction between *specificity* and *flexibility* (another mechanism category) is made here. Bernauer (2002) notes an apparent contradiction between specific management and *flexibility*. For clarification, *specificity* of frameworks refers to the amount of detail for the implementation/ management, but does not relate to adaptability to fluctuations in water supply/demand, politics, and environment.

3.3.4 Integrativeness

The term *integrativeness* summarizes the idea of how broad and diverse the scope of a treaty is regarding subjects outside of what we normally consider typical for a water treaty, namely water quantity and quality. If *scale* is considered as the vertical integration of parties and issues, *integrativeness* can be thought of as of the horizontal expansion of water treaties as they address cross-topic cooperation and exert influence outside of the water sector. Dreischova (2008) describes this as the "broadening of cooperation beyond the direct focus on water." Wolf (1999) postulates that by enlarging the scope of benefit sharing water to include non-water issues, water conflict resolution may be facilitated. Kimball (1999) notes that international institutions are a means to achieve defined goals, and that sometimes those goals overlap, creating the potential for synergy. *Integrativeness* is broad in its definition since water impacts numerous social sectors and industries.

According to Chasek (2006), the international arena lacks clear frameworks and organization for integration, making effective linkages sometimes difficult to achieve. Without a framework, Michel (2009) states that the identification of benefits and similar interests that accrue from a shared resource can be a contentious and difficult exercise. Because of the wide, systems level impacts, water institutions creating a framework for integration have the potential to include land-use change, forestry, fishing, adaptation, technology transfer, economics, and numerous other topics. Selby illustrates this point by stating, "water problems are not water problems alone, but are in large measure products of the relative ability or inability of different states and societies to address their economic and social problems, water problems included" (Selby, 2006).

The timing of individual cost and collective benefits can also be a complicating factor for integrative international agreements. The timing of costs and benefits requires that individuals bear the costs before a collective benefit is achieved. For example, benefits from a river system could include hydropower generation, agricultural productivity, and enhanced water resource management, which have implications for development, employment, health, economics, and the environment (Vivekanandan & Nair, 2009). Within this realm of possibility for treaties to address, "there are immediate gains, such as flood mitigation, and long term gains, such as a well-developed agricultural sector" (Vivekanandan & Nair, 2009). Consequently, benefit sharing must not only offer rewards greater than those achieved unilaterally, those benefits must be achieved within a mutually acceptable timeframe.

Durth (1996) notes that cooperation and problem solving capabilities are stronger in settings where the societal, economic, and political are “integrated,” or where relations are strong across these multiple boundaries. The realized benefits from a theoretically positive integrative agreement are often tied to the effectiveness of domestic policy and the distribution of gains to the different sectors. The effect of a water treaty is felt at all scales, and the impacts are dynamic in their interaction. A net positive impact for all sectors can only be achieved where benefits gained are effectively managed and distributed. Domestic measures employed by each nation are therefore instrumental in ensuring the success of any integrative transnational agreement. Mismanagement and poor national water policies can render even the most synergistic agreements ineffective.

3.3.5 Enforcement

Enforcement is defined here as the means to apply leverage for the purpose of influencing adherence to the treaty. These means can include both positive and negative incentives (carrots and sticks). Barrett (2006) proposes that behavior in response to treaties is most significantly shaped by the underlying incentive structure than by other parameters. The *enforcement* mechanism also provides a method to mitigate and overcome conflict when it does occur. Subedi (2003) notes that “thus the challenge…is not only to resolve water disputes between states, but also to facilitate negotiation in order to resolve 'issues' before they become 'disputes' in the traditional and legal sense of that term.” While most bi-lateral and regional treaties include some means for managing a dispute, many struggle with an absence of a mechanism designed to facilitate negotiations, provide incentives for compliance, interpret disagreements over treaty parameters, and, if necessary, enforce the agreement.

International water law does not have a standard protocol or mechanism with which to deal with water disputes. The closest to a universal mechanism is the 1997 UN

Watercourses Convention, but it is limited in scope and has not yet entered into force. Ambiguity and conflictive language within the convention also limits, and sometimes even confuses, its application. For example, the question of precedence is not clearly defined regarding the two most frequently referenced tenets of international law (First, reasonable and equitable utilization of the water resources of an international river by a riparian state; and Second, the requirement to not cause significant harm to other riparian states when utilizing the water resources of a river) (Subedi, 2003). Most disputes consist of polarized groups, each with a claim that leans towards opposite ends of these twin pillars of international law. The result is that both sides have a legitimate legal argument and the delicate theoretical balance that the convention attempts to achieve is sometimes difficult to interpret and apply. The absence of an established authority or mechanism designed to break stalemates can cause enforcement to become a matter of evaluating the shades of the legal grayness of international law.

In general, institutions at the international level typically are organized differently and have less authority than those within states. Andanova (2009) notes that “traditionally, the capacity to set rules and generate compliance is equated with a hierarchical, sovereign form of power backed by (the threat of) sanction.” With international water law, there is no governing body that enforces or threatens sanction. Undermining actions are often easy for nations to take since the agreement exists, and is enforced, only with the mutual consent of both parties. With no clear authority, nations may be tempted to not adhere to the treaty stipulations, yet take advantage of adherence by other nations (Hardin, 1968). *Enforcement* mechanisms help signatories to take responsibility for defining and managing problems of adherence. The “incentives for parties to deceive creates an incentive for others to monitor and enforce” (Barrett, 2006).

“To maintain long-term cooperation, states must overcome their fear that others will cheat” (N. Zawahri, 2006). *Enforcement* mechanisms geared toward this purpose can take on many forms and are applied at several scales. Dombrowsky (2008) notes that one technique involved the monitoring of implementation by regularly publishing progress reports on the internet, which effectively served as an *enforcement* mechanism. An institution can accomplish this task by monitoring member states' behavior, making commitments more credible, sanctioning cheaters, and managing disputes (N. Zawahri, 2006). *Enforcement* has an element of *scale* since implementation of agreed measures will likely take place at sub-national levels. Effective enforcement relies on the fluid interaction between the international and national levels in terms of delegating responsibilities, implementation, and monitoring.

Enforcement of a treaty is sometimes difficult to define and recognize. Woodhouse (2008) notes that covert forms of power, such as coercion, manipulation, and incentives are used to control some water sharing regimes, which could complicate the enforcement of the intended goals of the treaty. To avoid treaties being dictated by the stronger of the states in the agreement, cooperation may require international organizations and their accompanying bureaucracies to oversee the efforts of both states to ensure their compliance with the treaty. Compliance also will require the ability to accurately report the hydrologic situation, likely requiring a system of joint monitoring and data collection capabilities. Hamner (2008) notes that some treaties will have side payments with non-water externalities, concessions, obligations, or perhaps only elements of political goodwill. Many of the above components are not quantifiable which can complicate the determination of compliance and enforcement.

3.3.6 Scale

Ideally, water institutions provide policy direction for regional, national, and local management, especially since it is at the local level where all policies (even international) will have to produce effects (Wouters, 2002). The final report of the World Water Forum in 2000 stressed the need to "make water management more participatory, to make water everybody's business" (World Water Council, 2000). If there is public participation in the decision-making process, this should increase the available knowledge as well as the legitimacy of the respective regime and foster its effectiveness (Marty, 1999). One of the key elements missing in many treaties is the identification and inclusion of all stakeholders at the local, regional, and international scale. Scale below the national level is especially often not addressed. According to Wolf:

> "A key stage in enforcing access to the resource is determining legal entitlement, or identifying all stakeholders…international law is centered on the preservation of rights in interactions between states and generally does not address the rights of smaller-scale entities. This causes some groups, such as the Palestinians along the Jordan or the Kurds along the Euphrates, that may be entitled to or have legal standing in water disputes to fall through the legal cracks and remain unrepresented by such mechanisms as the International Court of Justice" (A. Wolf, 1998).

Cash (2006) notes that from a management perspective, systems that "more consciously address scale issues and the dynamic linkages across levels are more successful at 1) assessing problems and 2) finding solutions that are more politically and ecologically sustainable." Young (2006) states that it is important to focus on the different scale interactions since higher-level arrangements are not always reflected in lower-level application; the cross-level interactions tends to lead to serious problems "framed in terms of considerations such as ecological sustainability, social efficiency, and equity." Institutions that are designed to recognize and correct such problems are likely to elicit positive results across multiple scales.

There is an increasing need to resolve both regional and local issues with water management strategies. Globalization and increased interconnectivity has blurred national, regional, and local boundaries and views of natural resources. Each of these very different levels impacts directly on water resources. Consequently, water legislation has an increased need to include a broader and more integrated management framework. Treaties are important tools for determining how stakeholders interact at the different levels to ensure equitable and sustainable management.

While discussed in-depth in the environmental regime literature in general, *scale* may be especially important to water institutions. Turton (2008) discusses water conflict events in

South Africa, noting that all water conflict incidents are at local scales between individuals and/or between communities. Wolf (1997; p.255) also notes that "…while no water wars have occurred, there is ample evidence that the lack of clean freshwater has led to occasionally intense political instability and that, on a small scale, acute violence can result. What we seem to be finding, in fact, is that geographic scale and intensity of conflict are inversely related." It is likely that a primary cause of conflict at the smaller scale is from a lack of policies and institutional direction that mitigate social conflicts at that scale. Turton (2008; p. 314) suggests that if institutions better "customize their processes, tools, and institutions to make them more site-specific, so that they more closely suit the needs of the communities and countries involved," then conflicts at the smaller scale are more likely to be avoided.

One strategy by which states control transboundary water resources is by omitting parties that may have legitimate legal rights to water resources, thereby "pre-empting the rights of the non-signatory states"(Zeitoun and Warner, 2006). This weakness is found within the *scale* mechanism of the treaty. International law has provided general guidelines which can expand the options available to actors towards equitable sharing, but in most cases only recognized actors can fully utilize legal principles and be in a position to interact, discuss, and negotiate their shared water resources.

3.3.7 Uncertainty Management

The *uncertainty management* mechanism (hereafter referred to simply as *uncertainty*) is defined as the extent to which the institution recognizes, investigates, and actively plans for the possibility that available data may not accurately reflect current conditions or that the future may be very different from the current environment. Even under ideal laboratory conditions, data are subject to bias and subjectivity. Water quantity and quality is inherently difficult to measure, and its uncertainty is further heightened by the potential for political bias. Therefore, a major aspect of producing credible data is the proper management of uncertainty through recognition of the fallibility of data and planning for improved data access and optimization. Even if data accurately reflects current conditions, it may not be adequate to forecast and address future scenarios that may occur.

One of the key steps to reaching consensus regarding the credibility of data is a mutual and explicit recognition of uncertainty. Andanova (2009) recognizes that institutional mechanisms are important in both data sharing and in enhancing and protecting the credibility of data. She notes that while data sharing is important, it is essential that the data are legitimate, clear, and credible. Chasek (2004) notes that the Montreal Protocol—perhaps the most effective environmental regime—had strong scientific consensus that the ozone layer was in fact decreasing in size. However, it can be argued that a perfect dataset does not exist and that uncertainty to some extent will always be present. Barrett (2006; p.376) notes that while the results for global warming may be the best available, to derive them "you have to start with the science, which is uncertain, add in the impacts, which are uncertain, predict adaptation responses, which are uncertain, and then value all these changes—adding another layer of uncertainty." Therefore, recognizing and planning for potential data fallibility is one step towards improving the data.

Uncertainty, if not properly managed, can cause decisions to be made on spurious data or without consideration of the full range of possible scenarios. Uncertainty can certainly be recognized and planned for within an agreement. Parameters that plan for uncertainty can address flow, climate, and other scientific uncertainty, but can also include a broader range of areas such as political, financial, and economic sectors. The latter areas may initially seem less relevant than the former categories, but perhaps may have more of an impact on relations and treaty implementation than seemingly more applicable categories such as flow variability.

Alternative scenarios and prediction models are two tools used to manage uncertainty. Alternative scenarios help to recognize potential improvements to existing data, and plan for different scenarios that may unfold with different information. Prediction models implicitly recognize and decrease uncertainty of future conditions that otherwise could only be achieved with actual observations of changes to climate and to river flows. Such models attempt to characterize the relationships of different components across time and space to better develop tools to manage change and impacts, which in turn increases adaptive capacity. Since the timing of environmental disturbances often does not coincide with the social and institutional abilities for meeting that change, earlier awareness better allows for adaptive capacity to effectively respond. These tools are best utilized by explicitly recognizing that there is variability in flows, such as during flood and drought. Accurately predicting and planning for variability is also enabled by the availability of data through adequate monitoring mechanisms.

Uncertainty and *flexibility* have many of the same goals, but are distinct in that *uncertainty* considers the sources of data inadequacies and aims for proactive mitigation. Although provided in more detail in the methodology Chapter 4.2.2, the similar nature of the goals of the two mechanisms makes it is useful to present here a comparison of the parameters used to measure each mechanism in order to illustrate their differences (Table 2).

The *flexibility* and *uncertainty* mechanisms both deal with the management of change and have several similar components, including variability management and a method to relay information (monitoring and consultations). The primary difference between the two is a matter of timing: *uncertainty* recognizes and plans for future change (or a change in the way the problem is understood), while *flexibility* enables the implementation of available information towards improving current management. The *uncertainty* components of prediction models and alternative scenarios are forward leaning and proactive in their approach towards planning for change. The *flexibility* mechanism relates to the *uncertainty* mechanism in that it better allows for the predictive /clarifying results to be applied.

Table 2 A comparison of the *flexibility* and *uncertainty* mechanism components.

Flexibility	***Uncertainty***
Amendment mechanism: This component measures whether the agreement text specifically mentions the possibility of amending the treaty.	*Uncertainty* explicit: Treaties in this study were found to have *uncertainty* explicitly stated across several broad categories.
Joint management body: Joint management, if properly implemented, can help to manage the vagaries of flow and requirements that are likely to change over time.	Alternative scenarios: Recognition of potential improvements to existing data, and planning for different scenarios that may unfold with different information, is one way of managing *uncertainty*.
Variability management This component measures whether a treaty plans for events outside normal operations, such flow variability relative to flood and drought.	Prediction models: Models are a tool to better predict future events and help decrease *uncertainty* of future conditions that otherwise could only be achieved with actual observations of changes to climate and to river flows.
Consultations: This component is included in calculating the *flexibility* mechanism since flexibility requires streamlined and timely action in response to change.	Variability management: The recognition of variability in both requirements and resources is one method of managing *uncertainty*.
	Monitoring: The main reason for including monitoring in a treaty is not to better manage *uncertainty*; however, monitoring likely has a positive impact on it through improvements to data and planning.

3.4 Hydrohegemony and Power: Impact on Relations

Differences in power are always sure to exist, but treaty mechanisms may enable greater equity through providing structure and universal rules for interaction. "*Absent legal constraints and well-defined rights*, relatively powerful downstream states began resorting to economic and military threats to elicit cooperation, while relatively weaker riparians acquiesced and actual practice reflected the regional balance of power" (Eyal Benvenisti, 2002; italics added for emphasis).

The dynamics of power in shaping the interactions between riparians is not the primary focus of this research, but it is an important underlying factor in conflict analysis that needs to be accounted for when considering the source of complaints (which are in turn used in this study to evaluate a treaty's capabilities to respond to and mitigate stresses). Differences in power are used both in the quantitative analysis and are expanded on in the case study discussions.

Intertwined with the cooperation that treaties theoretically help engender, cooperation over water is often driven by the larger politics and is often “neither smooth nor equitable” (A. Jagerskog, 2008). Analyzing the broader political context and power asymmetries is one way to gain useful insights into transboundary water interactions; namely, how and why allocation of water occurs as it does. Mark Zeitoun has described power asymmetries in a water sharing context, and argues that cooperation and conflict can coexist where the hegemon, i.e. the most powerful actor, imposes its own policies on others, labeling it ‘hydrohegemony’ (Lowi, 1993; Mark Zeitoun & Warner, 2006). In this process, the ‘hydrohegemon’ is the dominant power in the basin and uses its position of power to receive or control more than its equitable share of the water, or in some other way maximizes their objectives regarding the resource. The control comes despite the apparent consent of the non-hegemon and can take many forms with various outcomes; a hegemon may gain greater volume of flows, or control of the water resources may be ceded to gain benefits in other areas. Allan (2007) notes how power can be “insidiously invested in text, knowledge, and discourse.” Hydrohegemony postulates that while the objectives are variable, the nature of interaction and form of agreement is determined by the hegemon.

Power can be defined and applied in different ways. Cascao (2008) makes a distinction between structural power and bargaining power. Structural power is economic or military based, while bargaining power is based on diplomatic and political capacities to influence decisions and outcomes. Zeitoun and Allan (2008) take this a step further by summarizing three different forms of power that can be applied to transboundary water analysis, namely economic/military/political power, riparian position (upstream/downstream), and resource exploitation potential (infrastructure, technological capacity). In some basins, the riparian position and resource exploitation potential are also considered when measuring the degree of control, but ultimately hegemonic determination is largely a reflection of the relative economic and political power of the basin (A. Jagerskog, 2008). For example, in the Nile Basin, Egypt is the hegemon since it is dominant in political, military, and economic power. In this case, Egypt is able to control water sharing with other forms of power that overcome its weak downstream location.

4 Data and Methods: Treaties, Power, Scarcity, and Conflict

The primary datasets used in this analysis include: data extracted from the treaties (summarized as *mechanisms)*, summary statistics of the GDP and stability indices for each country used to estimate power differences, a historical drought index for each basin, and historical conflict data from Oregon State University's Transboundary Freshwater Dispute Database. From the treaty data, specific components are summed to estimate a value for each of seven different mechanisms that together make up the strength, or resiliency, of a treaty. Projected water variability data extracted from global climate and runoff models is used in the case study analysis.

4.1 Methodology Overview

This research intends to show that climate-related conflict within basins governed by treaties can be at least partially explained by the presence or absence of certain treaty mechanisms. In other words, some treaty designs and mechanisms may be better at mitigating grievances and complaints that originate from hydrologic stresses to the basin, such as decreases or increases in flow. For example, these mechanisms may allow for more stable relations by enabling the signatories to communicate more effectively, to better enforce the treaty, and to involve a broader range of shareholders. By identifying and quantifying the amount of conflict associated with a treaty, the hydrologic stress to the basin that the treaty governs, and the parameters that each treaty contains, the three hypotheses are explored in the following way:

Hypothesis 1 is that drought and hydrologic stress have and will increase the frequency of complaints or state grievances over water sharing agreements. The methodology to test this hypothesis includes a comparison of several different techniques for measuring hydrologic stress relative to transboundary treaty parameters and is summarized in Appendix C. A two-year running average of the Palmer Drought Index was chosen as the most appropriate method for measuring hydrologic stress and is compared against the presence and magnitude of conflict. The OSU TFDD is used as a data source for the number and severity of complaints that have been filed for each treaty. The complaints are further segregated into whether they are climate related or non-climate related based on their description. A statistical analysis is used to determine if there is a relationship between conflictive events within the BAR and hydrologic stresses to the system.[21]

Hypotheses 2 and 3 both postulate that treaty traits and mechanisms are important to providing increased institutional capacity to manage hydrologic stress. The presence and severity of conflict/complaints, then, is at least partially related to the presence or absence of specific treaty traits when stresses are applied to the system. For the testing of both of these hypotheses, steps for institutional analysis as suggested by Mitchell (2002) and King et al (1994) provide a quantitative methodology to consider institutional effectiveness. The underlying premise of this methodology is similar for both quantitative and qualitative studies: to determine causal inference, known facts are used to learn about something that is not known. The known facts are one or more input variables (independent) that are observable and can be used to estimate or predict a single output (dependent) variable. If the dependent variables can be explained with a single or a few causal, observable independent variables, then there is good leverage over the question. The variables used in this study include the following:

1. **Dependent variables used to define a potential consequence of the treaty.** This study uses the TFDD BAR dataset, which estimates intensity of cooperation/ conflict, as an indicator of the overall health of the system and as our dependent variable. The dependent variable is a combination of frequency and severity of

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[21] While many assertions of water-scarcity driven wars have been made, the first empirical study of the extent and magnitude of water's impact on international and internal conflict was not conducted until 1998 by scholars involved with the BAR project at OSU. The study concluded that water scarcity does not increase the likelihood of interstate conflicts. However, the BAR study did not have annual flow/precipitation/ drought data available, such as the PDSI data used in this study, to correlate with political activity.

complaints for each treaty. Each complaint is segregated into climate/non-climate categories.

2. **Independent (or non-systematic) variables of interest used to define treaty/institutional characteristics that may influence the dependent variable.** These independent variables are the theoretically-based explanatory mechanisms that are used to understand the variations in the dependent variable (TFDD BAR)**.** This study analyzes a number of treaty mechanisms derived from the literature cited previously, including: *uncertainty, enforcement, specificity, communications, flexibility, integrativeness*, and *scale.* How each variable is measured/observed is discussed in-depth later in Chapter 4.2.2**.**
3. **Other control (or systematic) variables that are predicted to affect the dependent variable.** Drought data is used to determine when and how much hydrologic stress has been applied to the basin. Although the primary control variable of interest is flow variability/hydrologic stress, other factors that shape the political environment are also considered. Differences in socio-economic and political influence are considered using a suite of control variables, including GDP, development, and political stress and stability, together called 'Delta Power' as detailed in Chapter 4.2.3.

Hypothesis 2 postulates that a treaty with more mechanisms is more robust and resilient. To test this hypothesis, the overall resiliency of each treaty is first approximated by summing the mechanisms (primary independent variables) that are within the agreement. The mechanisms are calculated by segregating and allocating treaty components (e.g. joint management bodies, data reporting, dispute resolution protocols, etc) to a mechanism according to the relationship and theoretical contribution to the mechanism. Together, the mechanisms and their components represent the institutional resiliency of the treaty.

The dependent variables, or the complaints associated with the treaty, are used to categorize the treaties according to the type of complaints. Treaties are grouped according to whether there has ever been a climate-related complaint, a non-climate related complaint, or no complaints filed regarding the treaty. With the treaties segregated according to the presence/absence and type of complaints, the relationships between the average estimated resiliencies of the treaties and the associated hydrologic stress and severity of complaint are explored, with the primary emphasis on treaties with climate complaints.

Hypothesis 3 postulates that some mechanisms are more important to providing increased institutional capacity to manage stresses to the system. The key hypothesis is that certain treaty structures/mechanisms (our independent variables) either dampen or enhance the BAR signal when hydrologic stresses are applied. To explore these relationships, a multiple linear regression analysis is conducted using the dependent, independent, and control variables described above.[22] The result of this analysis is a regression equation with coefficients that represent the influence that each mechanism has on complaints.

The results from the analysis of all three hypotheses are utilized within and are examined further in the case studies. The feasibility of each hypothesis is discussed in the discussion and conclusions sections using a combination of the treaty, conflict, and case study results.

4.2 Datasets and Measurements

World Bank (WB) parameters for the study have helped to shape which basins are used in this study (Figure 1). The case selection includes a wide range of basin sizes, flows, relative importance to economy, and historical levels of conflict. However, the primary

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[22] Some suggest that there is not enough empirical research or observations to identify critical causal factors, which are required to create regression equations geared to determine causality (USACE, 2006). Others have found that the effectiveness of conflict resolutions mechanisms is strongly influenced by administrative and institutional frameworks, based on a few case-study basins (Saleth and Dinar, 2004; Jagerskog, 2003).This study recognizes and hopes to address these limitations with new treaty and drought data, as well as with in-depth case studies to explore the regression findings.

selection criteria for basins selection were that each must have a treaty that includes a water quantity, flood control, or hydropower component. Data availability also was considered in choosing the basins.[23] Existing treaty databases were used as sources for analysis, specifically those compiled by OSU and the International Water Management Institute (IWMI). The databases contain the treaties, along with a dissection of their main components. The database includes 450 treaties, of which 146 were used for this analysis.

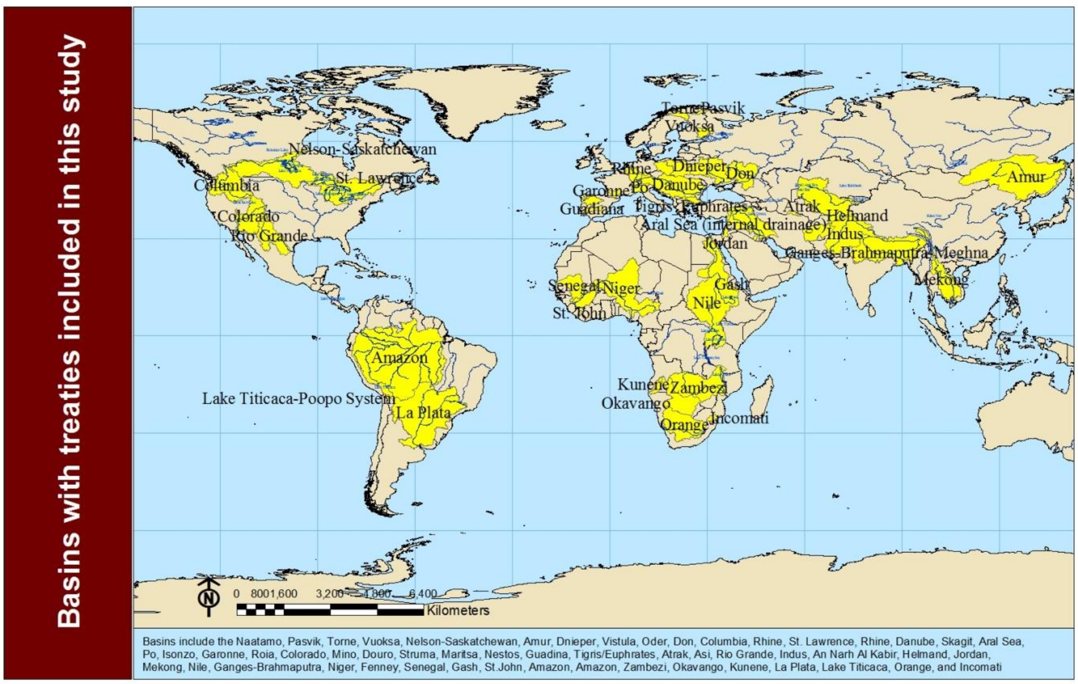

Figure 1 Basins with treaties that were used in the analysis

The 146 treaties used in this analysis were evaluated for their contents and were coded according to the primary purpose of the treaty, as well as the legal and physical aspects of the agreement. Treaties for a variety of water-related issues were used in this study, with the assumption that regardless of issue the treaty mechanisms will have a similar impact on the adaptation or management of complaints or grievances. Data for water quantity,

[23] It is recognized that this selection methodology introduces a certain amount of bias.

hydropower, and flood-control treaties were utilized towards determining which treaty parameters and designs are most important for resiliency. Of the total 146 treaties used for the study, 101 were focused on water quantity, 26 were hydropower, and 18 were flooding related. The treaty mechanisms considered and the calculation of results involve the same parameters and procedures regardless of issue.

Each of the four primary categories of data considered in this analysis (BAR/conflict data, treaty mechanisms, Delta Power, and drought) was analyzed using two statistical methods of analysis: MLR and count/descriptive. The four primary categories were further subdivided into more specific categories. First, each of the four primary categories was separated and grouped according to basin and treaty. For the treaty category, the data is summarized for each of the 146 treaties in the study. For the basin category, data for all treaties that occur within each of the 53 basins in the study are used to compile summary data for the basin. In other words, each basin has one or several treaties associated with it that is used to evaluate the basin, whereas in the treaty category only data specific to each treaty is used.

Each basin and treaty dataset was then further segregated according to the types of complaints recorded for that basin/treaty. The three types of complaint categories that are used to separate the datasets are: no complaints, climate-specific complaints (such as complaints over low or inadequate flows), and a catch-all category that measures all complaints regardless of issue. The ‘any type of complaint’ category is intended to capture any overlooked or climate-influenced complaints. The reason for this segregation is two-fold: first, it allows for more in-depth analysis of how both basins and treaties are able to manage both climate and broader conflict issues. Second, it acknowledges that some climate complaints may not be easily recognized and may have been inadvertently excluded from the climate complaint dataset. Summary count and MLR statistics for each basin and treaty were calculated for each of the primary complaint categories.

Table 3 Data categories and analytic techniques used in the study.

Primary Categories (Dependent and Independent Variables)	Method of Analysis	Secondary Category	Tertiary Category
Dependent: Complaints/BAR **Independent:** 7 Treaty Mechanisms	Count/Descriptive (called Literature Review)	Basin	No Complaints
			Climate Complaints
		Treaty	Any Type of Complaint
Delta Power, Drought/PDSI	MLR	Basin	No Complaints
			Climate Complaints
		Treaty	Any Type of Complaint

4.2.1 <u>Dependent Variables: Conflict/Events Data</u>

Yoffe's 'Basins at Risk'(BAR) study of river basins and conflict created a large global event database in an attempt to compile all reported instances of conflict or cooperation over international freshwater resources in the world (Gleditsch et al., 2004; S. Yoffe et al., 2003). Events are reported according to the river basin in which it occurred, the date, the level of intensity of conflict or cooperation, and the main issue associated with each event. Each event has been evaluated with a numerical representation from "a 15-point 'BAR scale' that ranges from +7, the most cooperative event (voluntary unification into one nation over water) to -7, the most conflictive (formal declaration of war over water), with 0 representing neutral or non-significant acts" (Yoffe et al, 2003; Figure 2). The database considers a broad range of incidents including territorial disputes, purchasing and selling of hydroelectricity, and issues internal to a country.

COPDAB Scale	Recentered BAR Scale	Antilogged, Recentered Scale	Event Description[b]
15	−7	−198.3	*Formal Declaration of War*
14	−6	−130.4	Extensive War Acts causing deaths, dislocation or high strategic cost
13	−5	−79.4	Small scale military acts
12	−4	−43.3	Political-military hostile actions
11	−3	−19.8	Diplomatic-economic hostile actions. *Unilateral construction of water projects against another country's protests; reducing flow of water to another country; abrogation of a water agreement.*
10	−2	−6.6	Strong verbal expressions displaying hostility in interaction. *Official interactions only.*
9	−1	−1.0	Mild verbal expressions displaying discord in interaction. *Both unofficial and official, including diplomatic notes of protest.*
8	0	0.0	Neutral or nonsignificant acts for the internation situation
7	1	1.0	Minor official exchanges, talks or policy expressions-mild verbal support
6	2	6.6	Official verbal support of goals, values, or regime
5	3	19.8	Cultural or scientific agreement or support (nonstrategic). *Agreements to set up cooperative working groups.*
4	4	43.3	Nonmilitary economic, technological or industrial agreement. *Legal, cooperative actions between nations that are not treaties; cooperative projects for watershed management, irrigation, poverty-alleviation.*
3	5	79.4	Military economic or strategic support
2	6	130.4	Major strategic alliance (regional or international). *International Freshwater Treaty*
1	7	198.3	Voluntary unification into one nation

[a]See *Yoffe et al.* [2003].
[b]Italic type represents our modifications and water-specific actions.

Figure 2 Water Event Intensity Scale (Yoffe et al., 2004)

Selected events from the BAR conflict database were used to calculate a dependent variable. As part of the event selection process, all events from the BAR database were pulled and segregated according to time, location, reason for the incident, and severity. The period from 1950 to 2005 was used as an event selection criteria due to the availability of basin-level drought data for that time period. Only complaints that were interactions between states at the government level were considered; informal complaints from non-government entities, such as NGOs or public citizens, were excluded. The data was further pared to include only 'conflict' events: in this case, events ranging from 0 (neutral) to the more extreme examples of conflict at -6 (strong displays of hostility).

Complaints were then segregated into either climate or non-climate related categories. Each event was evaluated to determine if it originated from flow variability or could be attributed to climate-related stress being applied to the system. Such events were classified as 'climate complaints.' Broad criteria were used for the climate complaint classification, including: 1) the mention of climate, flood, or drought in the complaint; 2) an inability to meet treaty flow or allocation obligations due to natural fluctuations; 3) conflict over deficiencies in treaty design relative to climate-driven changes in flow.

Conflict events other than those that originated from climate related flow variability or related issues were classified as ‘any type of complaint.’

For each basin, all available treaties were researched to determine general purpose, terms of the agreement, and relevant thresholds. Events were then compared with the treaties to determine if an event/complaint was specific to a particular treaty. The number and severity of annual complaints of each type since each treaty was signed was calculated. Summary statistics include the number/BAR of climate complaints, the number/BAR of overall complaints, the number/BAR of complaints during relative and absolute drought, and the number/BAR of complaints during non-drought.

Table 4 Summary of dependent variables

Dependent Variables
Complaints for the Treaty
Average BAR for the Treaty
Years the Treaty has been in effect
Complaints for the Basin
Average BAR for the Basin
Climate Complaints For the Treaty
Average BAR of Climate Related Complaints for the Treaty
Climate Complaints for the Basin
Average BAR of Climate Related Complaints for the Basin

4.2.2 Independent Variables: Treaty Mechanisms

A total of nine independent variables were utilized, including seven treaty mechanism variables for: *scale, enforcement, integrativeness, flexibility, uncertainty, communications* and *specificity*. The seven treaty mechanism variables are used to estimate an overall treaty ‘strength’. Two additional control variables were used to estimate climate and political factors. The first control variable is drought/hydrologic stress, as measured with the standard deviation of PDSI in the basin (discussed in Chapter 4.2.5). The second control variable is difference in power, or Delta Power, which is based on differences in

GDP/stability/human development (discussed in Chapter 4.2.4). The method for calculating the numeric value for each of these variables is discussed below.

Independent variables for measuring treaty mechanisms were estimated using measurements/data points extracted from an analysis of the treaties and from the literature. Unfortunately, treaties often do not state the underlying purpose and intent of certain parameters that were included. Therefore, each treaty was examined in detail and it was postulated how each parameter relates to the mechanism under consideration.

A spreadsheet of 146 treaties used in this study was compiled from the International Water Management Institute (IWMI) and the Transboundary Freshwater Dispute Database (TFDD). The spreadsheet contains over 100 treaty parameters, including general purpose of the treaty, signatories, details of complaints, communication protocol, dispute resolution mechanisms, and flow/distribution thresholds. For quantitative analysis, the presence or absence of most parameters was designated with a simple 0 or 1. If present and deemed of high value for the mechanism in question, an attribute was recorded as "1". If an attribute was not mentioned in a treaty or if it was unclear, the treaty was coded as "0". For some parameters, more detailed numerical values were applied where appropriate data was available.

A total of 35 measured treaty components were segregated according to contribution to one of the seven explanatory mechanisms discussed previously. The definition and function explained in the literature review for each of the seven mechanisms was used as criteria for segregation. Components that contributed to the stated purpose of the mechanism were accordingly grouped with that mechanism. In this analysis, four, five or six components are used to determine the presence or absence of a mechanism in a treaty, and to estimate the strength of each mechanism. Treaty parameters are not exclusive to one mechanism and can be grouped more than once across multiple mechanisms. The specific mechanisms of interest include: *specificity, enforcement, flexibility, scale,* *integrativeness*, *uncertainty*, and *communications*. Components for each mechanism are presented in the order of importance to that mechanism.

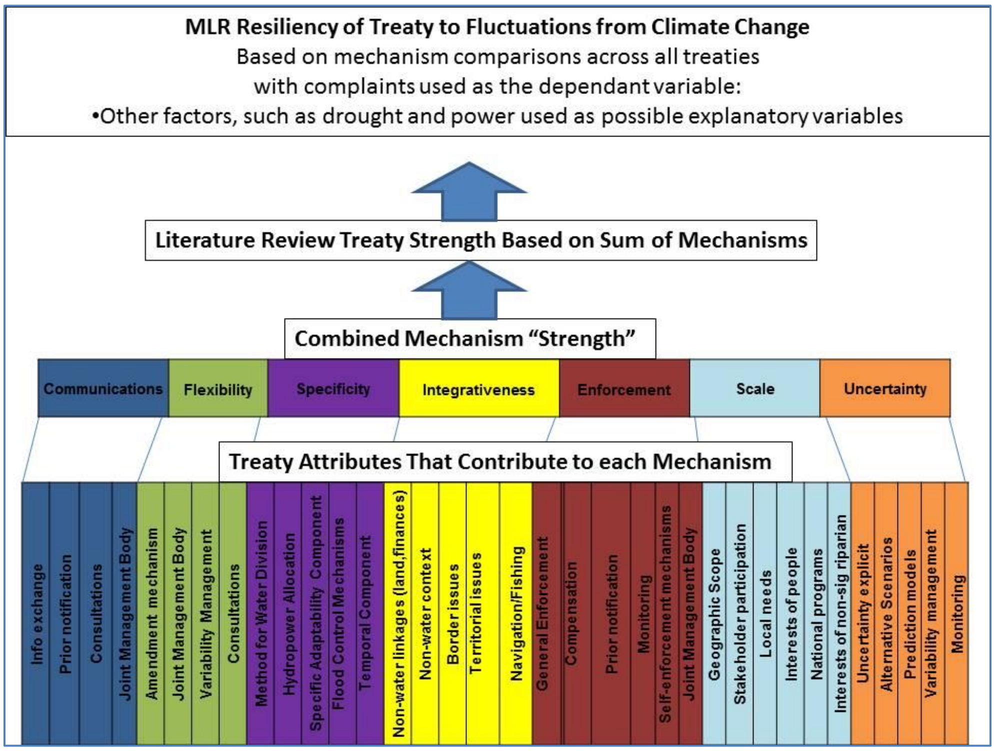

Figure 3 Mechanisms and their contributing treaty components

4.2.2.1 Estimating the Communications Mechanism

Communication networks and provisions can help address uncertainty, adaptability, and capacity issues that can hinder compliance and cooperation. An estimation of formalized communication networks within treaties is conducted by determining the existence of the following parameters:

1. **Information exchange:** "A yes/no variable as to whether the document contains provisions concerning the exchange of water-related information," such as technical meteorological and flow data (IWMI, 2008).
2. **Prior notification:** Communication is facilitated by treaties that require notification between the parties before changes to the status-quo are enacted. As in the

enforcement mechanism discussed previously, the following categories were used to segregate the component into levels of severity/hardness according to how much communication or coordination is required.

a. None/not mentioned.

b. Prior notification: One riparian to notify the other of planned measures.

c. Prior consultations: The riparians are required to consult with each other regarding any planned measures.

d. Prior consent: The other riparians have to agree to the plans before any action can be undertaken (IWMI, 2008).

Although there is variability in how parties are expected to respond to shared information, all of the above categories were judged to equally promote or expect communication. For quantification of the communication component, all treaties with any of the above components were given full marks, with the exception of treaties that did not mention prior notification, which were given scores of ‘0’.

3. **Consultations:** This component determines if the treaty provides for the parties’ direct and regular consultations on water issues through diplomatic channels.

4. **Joint Management Body:** This component determines if an agreement institutes some form of joint management institution or commission for dealing with the issues stipulated in the treaty. While most treaties institute a specialized institutional body, the scope is variable and depends upon the treaty. The purpose of the joint management body may be similar to, but more narrowly defined than a River Basin Organization (IWMI, 2008).

4.2.2.2 Estimating the Flexibility Mechanism

The management of unforeseen water issues is often accomplished at the individual or local level and done “on the fly.” However, treaty components can help enhance this ability through recognition of the importance of flexibility and by creating a framework for the smooth implementation of change. Here we estimate flexibility that is intentionally planned for within the treaty by measuring the presence/absence of treaty parameters that increase communications, flexibility in decision making protocols, and provisions that allow for the change of the existing treaty parameters. Specifically, *flexibility* is measured with the following components: amendment mechanism, joint management body, variability management, and consultations.

1. **Amendment mechanism:** This component measures whether the agreement text specifically mentions the possibility and protocol for amending the treaty. Treaties that from the outset do not consider the possibility of textual alteration to meet new or changed requirements are considered less flexible.
2. **Joint management body:** Joint management is intended to allow signatories to influence how the treaty is applied within the basin. Joint management, if properly implemented, can help to manage the vagaries of flow and requirements that are likely to change over time.
3. **Variability management:** This component measures whether a treaty plans for events outside normal operations, such as flow variability relative to flood and drought. Since flood and drought are considered extreme events, treaty inclusions for their management indicate that a treaty is more flexible in its application.
4. **Consultations:** The consultation component is measured by determining if a treaty provides for the parties' direct and regular consultations on water issues through diplomatic channels. This component is included in calculating the *flexibility* mechanism since flexibility requires accurate and timely information on which to base action.

4.2.2.3 Estimating the Specificity Mechanism

Specificity is estimated from treaty attributes that are meant to reflect how specific a treaty is with water/power allocation or management of fluctuations in supply. The treaty parameters that are used to evaluate the *specificity* mechanism are: methodology for water division, methodology for hydropower division, specific adaptability to drought, flood-control and a temporal component.

1. **Method for water or hydropower allocation (Parameters 1 and 2):** This allocation measurement determined if a specific and detailed methodology was used to allocate water and hydropower resources. The method for water and hydropower parameters were both determined in similar fashion and weighted equally (as a '5') when calculating the overall '*specificity*' mechanism. There was a broad range of water division methods found to exist within treaties and a simple present/not-present analysis was not sufficient. To make cross-treaty comparisons more feasible, each method was segregated into one of ten broad categories for water and hydropower division. The methods were then determined to be either high or low *specificity*, according to how specific and detailed the method is for allocation. The methods for water division that were determined to have high *specificity* were graded with a '1', and those with low/no *specificity* were graded with a '0'. There were no further gradations and different method categories were not evaluated further regarding their effectiveness. In other words, all methodologies in the high *specificity* category were given the same value/evaluation of '1'; a sharing method that allocated water through a fixed quantity formula was treated the same as a methodology that uses percentages based on seasonally available water supplies.

Table 5 Grouping of allocation methods according to high and low *specificity*.

Water/hydropower allocation methods with high *specificity*	**Water/hydropower allocation methods with low *specificity***
Fixed quantities	None/unclear
Fixed quantities which vary according to water availability	Consultation
Fixed quantities recouped in the following period	Prior approval (consent of the other party necessary for higher than usual water use)
Percentage of flow	
Allocation of entire rivers	
Fixed quantities and percentages	
Prioritization of uses (e.g. domestic use first, hydropower second)	

2. **Specific adaptability mechanism to drought:** There are a number of different methods that treaties have outlined to deal with episodes of drought. Most often treaties simply provide general guidance of what constitutes a drought or flow parameters to incorporate during periods of stress. For component measurement purposes, all types of drought mechanisms are graded equally if present in a treaty.
3. **Specific flood-control :** Similar to the drought component, treaties that include specific definitions and methods for managing drought are considered to have a higher *specificity*. The variable is recorded in the database as present or not present in the treaty.
4. **Temporal component:** Many treaties have timelines and seasonal requirements that are very specific and detailed. It is postulated that temporal guidelines are helpful as a standard baseline for allocating resources and for managing annual river flow fluctuations. Only treaties that clearly delineated a temporal component were graded as having the component present.

4.2.2.4 Estimating the Integrativeness Mechanism

Benefit sharing and increasing the scope of an agreement are often referenced as a solution to water conflicts around the world, although the methods of operationalizing the idea vary in scale and effectiveness. We use the term *integrativeness* to summarize the idea of how broad and diverse the scope of a treaty is regarding subjects outside of what we normally consider typical for a water treaty, namely water quantity and quality. *Integrativeness* is estimated by evaluating the content within a treaty that is not directly related to water as a resource. Components considered include: non-water linkages, border-issues, territorial-issues, navigation, and fishing.

1. **Non-water linkages:** This component determines if there are non-water exchanges or concessions linked to water issues in the document (e.g., exchange of land or money for water; trade concessions in exchange for water rights). Linkage categories

include: capital, political concessions, and other. All non-water linkages are weighted equally.

2. **Non-water context:** Agreements that include water among other primary topics allow water to be better integrated into a broader political or environmental sphere. This component is measured by determining if an agreement in which water (as a consumable resource) is only one issue in a larger overall agreement--for example as related to peace, navigation, or territorial delimitations
3. **Border issues, territorial issues (Components 3 and 4):** For border issues, the component determines if the agreement delineates, adjusts or reaffirms the border between two or more countries. The territorial issues component measures if the agreement (re)divides or affirms territorial sovereign rights. These two categories are weighted equally.
5. **Navigation and fishing (Components 5-6):** Navigation and fishing can be considered stand alone issues and when considered in conjunction with water issues, the treaty is considered to be more integrative. These two categories are weighted equally.

4.2.2.5 Estimating the Enforcement Mechanism

Enforcement is estimated by the presence of various incentives in the treaty intended to promote adherence. The cost/benefit of adherence is subjective, with incentives potentially including economic, political, moral, technical, or religious considerations. The specific treaty components that are considered for our estimate of *enforcement* are: general enforcement, compensation, self-enforcement, prior notification, monitoring, commission/council, and joint management body.

1. **General enforcement:** The enforcement component indicates whether the treaty contains provisions concerned with enabling one party to undertake action towards another party to enforce the specific requirements of the document. This is a general category that determines whether a party has any recourse for non-compliance as

stipulated in a treaty. Only the presence/absence of any enforcement component is gauged; the strength of the enforcement measures was not measured.

2. **Compensation:** A more specific kind of enforcement, this component indicates whether a treaty provides for any form of compensation in case one of the parties is harmed.
3. **Self-enforcement:** Treaty components, other than punishment, that are used to increase the likelihood of compliance are recorded under the label of self-enforcement. Some treaties make compliance more enticing through indirect reparation or rewards. Examples include side-payments, issue-linkage, compensation for flooded lands, ability to sell hydropower, and capital expenditures.
4. **Prior notification:** Treaties that require approval or consultation before changes to the status-quo are enacted (such as if a signatory wants to use additional water resources or construct infrastructure such as dams or diversion channels) have a higher degree of enforcement. The following categories were used to segregate the component into levels of severity/extent according to how much communication or coordination is required.

   a. None/not mentioned.

   b. Prior notification: One riparian has to notify the other about any planned measures.

   c. Prior consultations: The riparians are required to consult with each other any planned measures.

   d. Prior consent: The other riparians have to agree to the plans before any action can be undertaken (IWMI, 2008).

For quantification of the component, the above categories of enforcement were used to weight the treaties into gradations of enforcement capabilities. Agreements with prior consent were deemed to have the highest enforcement and were given full marks; treaties with prior consultations were given ¾ marks; and notification was given ½ marks.

5. **Monitoring:** Monitoring can be used to verify or enhance compliance of treaty stipulations. This variable measures whether the treaty contains provisions concerning monitoring associated with some aspect of shared water resources (e.g., flow, water quality, etc).
6. **Joint management body:** Treaties that involve joint management of basin or water resources may give signatories additional influence and recourse that can increase the enforcement of the treaty. This component measures whether the treaty institutes some form of joint management institution or commission – "a specialized institutional body for dealing with the issues stipulated in the treaty and whose scope of action and authority depends upon the treaty" (IWMI, 2008).

4.2.2.6 Estimating the Scale Mechanism

Water management is complicated by its simultaneous operation at different scales. Local, regional, and global issues must often be considered congruently since small-scale problems can often aggregate to reduce overall management capacity. Water management has almost always been approached from a top-down perspective. Regional and national requirements and arrangements are concluded and then interpreted within local contexts. In this case, treaties that consider more local scales when instituting cooperative arrangements at international and national levels are considered more robust. Geographic scope is considered when estimating *scale*, under the assumption that global/regional treaties that do not initially consider local scales may complicate implementation and management for sub-basin level management.

Associated with the geographic scale that the treaty addresses is the scale of the decision-making process. There has been increasing interest in enhancing public participation in water resource management, and thus allowing all possible stakeholders, both individuals and organizations, to participate in the decision process and to provide their own knowledge. As part of the scale analysis, local participation and consideration of riparians that are not signatories are also used as measurements. *Scale* was measured with the following treaty parameters: geographic scope, stakeholder participation, consideration of local needs, consideration of the interests of people as a whole (not just political/military interests), inclusion of national programs, and the consideration of the interests of non-signatory riparians. Each is discussed below.

1. **Geographic scope:** A broad range of geographic scales was found within the treaties, ranging from global to the sub-basin. Each treaty was evaluated for scale with the following groupings:

   a. Global: an agreement potentially open to any country but without reference to specific basins (e.g. 1997 UN Convention)

   b. Regional: an agreement potentially open to any country in a defined region but without reference to specific basins (e.g. SADC Protocol)

   c. All waters of two or more countries: an agreement covering all waters shared between two or more contiguous states but generally without reference to specific basins (e.g. Indus Basin)

   d. Entire named basin(s): an agreement covering the entire hydrologic area of one or more specifically named basins.

   e. Sub-basin(s) or other specified area(s): an agreement covering only a part of one or more specifically named or implied basins. For example, the boundary parts of basins, or an activity confined to only part of a specifically named or implied basin (e.g. some hydropower treaties) (IWMI, 2008).

In many cases, the conclusion and ratification of treaties has been enabled by broadening the scope to include more or all boundary waters. However, the nature of broad or package arrangements that have institutional and legal ramifications for all transboundary waters raises the risk that attempts to discuss or manage one part of the treaty reflects on its other parts, complicating both the implementation and renegotiation that may be required (Itay Fischhendler, 2007). For this analysis, the ideal management level follows the generally accepted principle that management at the basin level or smaller is ideal for water management. Treaties that are specific to a basin or sub-basin are graded as ‘1’ for this component.

2. **Stakeholder participation:** This component determines if there is some form of stakeholder involvement mentioned in the treaty. It is hypothesized by some (e.g. Selby, 2006; Foster, 1998) that water users and other interested parties need to be involved to varying degrees in the planning, development, implementation and monitoring of water management activities. This component measures to some degree whether a treaty provides the public effective means of participating in water-management decisions directly affecting them. The involvement of the public, "holds the promise of improving the management of international watercourses and reducing the potential for conflict over water issues" (Earle, 2006).
3. **Local needs:** This measures whether an agreement explicitly states that the needs of the local population living in border areas should be considered. While there are no international standards for public participation, this component measures whether the treaty plans for organized and adapted responses to local circumstances.
4. **Interests of people:** This component measures whether the treaty mentions if it has been signed to further the interests of the basin's inhabitants or that some measures were taken for that purpose. It is recognized that there are sometimes discrepancies between the goals of diplomats and the actual needs perceived by local people. This component does not determine the effectiveness of the measure at smaller scales, but only that local needs were taken into consideration.
5. **National programs:** This variable measures whether the treaty "obliges the parties to adopt national laws or develop national programs in order to meet treaty provisions" (IWMI, 2008). It is theorized that national programs used in conjunction with treaty goals can create strong interaction among international institutions and those at the local government level. Such interaction can facilitate accountability and distribution of responsibilities. Conversely, national policies that adversely constrain local policies can cause local actions that aggregate into large-scale problems that cross into the international realm.
6. **Interests of non-signatory riparian:** This component determines whether the treaty considers that non-signatory riparians "could have an interest in issues discussed in

the agreement" (IWMI, 2008). Some treaties reference the rights and interests of non-signatory states, indicating that the treaty considered different levels or scales to facilitate the management of joint resources. A bilateral water treaty that is acceptable to two signatory nations might be objectionable to other relevant, non-signatory nations who may feel that not only are their needs not being met, but new problems are being created.

4.2.2.7 Estimating the Uncertainty Mechanism

The *uncertainty* mechanism is measured by determining whether or not uncertainty is recognized within and planned for by the agreement. Treaty components that contain sections where *uncertainty* is evident or are intended to minimize uncertainty are used to measure the mechanism across treaties. We are primarily interested in flow, data, and scientific uncertainty, but uncertainty in a broad range of areas is explored. The treaty components that are used to measure *uncertainty* include: uncertainty explicit in the treaty, alternative scenarios, prediction models, variability management, and monitoring.

1. **Uncertainty explicit:** Uncertainty can be expressed for many types of data and applications. Treaties in this study were found to have uncertainty explicitly stated across eleven broad categories, listed below.

   a. Flow variability
   b. Environmental
   c. Treaty implementation
   d. Political
   e. Data
   f. Financial
   g. Effectiveness of treaty regime
   h. Scientific
   i. Infrastructural (e.g. work collapses)
   j. Demand uncertainty
   k. Economic (IWMI, 2008)

   All treaties that express uncertainty in any of these categories were graded as having the component present. Categories were weighted equally since all of these categories are relevant to a treaty's recognition and management of water resources. While political, financial, and economic uncertainty may initially seem less relevant than other categories, they do directly impact relations and treaty implementation, perhaps even more so than seemingly more applicable categories such as flow variability.

2. **Alternative scenarios:** Recognition of potential improvements to existing data, and planning for different scenarios that may unfold with different information, is one way of managing uncertainty. The 'alternative scenarios' treaty component measures if a treaty mentions "at least one situation in which a different development can occur and alternative modes of action are stipulated" (IWMI, 2008).
3. **Prediction models:** This component measures if a treaty "develops or mentions available mechanisms for predicting particular aspects about the future, such as the occurrence of floods" (IWMI, 2008). Treaties that utilize prediction models implicitly recognize and manage uncertainty. Models are a tool to better predict future events and help decrease uncertainty of future conditions that otherwise could only be achieved with actual observations of changes to climate and to river flows.
4. **Variability management:** For this component, variability relative to flood and drought is reviewed to determine if its management is accounted for in the treaty. The recognition of variability in both requirements and resources is one method of managing uncertainty. This component complements the 'uncertainty explicit' component section which determined if variability of flow and the parties' needs for water and/or hydropower is mentioned in the text.
5. **Monitoring:** Monitoring mechanisms intended for broad purposes were located and recorded, including mechanisms for monitoring treaty compliance and to supervise the construction of infrastructure. The primary intended reason for including monitoring in a treaty is likely not to better manage uncertainty; however, monitoring likely has a positive impact on it through improvements to data and planning. When measuring this component, any results within the general category

of monitoring were tallied and the purpose of the monitoring mechanism was not differentiated.

4.2.3 Calculating Treaty Mechanism Independent Variables

Treaty components, segregated into the mechanisms they influence, are used to calculate an overall mechanism coefficient, or mechanism strength, for each treaty. Three methods, one unweighted and two others using weighted values, were used to calculate a composite value for each of the seven mechanisms within each treaty. The unweighted method sums all the parameters together and makes no assumptions about the value of one component over another. The first weighted method uses the literature review to estimate the relative importance of each component that makes up the mechanism, and the second weighted method estimates the relative importance of each mechanism compared to other mechanisms. Each method is discussed in greater detail below.

The first steps for all three methods were the same, with the treaty attributes that constitute each mechanism being grouped and segregated according to mechanism. A score for each parameter was recorded; in most cases the parameter was measured as present or not-present with a 0 or 1. In the unweighted method, each parameter/trait is treated as equal and the total number of traits present in each treaty is divided by the number of traits that were considered for each mechanism. For example, the *flexibility* mechanism is made up of the following four traits: variability management, joint management body, consultations, and amendment mechanism. A treaty with two of the four possible traits would have a *flexibility* score of 2/4, or 0.5.

Table 6 Unweighted method of calculating treaty strength

Parameter	Variability Management	Joint Management Body	Consul tations	Amendment Mechanism	Unweighted Mechanism Score
Present/ Not-present	0/1	0/1	0/1	0/1	=(Total Number of Parameters Found in Each Treaty)/4

The two weighted methods both ranked each trait according to relevance and importance to the explanatory mechanism, as determined from the literature review. Within the literature, some components were mentioned often and were deemed very strong indicators and reflective of the mechanism definition. Other indicators were deemed less indicative, but still useful, and were ranked lower. For the first weighted method, or ‘weighted’, each component score was multiplied by the rank of importance to the mechanism. A sum of weighted parameters for each mechanism was tallied and then divided by the total possible, so that all mechanisms had values that ranged between 0 and 1. For example, ‘variability management’ was most often mentioned in the literature and determined to be the most important of the four traits that make up the *flexibility* mechanism. Variability management (weighted most heavily of the four parameters) was multiplied by four. Each parameter was progressively weighted less according to its ranking, as illustrated below.

Weighted Method:

$$\text{Flexibility Mechanism Weighted} = \frac{(\text{Variability Management x 4}) + (\text{Joint Management Body x 3}) + (\text{Consultations x 2}) + (\text{Amendment Mechanism})}{4+3+2+1}$$

The second weighted method, or ‘fully weighted’, uses the literature to compare and rank mechanisms against one another. The ‘fully weighted’ method builds on the first weighted method, with one additional step: the frequency with which each mechanism occurs in literature review was used as a multiplier. For example, 20 percent of all literature results mentioned flexibility as important to mitigating conflict. The cumulative *flexibility* score from the first weighted method was multiplied by 0.20 to give a weighted value that represents both the content of the treaty and the projected overall importance to mitigating conflict, as estimated by the literature.

Fully Weighted Method:

$$\text{Flexibility Fully Weighted} = \text{Flexibility Weighted} * \left(\frac{20 = \text{Number of times "Flexibility" mentioned in literature as a factor in treaty success}}{97 = \text{Total Number of Times All Mechanisms Are Mentioned in Literature Review}} \right)$$

In summary, each method uses the literature to an increasing degree. The unweighted method does not use the literature to calculate a score.[24] The first weighted method uses it to weigh each treaty attribute for calculating a mechanism score, and the second weighted method uses the literature to measure how much each mechanism contributes to an overall treaty score.

All results for unweighted, weighted, and fully weighted analysis are presented in Appendix F, but unless mentioned otherwise, the unweighted methodology is predominantly used in the results and discussion sections. This is done to simplify discussion and so that the literature is presented, but not overemphasized in this analysis.

4.2.4 Independent Variable: Power and Hydrohegemony

Among political scientists, a single uncontested definition of ‘power’ has not been established. Without a universal definition, it follows that measurements of power are also unclear, and in fact they are often debated (Allan, 2007). In the case of water management and for this project, power is important in that it influences interactions and relations between the actors. For an estimate of power, we utilize Zeitoun’s (2006) assertion that economic/political/military power is the prime determinant of water resource control for river basins in the MENA region. Quantification of each power mechanism employed by a hegemon is not necessary, but rather a broad estimate of the differences in economic and political power between all actors. To estimate differences in economic and political power, three datasets are utilized, including: Gross Domestic Product (GDP), the Failed State Index (FSI), and the Human Development Index (HDI) (Table 7). Each of these indices is intended to measure a component of power, or the ability to exert influence: GDP data from the World Bank measures economic power, the HDI measures development and technical capability, and the FSI indicates state cohesion and performance.

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[24] The literature is not used in calculations in the unweighted method, but it is used to determine which attributes to include in the analysis.

Table 7 Summary of indices used to calculate the differences in power between nations.

	Indices Utilized For 'Power' Estimation		
	Gross Domestic Product	**Failed State Index**	**Human Development Index**
Indicators	GDP is sum of gross value added, at purchaser prices converted at market exchange rates to current U.S. dollars, by all resident producers in the economy.	Demographic Pressures, Refugees/IDPs, Group Grievance, Human Flight, Uneven Development, Economic Decline, Delegitimization of the State, Public Services, Human Rights, Security Apparatus, Factionalized Elites, and External Intervention	Health is measured by life expectancy at birth; knowledge is measured by a combination of the adult literacy rate and the combined primary, secondary, and tertiary gross enrolment ratio; and standard of living by GDP per capita (US$).
Source	World Bank http://siteresources.worldbank.org/DATASTATISTICS/Resources/GDP.pdf	Fund for Peace http://www.foreignpolicy.com/articles/2009/06/22/2009_failed_states_index_interactive_map_and_rankings	United Nations http://hdr.undp.org/en/reports/global/hdr2009/

GDP by itself is sometimes used as an indicator of overall strength of a nation (Organski, 1961). In this study, multiple indices are used to capture sources of power other than economic, such as stability, human rights, and education. To test whether or not the Failed State and HDI indices do in fact differ from GDP, a correlation analysis was conducted for all three datasets for all countries worldwide. The results indicate that the three indices indeed capture different aspects of stability and influence that can then be used to estimate a ‘power’ coefficient.

Table 8 Correlation results for HDI, FSI, GDP, and the summed total of all three indices. GDP and FSI have the lowest correlation, while FSI and HDI have the highest.

	HDI rank	***FSI***	***GDP***	***Sum***
HDI rank	1.00			
FSI	0.80	1.00		
GDP	0.62	0.47	1.00	
Sum	0.93	0.87	0.80	1.00

For each index, every country was ranked against all countries worldwide. Rankings for each index were from 1 to 177, with 1 indicating the most 'power', with progressively higher numbers indicating lower relative 'power'. All three index rankings were averaged to provide a summary 'power' variable for each country. For example, the United States ranks first, seventeenth, and thirteenth for GDP, FSI, and HDI respectively, and when averaged provide a country-specific summary 'power' variable of 10.3.

Water related interactions are hypothesized to be partially guided by power asymmetry. Power asymmetry, which is also called Delta Power in this study, is estimated by using the above indices and calculating the difference in the country-specific power for all riparians. Delta Power is the absolute value of the difference between the two riparians in bilateral agreements, and the standard deviation between all riparians in multilateral agreements. An example of this calculation for the Colorado Basin is included below, and summaries for each basin are included in Appendix C. In the Colorado Basin example, a country power for the United States of 10.3 and a value of 45.7 for Mexico are used to calculate a difference in power of 35.3 for the basin.

Table 9 Delta Power calculations for the Colorado Basin

Basin	**Country**	**Gross Domestic Product**	**Failed State Index**	**Human Development Index**	**Average**
Colorado	Mexico	11	73	53	45.7
Colorado	United States	1	17	13	10.3
				Delta Power = Mexico-USA	**35.3**

4.2.5 Independent Variable: Measuring Hydrologic Stress

Three different modeling approaches (drought index, remotely sensed surface wetness, and water balance) that have the aim of simulating past hydrological time series were analyzed for their suitability for determining hydrologic stress. An extensive summary of the merits and weaknesses of each modeling approach is detailed in Appendix B. After considering the three methods, it was decided to use the more qualitative 'drought index' that utilizes various global data sets that are available and are useful to derive hydrological conditions in a region of interest. The drought index works with parameters that were regionalized or transferred to the entire world. For our purposes, the drought index values give a reasonable indication of whether a treaty was in compliance or not, without quantifying a specific flow, and is deemed the most adequate measurement system for historical flows. However, because of the data accuracy restrictions, only an indirect comparison of historical data and projections for future climate scenarios is made to determine future stresses to basins in this study.

Global datasets, such as the reconstructed Palmer Drought Severity Index (PDSI), are readily available and may correlate well with the occurrence of a country's difficulties with treaty compliance in case of a drought. However, in order to estimate a streamflow value from the drought index that could be compared to a treaty flow, gaged data would be necessary to derive a link between PDSI and flow. In addition, the PDSI is a climatological value and hence also does not include information on water management and regulation. It is also difficult to validate locally, which would be a necessary step considering that the parameters that were originally derived for the US Midwest were now applied globally. The drought index uses model outputs that don't need local information, but provide generally less specific or less accurate results, possibly not in the right location. Many variables are excluded and consequently the results may be wrong or imprecise to some degree, but the question of non-compliance is still reasonably answered (Zentner et al., 2008). This dataset also works well for historical estimations, but cannot be used to estimate future flows since to date there are no future PDSI projections available.

The other methods considered, but not used in this study, were more quantitative. The first method used remote sensing data of surface-wetness (Basist et al., 2001). The second method consists of a simple water balance model with input from global climate data sets and is a purely quantitative method that answers the flow questions of where, when, and how much. The main restriction with the two quantitative methods is that they require very good data and a precise knowledge of the processes involved. Both of these quantitative methods require a minimum of ten years of gauged streamflow data (and more in areas with high inter-annual variability) in order to fit the models that predict streamflow from remotely sensed surface wetness or climate variables, respectively.

4.2.6 Historical Drought/Scarcity Data

All drought index datasets are derived from several global models, with the most simple one consisting of an interpolation model that, for example, estimates precipitation amounts (e.g. by day/month/year) for a regular grid from an irregular network of precipitation stations. Available data sets relevant to water shortages include a global compilation of the Palmer Drought Severity Index (PDSI) from 1870 to 2003 by Dai (2004). Dai derived monthly precipitation and surface air temperature data for global land areas, except Antarctica and Greenland, on a 2.5° by 2.5° grid. The PDSI is a water balance measure that quantifies the cumulative departure (relative to local mean conditions) in atmospheric moisture supply and demand at the surface, using both precipitation and surface air temperature as input. Measures of the PDSI range from about 10 (dry) to 10 (wet) (Table 10), and can be used to make comparisons across regions and time. Hamner (2008) kindly provided individual watershed PDSI values for all transboundary watersheds. Using the Dai dataset as a source, Hamner was able to extract downscaled PDSI values with good resolution. GIS, gridded (raster) drought data, at the monthly and yearly level, were overlaid with river basins. Area-weighted average drought levels were then computed for each basin, for each time period, by extracting and summing the values of each basin polygon that had a drought value.

Table 10 Palmer Drought Severity Index (PDSI) classifications

PDSI Value Range	Classification
3.0 or more	very to extremely wet
1.0 to 2.99	slightly to moderately wet
0.5 to 0.99	wet spell
0.49 to -0.49	near normal
-0.5 to -0.99	dry
-1.0 to -2.99	mild to moderate drought
-3.0 to or less	severe to extreme drought

Source: (Palmer, 1965)

Two definitions of drought are applied in this study, both of which are based on the Dai/Hamner dataset above. The first definition used is *absolute drought*, which is any point on the PDSI with a value less than -0.99. As an example, if the Tigris-Euphrates Basin has a PDSI of -1.01 and the Jordan Basin has PDSI of -4.2, both of these basins are considered to be in absolute drought. The second definition is *relative drought* that uses the average PDSI for each basin since the treaty was signed as a baseline. Any point -1.0 below the average PDSI for the basin is considered relative drought. As an example, assume the Colorado Basin has a treaty that was signed in 1960 with an average PDSI of -2.4 from 1960-2005. Any point -1.0 below the average, or in other words below -3.4, is considered the threshold below which a situation can be considered to be a relative drought. In the Colorado Basin example, a PDSI of -2.7 would be considered absolute, but not relative drought. For the MLR analysis, the standard deviation of the PDSI is used to estimate relative drought within a basin.

4.3 Multiple Linear Regression (MLR)

Regression analysis is used to investigate the relationships between each independent variable and the dependent variable. Linear regression can be applied to either predict the dependent variable based on the independent variables, or to study the relationship between the dependent variable and independent variables. According to Mitchell (2002), regression coefficients can be interpreted as the "average magnitude of the 'effect' the independent (and control) variable has on the dependent variable, having controlled for all other independent variables." By using software based multiple linear regression algorithms (those imbedded in SPSS), regression coefficients that minimize the difference between predicted values and actual values are automatically generated.

Multiple linear regression typically fits a linear model, which in our study is of the form:

$$Y= b_0 + b_1X_1 + b_2X_2+ .... + b_kX_k$$

where Y is the dependent variable (based on BAR/conflict data) and X_1, X_2,.. .,X_k are the independent variables (observable aspects of treaty parameters, including *enforcement, flexibility, scale, uncertainty, integrativeness*, and *communications*). The variables b_0 , b_1, b_2, ... b_k are known as the regression coefficients, and are estimated from the data.

As part of hypothesis 3, it is important to determine how much influence a treaty has on determining whether or not conflict or complaints occur compared to other factors. This study's linear regression analysis investigates the relationship between complaints/conflict and composite values of power/stability, hydrologic stress, and treaty strength. Several combinations of independent and dependent variables were used to extract regression coefficients for the independent variables. A total of 24 MLR models were used, incorporating a combination of nine dependent variable and five independent variables. A more thorough explanation of the MLR methodology and variables used is presented below.

4.3.1 Independent Variables in MLR

The independent variables of primary interest for predicting the dependent variable are the ‘unweighted’, ‘weighted’ , and ‘fully weighted’ treaty mechanism scores for: *scale*, *enforcement*, *integrativeness*, *flexibility*, *uncertainty*, *communications* and *specificity*. In addition, two control independent variables were used to estimate factors outside of the treaty. The first control variable is drought/hydrologic stress, as measured with the standard deviation of PDSI in the basin. The second control variable is difference in power, or Delta Power, which is based on differences in GDP/stability/human development. All independent variables used are summarized in Table 11 below.

Table 11 Independent variables used in MLR analysis. All results are presented in Appendix F; blue highlights indicate the variables of primary interest.

Letter Designation	Independent Variable Description
V	Unweighted 7 Treaty Parameters (*Scale*, *Enforcement*, *Integrativeness*, *Flexibility*, *Uncertainty*, *Communications* and *Specificity*
W	Weighted 7 Treaty Parameters (*Scale*, *Enforcement*, *Integrativeness*, *Flexibility*, *Uncertainty*, *Communications* and *Specificity*
X	Fully weighted 7 Treaty Parameters (*Scale*, *Enforcement*, *Integrativeness*, *Flexibility*, *Uncertainty*, *Communications* and *Specificity*
Y	Drought STDEV for the Basin
Z	Delta Power for the Basin

A total of six different combinations of independent variables were used. The first three independent variable combinations used only the unweighted, weighted, and fully weighted treaty variables as conflict explanatory variables, summarized on the right side of the equation as:

Independent Variables = ($b_1 * enforcement$) + ($b_2 * flexibility$) + ($b_3 * scale$) + ($b_4 *$ *uncertainty*) + ($b_5 * integrativeness$) ($b_6 * communications$)

where the regression coefficients b_0 , b_1, b_2, ... b_k are determined from regression analysis.

The other independent variable combinations used the unweighted, weighted, and fully weighted treaty variables, but also incorporated values of drought and differences in power. Drought or hydrologic stress is measured by the standard deviation of absolute drought in the basin since the treaty was signed. The standard deviation of the PDSI is intended to estimate variability, which is used as a rough estimate of relative drought. The power variable was discussed previously and is the difference in political power/stability between the treaty signatories. The final three independent variable combinations using unweighted, weighted, and fully weighted mechanisms along with drought and Delta Power within MLR can be summarized as:

Independent Variables = ($b_1 * enforcement$) + ($b_2 * flexibility$) + ($b_3 * scale$) + ($b_4 *$ *uncertainty*) + ($b_5 * integrativeness$) ($b_6 * communications$v **+** (b7 * drought (STDEV of PDSI)) + (b8*Delta Power)

where the regression coefficients b_0 , b_1, b_2, ... b_k are determined from regression analysis.

The different combinations of independent variables were used to better isolate the impact of the treaty mechanisms, drought, and power on the dependent variable. By considering the treaty mechanisms separately, a comparison can be made with the other combinations to determine both if the results remain consistent and to judge the source of any discrepancies.

4.3.2 Dependent Variables in MLR

A suite of parameters extracted from the BAR and PDSI data sets are used to estimate dependent variables. Eight combinations of dependent variables are used based on the following variables: the number of total complaints, the average BAR for all complaints, the number of climate-related complaints, the average BAR of climate related complaints, and the number of years the treaty has been in effect. For treaties that have complaints of any kind, the following dependent variable was used:

$$\text{Dependant Variable} = \frac{(\text{BAR}) * (\#\text{ of Complaints})}{(\#\text{ of Years Treaty Has Been In Effect})}$$

For treaties with climate complaints, the following dependent variable was calculated:

$$\text{Dependant Variable} = \frac{(\text{Climate Complaints BAR}) * (\#\text{ of Climate Complaints})}{(\#\text{ of Years Treaty Has Been In Effect})}$$

The above calculations are done at both the treaty and basin level. Treaty-specific data are the ideal since it allows for direct comparison of treaty parameters and the independent variables. However, basin data are also considered valuable since not all complaints can be delegated to a specific treaty and there is likely overlap between the influence and impact of multiple treaties within a basin.

4.3.3 Summary of Dependent and Independent Combinations Used in MLR

Table 12 presents a summary of the twenty-four dependent and independent variable combinations that were ran in MLR. In addition to the regression analysis, count, correlation, and other statistical analysis using variables from the datasets are used to further examine the hypotheses.

4.3.4 Projected Drought/Scarcity Data

To date, no future scenario predictions are available for PDSI. Such predictions would have to be calculated from a homogenized data set of past and future model output for the numbers to be comparable. Analysis using PDSI is therefore restricted to past conditions. In order to predict the amount of increased hydrologic stress for a basin, a different measurement than PDSI is used.

The estimate of future changes is hampered by the fact that General Circulation Models (GCMs) predict climate and hence climatic variables which are relevant to streamflow, but do not explicitly predict streamflow for the future. Thus, existing climate change models do not directly estimate the future probability of flow rates associated with water allocations in treaties. The models used to estimate flows focus first and foremost on the likely "first-order" geophysical effects that increased greenhouse gases (GHGs) will have on climate. We then consider (with somewhat less certainty) what second-order effects these climate changes will have on biophysical systems. We then assume (with even less certainty) that that these biophysical systems will in turn create third-order effects that greatly impact humans —changes in patterns for drought, famines, agriculture production and so on— in a way that is similar to historical occurrences. Finally, we can merely speculate about how the treaties' mechanisms might respond to these third-order effects—by which time we're talking about fourth-order effects. Accurate prediction of the impact of climate change is clearly impossible, but predicting the general direction and magnitude may be within the realm of our capabilities.

Table 12 Summary of the twenty-four dependent and independent variable combinations for MLR analysis.

Model	Dependent Variable	Independent Variable	Model	Dependent Variable	Independent Variable
1	(A*B)/C	V	**13**	(A*B)/C	V,Y,Z
2	(A*B)/C	W	**14**	(A*B)/C	W,Y,Z
3	(A*B)/C	X	**15**	(A*B)/C	X,Y,Z
4	(D*E)/C	V	**16**	(D*E)/C	V,Y,Z
5	(D*E)/C	W	**17**	(D*E)/C	W,Y,Z
6	(D*E)/C	X	**18**	(D*E)/C	X,Y,Z
7	(F*G)/C	V	**19**	(F*G)/C	V,Y,Z
8	(F*G)/C	W	**20**	(F*G)/C	W,Y,Z
9	(F*G)/C	X	**21**	(F*G)/C	X,Y,Z
10	(H*I)/C	V	**22**	(H*I)/C	V,Y,Z
11	(H*I)/C	W	**23**	(H*I)/C	W,Y,Z
12	(H*I)/C	X	**24**	(H*I)/C	X,Y,Z

Where the variables are:

Letter Designation	**Dependent Variables Description**
A	# Complaints for the Treaty
B	Average BAR for the Treaty
C	Years the Treaty has been in effect
D	# Complaints for the Basin
E	Average BAR for the Basin
F	# Climate Treaty Complaints
G	Average BAR of Treaty Climate Complaints
H	# Climate Complaints for the Basin
I	Average BAR of Basin Climate Complaints

Letter Designation	**Independent Variables Description**
V	Unweighted 7 Treaty Parameters (*Scale*, *Enforcement*, *Integrativeness*, *Flexibility*, *Uncertainty*, *Communications* and *Specificity*
W	Weighted 7 Treaty Parameters (*Scale*, *Enforcement*, *Integrativeness*, *Flexibility*, *Uncertainty*, *Communications* and *Specificity*
X	Fully weighted 7 Treaty Parameters (*Scale*, *Enforcement*, *Integrativeness*, *Flexibility*, *Uncertainty*, *Communications* and *Specificity*
Y	Drought STDEV for the Basin
Z	Delta Power for the Basin

Data to predict future scenarios of water availability was provided by Ken Strzepek and Alyssa McCluskey who developed historic and future hydrologic indicators for the World Bank project. Similar to De Stefano et al. (2009), these data are provided at the country-basin unit (CBU) scale, which is defined as the spatial portion of an international basin that is within a single country. The scale of this data is different from the basin-level PDSI data used for historical hydrologic stress analysis. The reason for this is two-fold: first, the PDSI data provides more precise, annual temporal data necessary to determine relationships between drought and conflict; second, the Strzpek data is spatially more exact, broken down into the country-basin unit, which allows for more nuanced predictions for each area. These differences in data sets add strength to the analysis since each provides added emphasis and granularity where it is needed: the PDSI data allows for historical comparisons at the annual level, while the Strzpek data provides temporally broad analysis, that is common for future projections, but at a spatial scale where the predictive analysis can be better applied.

Quantitative values capturing runoff variability in each CBU were provided by Strzepek and the process is summarized by De Stefano et al. (2009). Strzepek used data from the A1B scenario[25] of the AR4 (IPCC the Fourth Assessment Report of the IPCC Special Report on Emission Scenarios) and hydrologic models (CLIVARII) to provide precipitation and runoff input, respectively. Using this data, a coefficient of variation, or standard deviation divided by the mean of all annual values within a given time period, was calculated for both precipitation and runoff. The CVs were further broken into general categories with “low” defined as less than 0.25, “medium” between 0.25 to 0.75 and “high” greater than 0.75. Strzepek calculated CVs for both a historic baseline period of 1961-1990 (referred to as ‘present’) and for future scenarios 2025-2035 (referred to as

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[25] The A1B scenario assumes a homogenous world of “very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies” (IPCC, 2007). It also assumes a balanced use of energy sources. The most likely temperature rise in the A1B scenario is 2.8 °C, with a potential range of 1.7 to 4.4 °C.

‘2030’) and 2045-2055 (‘2050’), as well as historic baseline data for 1961-1990. For the purposes of the World Bank report, the wet and dry extremes and an average scenario were used to illustrate the range of climate predictions. One Driest (DRY), Middle (MED) and Wettest (WET) scenario for each region was selected from the 22 different A1B GCMs used in the climate model intercomparison in AR4.[26] Each scenario was then further scaled down to the CBU scale and runoff CVs were calculated based on the regional DRY, MED, WET scenarios (De Stefano et al., 2009).

[26] The scale and regions used for the modeling were defined by the World Bank. Some World Bank regions do not coincide exactly with basin delineations, resulting in some cases where CBUs of the same river basin belong to different regions and consequently CV values derived from different climate models. De Stefano et al. provide the Nile basin as an example where the ‘Ethiopian share of the Nile River basin is based on the ranking of models in the Sub-Saharan African region’ but the Egyptian share is “based on the ranking of model results for the Middle East and North Africa Bank region” (De Stefano et al., 2009).

5 Results

The analytic results are summarized at both the treaty level and at the basin level. By investigating the conflict level and attributes associated with a particular treaty, a measurement of how the treaties mechanisms affect a specific scope of conflict is obtained. The reason for the inclusion of the basin-level analysis is to examine the impact that a treaty may have at minimizing conflict when combined with all other treaties in the basin. The results are further separated into categories of climate-specific complaints, all types of complaints, and treaties with no complaints in order to come to general conclusions about what attributes best mitigate and manage conflict. The strength of each treaty is summarized using both the Literature Review based count method and the MLR methodologies. Climate model-based future scenarios are presented within the case studies.

5.1 Count Models/Summary Statistics

Treaty level results show that the majority of treaties, 71 percent, did not have any type of complaint filed since the treaty was signed (Table 13). Among the 29 percent of treaties with any type of complaint, about half had climate-related complaints. Despite the relatively small number of treaties with climate complaints (20, or 14 percent), these treaties received the majority of complaints of all varieties, including complaints other than climate-related (330 of 388, or 85 percent). The 22 treaties with complaints only of a variety other than climate-related had a total of only 58 complaints. In other words, treaties with climate complaints had more complaints in general compared to treaties with other types of complaints. Treaties with climate complaints had an average of 16.5 complaints per treaty (of which 4.3 were climate related), while other treaties averaged only 2.6 complaints.

Table 13 Summary statistics for the number of treaties in each conflict category

	Number of Treaties in Each Category	Percent of Treaties in Each Category	Number of any Type of Complaint in Each Category	Number Climate Complaints in Each Category
Climate Complaints	**20**	**14%**	**330**	**85**
Any Type of Complaints	**42**	**29%**	**388**	**85**
No Complaints	**102**	**71%**		
All Treaties	**146**	**100%**	**388**	**85**

Note: The climate totals above are slightly inflated since several treaties have overlapping issues (hydropower and flooding), and complaints are totaled according to issue. The actual total number of complaints is 365, with 62 climate complaints.

The severity of complaints, as measured with BAR data, indicate very little difference between the BAR measurements for treaties with and without climate complaints (Table 14). Treaties with climate complaints have more total complaints filed, but the overall BAR for all complaints in the basin does not change significantly. Of interest is that for treaties with climate complaints, the average BAR for non-climate related complaints (-1.78) is more negative and severe than the climate related complaints (-1.33). In summary, the overall BAR does not shift substantially between treaties in the climate, non-climate, and no-complaint categories; however for each treaty, the BAR for climate/non-climate complaints within these categories shows marked differences and climate complaints have generally less severe conflict.

Table 14 BAR values for treaties in each conflict category and according to type of complaint. BAR results are similar for all complaint categories.

	Treaty BAR All	Treaty BAR Non-Climate Driven	Treaty BAR Climate Driven
Treaties with Climate Complaints	-1.55	-1.78	-1.33
Treaties with Only Non-Climate Complaints	-1.47	-1.47	
Treaties with Any Type of Complaints	-1.51	-1.61	

Basin data indicates that a majority of basins (92 percent) had at least one treaty with a complaint logged. This differs from the treaty results, where most treaties did not have complaints. This is because most basins have several treaties that govern their waters and complaints for each treaty are grouped together to calculate basin results. Thus, the probability of a complaint filed at a basin level is much higher. Similar to the treaty results above, basin-level data indicates that basins with climate complaints have a higher proportion of complaints and are more contentious in general. Climate-complaint basins make up only 29 percent of all basins, yet have 87 percent of all complaints. The 11 basins with complaints only of a variety other than climate-related had a total of only 45 complaints, or 13 percent of all complaints (Table 15).

Table 15 Summary basin statistics according to complaint category. Climate-complaint basins make up only 29 percent of all basins, yet have 87 percent of all complaints.

	Number of Basins in Each Category	Percent of Basins in Each Category	Number of any Type of Complaint in Each Category	Number Climate Complaints in Each Category
Basins with Climate Complaints	**15**	**29%**	**320**	**62**
Basins With Other Types of Complaints	**11**	**21%**	**45**	
No Complaints	**26**	**50%**		
All Basins	**52**	**100%**	**365**	**62**

BAR data for basins indicates very little difference in the severity of complaints for basins with and without climate complaints (Table 16). Results from both treaties and basins indicate that the severity of climate complaints tends to be lower than for other types of complaints, with an average basin BAR of -1.20 compared to -1.67 for non-climate complaints. While climate may be a cause for filing a complaint, the action taken seems to be less conflictive than actions taken for other matters.

Table 16 Basin specific BAR data according to type of complaint. Note that the the severity of climate complaints tends to be lower than for other types of complaints.

Basin	BAR All Complaints	BAR Non-Climate Complaints	BAR Climate Complaints
Amazon	-2	-2	
Aral Sea	-2	-2	
Colorado	-1.8	-2.5	-1
Columbia	-1.5	-2	-1
Danube	-1.5	-1.5	
Douro/Duero	-1.3	-1	-2
Fenney	-1		-1
Ganges-Brahmaputra-Meghna	-1.5	-1.3	-1.6
Guadiana	-0.8	1	0
Helmand	-1.4	-1.5	-1
Incomati	-1	-1	
Indus	-1.8	-1.8	-1.3
Jordan	-1.6	-1.5	-1.8
Kunene	-2	-2	
La Plata	-1.2	-1.2	
Minho	-1	-1	
Maritsa	-2	-2	
Moa	-1	-1	
Nelson-Saskatchewan	-2.2	-3	-2
Nile	-1.9	-2	-1
Nestos	-1		-1
Orange	-2	-2	
Rio Bravo/Rio Grande	-2.2	-3	-2.2
Tigris/Euphrates	-1.4	-1.4	0
Zambezi	-2	-2	
All Basins Average	**-1.58**	**-1.67**	**-1.2**
Basins with Climate Complaints	**-1.51**	**-1.67**	**-1.2**
Basins with Only Non-Climate Complaints	**-1.67**	**-1.67**	

5.2 Literature Review Based Mechanism and Treaty Strength Results

Every treaty contained at least one mechanism as part of its content, with *communications* the most prevalent, found in 90 percent of treaties. *Integrativeness* was the least prevalent, found in only 44 percent of treaties. There was some difference in the number of mechanisms found in treaties with no complaints, climate-complaints, and any type of complaint (Figure 4). Compared to other treaties, climate-complaint treaties consistently had equal or higher percentages of each mechanism, except for *scale*. Of particular interest is that every climate-complaint treaty had an *enforcement* mechanism, compared to only 86 percent for other treaties. A similar relationship was found when an average mechanism per treaty comparison was conducted, where climate complaints had a higher average number of mechanisms per treaty (5.7) than other treaties (all other treaty categories average 5.3 mechanisms per treaty).

Treaty categories other than those with climate complaints were generally similar, with a few exceptions. Treaties with complaints were 10 percent more likely to contain the *flexibility* mechanism than treaties without complaints. A comparison of treaties with any type of complaint and treaties with no complaints indicates that no-complaint treaties had a higher percentage of treaties with *uncertainty* and *specificity*, while treaties with complaints had a higher percentage with *flexibility*, *integrativeness*, and *enforcement* mechanisms.

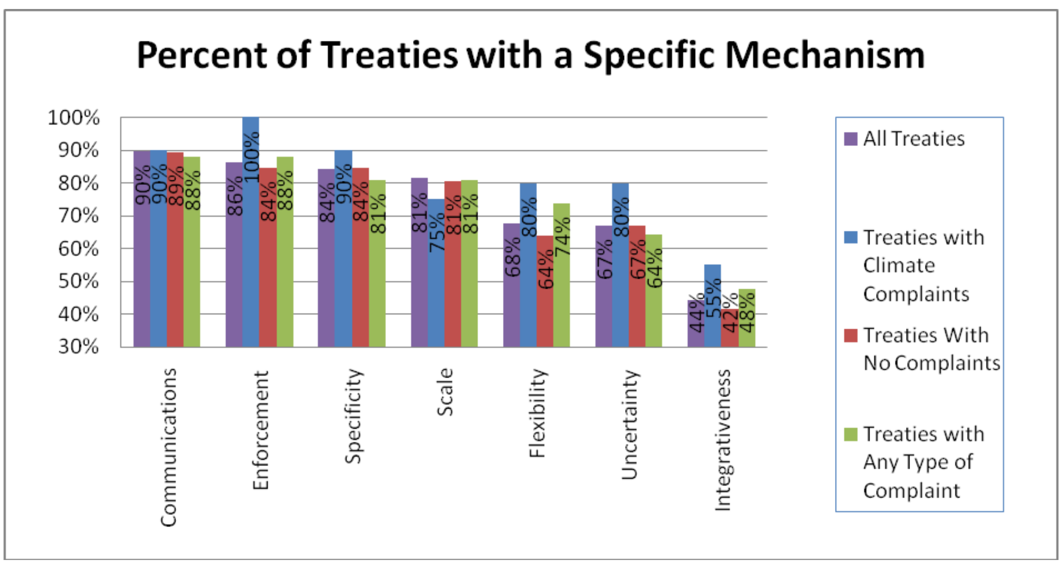

Figure 4 Mechanism count summary according to treaties with and without different types of complaints.

These results are somewhat surprising since one of the primary hypotheses was that treaties with fewer mechanisms were less strong and thus more likely to have complaints. Yet, in the case of this data set, treaties with climate complaints were shown to have more mechanisms than other treaties. These results indicate that treaties with no complaints in fact had fewer mechanisms and are ostensibly less robust than those with climate complaints. An expanded discussion on possible explanations for these results is presented in Chapter 6.3.2.

Results for the non-weighted, weighted, and fully weighted treaty analysis were similarly surprising, with the highest treaty scores for treaties with climate complaints (weighted score of 2.60), followed by treaties with any type of complaint (weighted score of 2.3) (Figure 5). Treaties with no complaints had the lowest ratings, with a 1.9 weighted score. The presence of complaints seems to be an indicator of stronger, rather than weak, treaties. Also of interest was that weighting (both weighted and fully weighted) did not appear to impact the relative ranking of complaint categories. For all three methods, treaties with climate complaints remained the strongest treaties and treaties with no complaints the weakest. The percent difference between the categories also remained relatively constant regardless of whether or not weights were applied.

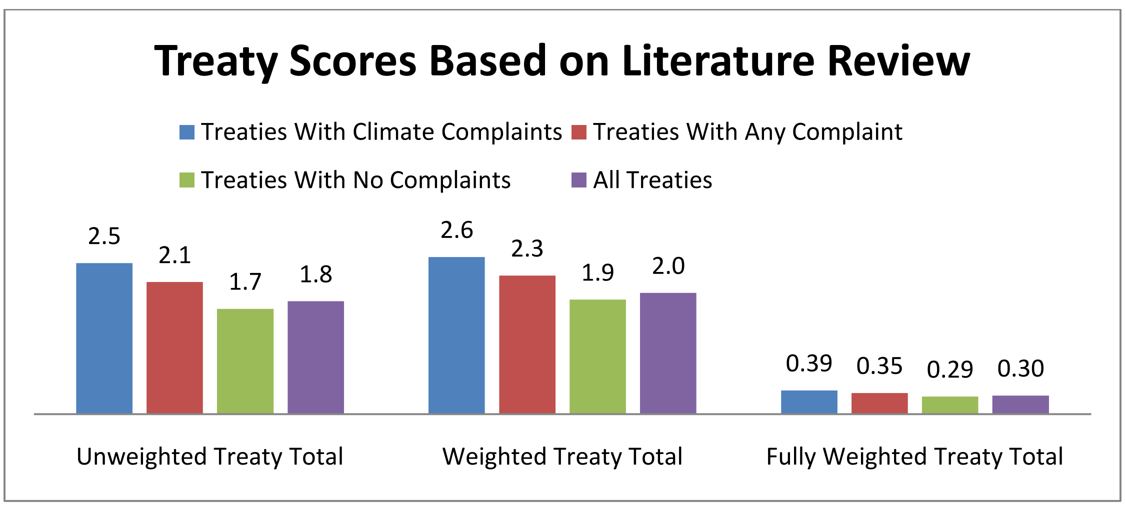

Figure 5 Treaty scores according to the three weighting methods. Note that the treaties with climate and other complaints have the highest scores.

Mechanism interrelationships were evaluated to determine if the presence of a mechanism correlates with the presence of other mechanisms, and if the coupling of these mechanisms was found more often in treaties with complaints (Table 16).[27] The unweighted treaty mechanism strengths, which measure the extent that a treaty contains the attributes of each mechanism, were tested for correlation. Results with a greater than 70 percent correlation for all treaties and for groups separated according to the presence or absence of complaints are shown in Table 16. This correlation test revealed several interesting findings. First, when considering data from all treaties the *communications*, *flexibility*, and *uncertainty* mechanisms were strongly correlated with each other. This correlation is expected since management of *uncertainty* and increased *flexibility* at their core requires strong *communications*. Secondly, treaties with no complaints had the least amount of correlation between mechanisms, with only *communications* and *flexibility* correlating strongly. Conversely, treaties with complaints, both overall and climate-specific, had strong correlation across several mechanisms. Third, strong *integrativeness* and *scale* mechanism did not correlate strongly with any other mechanism, and *specificity* only had a correlation with *flexibility* for climate complaints.

[27] Mechanisms clustered together have the potential to synergistically improve their capacities to manage conflict. For example, it seems intuitive that a treaty with a strong *specificity* mechanism would benefit from a strong *flexibility* mechanism to account for periods when the specific allocation requirements are not possible due to unusual and unpredicted hydrologic conditions.

Table 16 Correlations between different mechanisms

Mechanism	All Treaties	Treaties with Climate Complaints	Treaties with Any Type of Complaint	Treaties with No Complaints
Communications	*Flexibility, Uncertainty*	*Uncertainty*	*Flexibility*	*Flexibility*
Uncertainty	*Flexibility, Communications*	*Flexibility, Communications*	*Enforcement, Flexibility,*	None
Enforcement	None	*Integrativeness*	*Uncertainty*	None
Flexibility	*Communications, Uncertainty*	*Uncertainty, Specificity*	*Communications, Uncertainty*	*Communications*
Integrativeness	None	None	None	None
Scale	None	None	None	None
Specificity	None	*Flexibility*	None	None

5.3 Linear Models

The regression analysis is used to provide the average magnitude of the effect of each independent variable, from which we can estimate the relative resilience for each treaty. Results for the MLR models for the twenty-four dependent and independent variable combinations are presented in Appendix G. For ease of discussion, unweighted treaty scores and an average of all significant scores are highlighted here in the text. The unweighted dependent variables (including the additional dependent variables of *power* and *drought*) are used as the primary results for discussion. Unweighted results have the least amount of bias from the literature. Additionally, the use of the unweighted results as a typical indicator of all results is justified by the treaty score discussion in Chapter 5.2, which shows that the three mechanism weighting techniques yielded similar relative overall treaty scores.

Table 17 Coefficient results for each mechanism using the unweighted dependent variables

	Treaty-Specific Data (# Climate Complaints *Average Climate BAR)/Years Enforced		Treaty-Specific Data with STDEV Drought and Power (# Climate Complaints*Average Climate BAR)/Years Enforced	
	Coefficients	P-value	Coefficients	P-value
Intercept	0.11	0.00	0.11	0.01
Communications	-0.39	0.00	-0.41	0.00
Uncertainty	-0.08	0.29	-0.09	0.25
Enforcement	0.08	0.40	0.07	0.47
Flexibility	0.15	0.13	0.16	0.14
Integrativeness	-0.06	0.62	-0.08	0.56
Scale	0.33	0.01	0.36	0.01
Specificity	-0.34	0.00	-0.35	0.00
Delta Power			0.00	0.86
Drought Standard Deviation Since Treaty Signed			0.00	0.44

Table 17 presents MLR results specific to the unweighted/treaty/climate-related complaints dataset. The unweighted mechanisms with the largest coefficients (both + and -) are *scale*, *communications*, *specificity*, and *flexibility*. All four of the largest coefficients are statistically significant with confidence intervals above 95 percent. Based on these results, a regression equation can be created that estimates the impact of each of the seven treaty mechanisms, as well as drought and Delta Power. This dataset and regression results are labeled as ‘Model 1’ and are expressed in linear form as:

Model 1:

*((*number of climate complaints*average climate BAR) / Years Enforced)= *0.11* - 0.41 (*Communications*) –0.09 (*Uncertainty*) + 0.07 (*Enforcement*) + 0.16 (*Flexibility*) – 0.08 (*Integrativeness*) + 0.36 (*Scale*) - 0.34 (*Specificity*) *+ 0.00 (Power) +0.00 (Drought)*

An inspection of the p-values for the unweighted results above shows that *integrativeness, uncertainty* and *enforcement* are not statistically significant, with p-values greater than 0.05. This raises the question of how to better predict the impact, if any, that the mechanisms with higher p-values have on the dependent variable. This problem is typical for all results (unweighted, weighted, and fully weighted), with no one regression result providing statistically significant coefficients for all mechanisms.

Towards the goal of filling these gaps and obtaining accurate coefficients, a second MLR model (Model 2) was utilized. Data from the 24 iterations of multiple linear regression analysis were averaged to create catch-all summary coefficient values that are statistically significant for each mechanism. For each of the three broad categories of unweighted, weighted, and fully weighted, there were eight different variations of dependent variables used in MLR. Each of the different variations provide a dataset that estimates the coefficients and can be used to estimate the average coefficient for each treaty mechanism. For an 'averaged' coefficient, regression results from the dependent variable combinations (treaty, basin, climate, and non-climate complaints) were reviewed and statistically significant results were collated and averaged. This summary coefficient incorporates all dataset variations with statistically significant results (very high confidence above 95 percent as indicated by P values less than .05). Results that were not statistically significant were omitted from this average. This summary/average method is considered viable since the independent variables remain constant for all regressions, with shifts only in the inputs used in the dependent variables. The results for this second method of determining a regression equation are presented below in Table 18.

Table 18 Average of all significant results with P<0.05 for Treaty, Basin, Climate Complaints, and All Complaints Data. The model was tested for violations of the assumptions of linearity and normality, which justify the use of linear regression models.

	Only Significant Results (P< 0.5)		
	Unweighted Coefficients	Weighted Coefficients	Fully Weighted Coefficients
Intercept	0.11	0.09	0.09
Communications	-0.40	-0.29	-1.11
Uncertainty	NA	NA	NA
Enforcement	NA	NA	NA
Flexibility	NA	NA	NA
Integrativeness	-0.92	-0.93	-7.07
Scale	1.23	0.98	9.13
Specificity	-1.05	-1.11	-8.22
Drought Standard Deviation Since Treaty Signed	NA	NA	NA
Delta Power	-0.01	-0.01	-0.01
	Model 2		

While recognizing that this expanded dataset reaches beyond just the ideal unweighted/climate/treaty specific data, it does allow us to obtain statistically significant coefficient results for all mechanisms. These results can be used to provide an optimal regression equation, shown below using the unweighted significant/average results and labeled as Model 2:

Model 2:

(Average Dependent Variable-Only Statistically Significant Results) = *0.11*-0.40 (*Communications*) - 0.92 (*Integrativeness*) + 1.23 (*Scale*) - 1.05 (*Specificity*) - 0.01 (Delta Power)

5.4 Regression Based Treaty Strength Results

The coefficients in Model 1 and Model 2 describe the size of the effect the treaty mechanisms are having on the BAR results. The coefficient for each treaty mechanism indicates how much the conflict-based dependent variable is expected to change when the mechanism variable increases by one, holding all the other mechanism variables constant. In Model 1, the conflict variable is predicted to have a value of 0.05 when all the independent variables are equal to zero, as indicated by the intercept value. In Model 2, the intercept is 0.11. Of interest when comparing the unweighted (Model 1) and significant/average (Model 2) methods is that there is variability in the coefficient magnitudes between the two methods, but the sign/direction of the coefficient does not change for all three weighting methods. This indicates that the direction of influence (positive or negative) of a variable can be accurately determined, while the extent of influence may fall within a range of magnitudes.

Model 1 (unweighted/treaty-specific/climate-related complaints dataset):

*((*number of climate complaints x average climate BAR) / Years Enforced)*= 0.11* -0.41 (*Communications*) –0.09 (*Uncertainty*) + 0.07 (*Enforcement*) + 0.16 (*Flexibility*) – 0.08 (*Integrativeness*) + 0.36 (*Scale*) - 0.34 (*Specificity*) + *0.00 (Power) +0.00 (Drought)*

Model 2 (statistically significant results from all unweighted MLR):

(Average Dependent Variable-Only Statistically Significant Results) = *0.11*-0.40 (*Communications*) – 0.92 (*Integrativeness*) + 1.23 (*Scale*) - 1.05 (*Specificity*) – 0.01 (*Power*)

In Model 1, the coefficients obtained from regression analysis indicate that an increase in *scale*, and *enforcement* within a treaty result in less conflict or complaints. In model 1, *scale* has the largest positive coefficient (+0.30), or impact, and is one of the three variables that is statistically significant (with a 95 percent probability that the variable is having the predicted effect on the BAR results). *Flexibility* (0.16) has the next largest positive impact, but is not statistically significant. *Enforcement* (coefficient of 0.07) has low confidence levels at 47 percent.

In both models, the negative coefficients for *communications*, *specificity*, and *integrativeness* tend to indicate more conflict. In Model 1, *communications* (-0.41) and *specificity* (-0.35) are both significant and have the largest negative coefficients. In Model 1, both *uncertainty* (-0.09) and *integrativeness* (-0.08) have coefficients close to zero and have minimal impact on the BAR dependent variable, but with low confidence.

The largest quantitative shift between Model 1 and Model 2 was in *integrativeness*, which changed from close to zero in Model 1 (but with low confidence) to -0.92 in model 2 with higher confidence. Also with a large shift was *specificity*, which went from -0.35 in Model 1 to -1.05 in Model 2. Both models indicate that power and drought differences had little impact on the independent variable. Drought shifted from no impact in Model 1 to a slightly negative impact in Model 2. The lack of impact for drought and Delta Power indicates either that these variables did not adequately represent outside influences, or that the other independent variables (treaty parameters) indeed had a significant impact on the independent variable that overwhelmed the impact of drought and Delta Power.

Table 19 Comparisons and rankings of coefficients using the regression and Literature Review analysis. The Literature Review and regression models have dissimilar rankings of importance for the seven mechanisms.

	Number of times mentioned in literature as a factor in treaty success	Literature Ranking of Impact	Model 1 Regression Coefficient	Model 1 Regression Ranking of Positive Impact	Model 2 Regression Coefficient	Model 2 Regression Ranking of Positive Impact
Communications	25	1	-0.41	7	-0.40	2
Flexibility	20	2	0.16	2		
Specificity	13	3	-0.35	6	-1.05	4
Enforcement	12	4	0.07	3		
Integrativeness	12	4	-0.08	4	-0.92	3
Scale	11	6	0.36	1	1.23	1
Uncertainty	4	7	-0.09	5		

The relative importance of mechanisms as determined from the Literature Review differs significantly from the linear regression results (Table 19). Of the top three mechanisms that the academic literature cites most often as important to decreasing conflict, only one (*flexibility*) is shown empirically to have a positive influence. Of the other two, one is shown to have more of a negative impact (*communications*) and, according to the first model, one has a slightly positive impact (*enforcement*). *Scale*, the mechanism shown by regression to have the greatest positive coefficient, was not predicted to be so influential since it was cited in only 11 of 48 articles as being important, compared to 20 for *flexibility*, which the literature and regression analysis ranked as second most important.

Results comparing the regression-based analysis of all treaties and the Literature Review method are shown in Figure 6, broken into groups according to presence of complaints, climate complaints, and no complaints. For comparative purposes in the discussion below, both MLR models are based on the unweighted mechanism datasets.

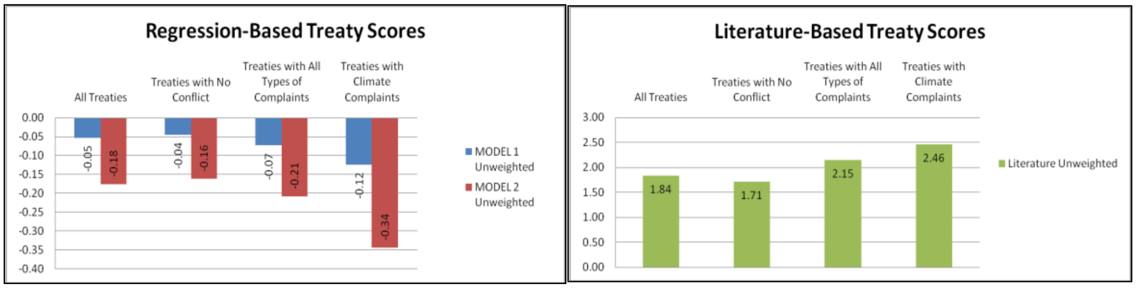

Figure 6 Regression and literature-based treaty score comparison.

More negative regression based scores indicate treaty designs that lead to more conflict. More positive literature based scores predict stronger treaties. Literature scores are obtained by a count of each mechanism and adding them together to obtain an estimated score, or strength.

The treaty scores from the regression analysis were very different from the values obtained when the treaty mechanisms were simply added together in the literature based analysis. The additive results surprisingly and somewhat counter-intuitively indicated that treaties with complaints tended to have a larger total mechanism value, or were 'stronger' treaties. The regression values are different because they are not simply additive, but emphasized mechanism differences between conflict and non-conflict treaties and consider the interactions and possibly deleterious effect that some mechanisms (*communications* and *specificity*) apparently have on the estimated treaty strengths. The average regression values for basins that had complaints were higher than for basins without complaints, indicating that the regression technique has some predictive power for estimating each mechanism's importance for mitigating conflict.

5.5 Hydrologic stress, drought, and conflict

Drought data used in regression analysis was simplified to include only one summary data point: the standard deviation of drought for the basin over the entire period of time since the treaty was signed. While this data provides an indicator of drought fluctuation, the nuances of how drought is a factor in political relations may not be captured. In fact, the regression analysis indicates that drought and hydrologic stress has little impact on the presence or absence of complaints. This section provides a more in-depth analysis of drought and conflict than that presented in the regression analysis in order to determine the extent that drought over shorter periods (from two or more years) impacts conflict and complaints made regarding a treaty.

For this expanded discussion, drought data are separated into basin and treaty categories similar to the complaint data used for regression analysis. This is done partially because not all climate complaints in a basin could be allocated to a specific treaty. Therefore, the basin dataset is more robust and inclusive, while the treaty data allows for analysis of specific treaties. Additionally, analysis at the basin level allows for detection of conflict and drought trends that may transcend a single treaty and extend across an entire basin. Basin results take into account any of the 146 study treaties that occur within that basin. Treaty data are specific to each treaty and are not dependent on or related to other basin data. These two categories are further subdivided by the presence or absence of any type of complaint, climate complaint, or no climate complaints. Results for drought and conflict may differ significantly between the treaty and basin sections. The treaty results take into account all treaties per basin and thus the results may be skewed towards one basin's PDSI results. For example, there are five treaties that govern the Colorado Basin and the Colorado Basin PDSI results are used five times in the treaty averages/results.

5.5.1 <u>PDSI Summary According to Presence/Absence of Complaints</u>

The average PDSI since a treaty was signed and over the entire period of its application was calculated for each treaty and then grouped according to the presence and type of complaints lodged for that treaty (Figure 7). Similar to the regression analysis results that estimate a drought coefficient close to 0, the average PDSI results indicate that there is very little difference in overall magnitude of drought between treaties with no conflict and those with climate conflict over the entire period since an agreement was signed. In other words, the data indicates no correlation between wet/dry regions and the presence/absence of climate complaints. Contrary to the idea that more climate complaints are more likely to occur in areas with more severe drought, the minor differences in the data indicate that treaties with climate complaints have slightly less drought (by 0.03 on the PDSI) than treaties with no complaints.

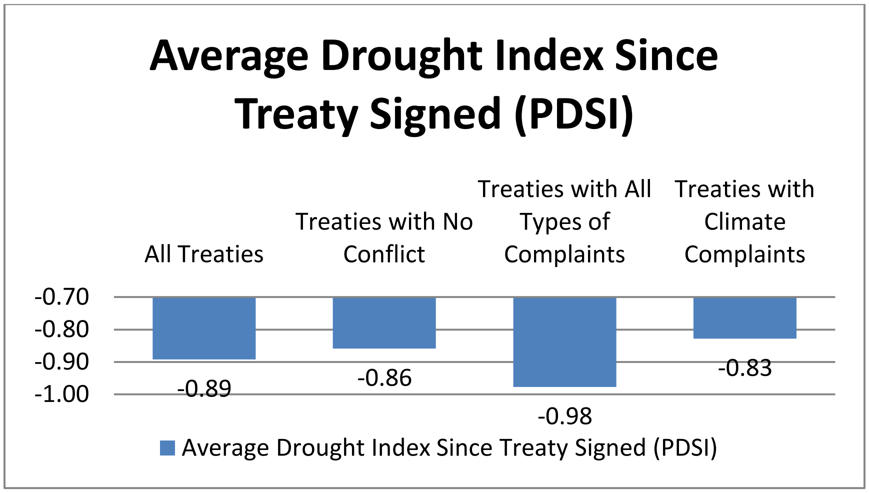

Figure 7 Average PDSI since a treaty was signed according to complaint type. Treaties with climate complaints have slightly less drought than treaties with no complaints.

Data for the sum-total of time that a treaty's basin was in drought also indicate a decrease in drought frequency for climate conflict treaties when compared to no-conflict treaties (Figure 8). Treaties with climate complaints were in a relative or absolute drought situation between 18 and 20 percent of the time since a treaty was signed, compared to 23 and 24 percent of the time for treaties with no or other types of complaints.

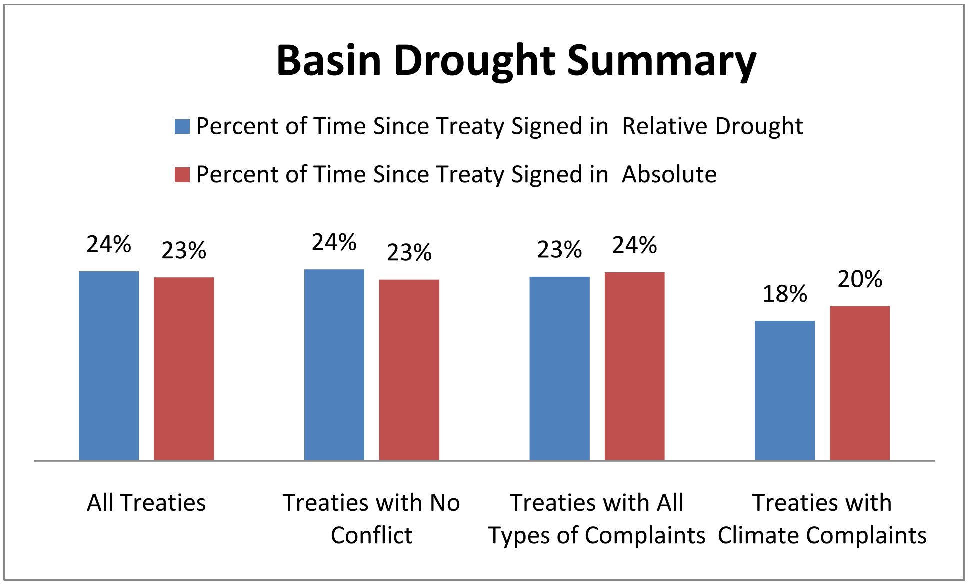

Figure 8 Percent of time a basin was in relative and absolute drought since a treaty was signed according to type of complaint. Climate complaints are not generally filed in basins with the most time in drought conditions.

In addition to the average drought values, variability of drought is also lower for treaties with climate complaints. Treaties with climate complaints on average have 0.18 lower standard deviation of drought compared to treaties with no complaints (Figure 9). In summary, treaties with climate complaints are in absolute and relative drought less often, have a lower overall drought severity, and have less variability than treaties that have no conflict.

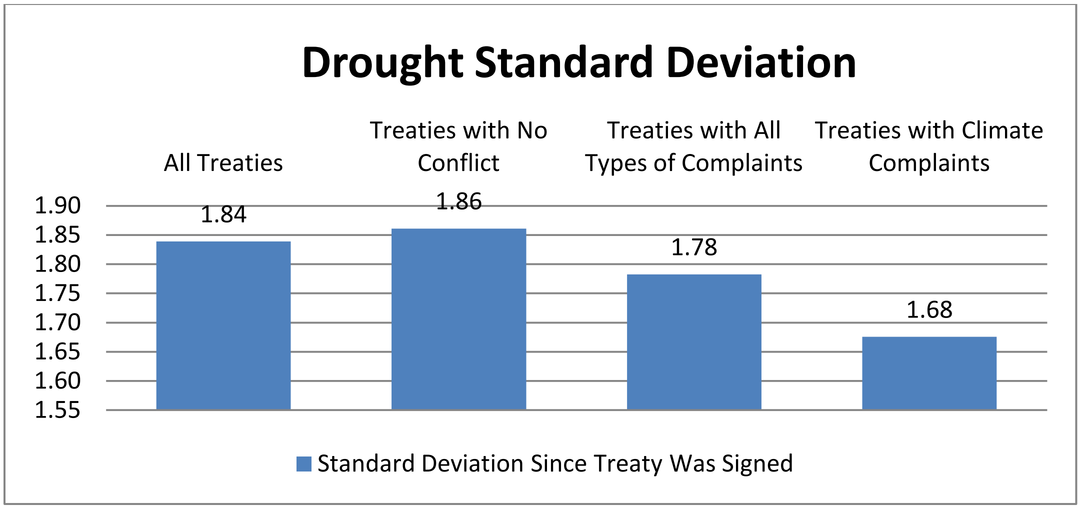

Figure 9 Standard deviation of drought according to types of complaints. Note that treaties with climate complaints surprisingly have a lower drought variability.

5.5.2 In Depth Analysis of PDSI Specific to Basins with Complaints

Having established that overall drought severity and drought variability over the entire period of a treaty's application does not seem to be an indicator of conflict, smaller-scale annual periods of drought and conflict were explored. Drought indices for years where there were no complaints, years where there were climate-related complaints filed, and years where non-climate related complaints were filed were calculated for each basin. The drought indices during these periods were then compared to a baseline average drought index for the basin since a governing treaty was signed. Wolf et al. (2003) indicate that historically extreme events of conflict over water have been more frequent in water scarce regions and where extreme conditions characterized by high inter-annual hydrologic variability occur. Rather than measuring an overall PDSI average as in the previous chapter, this comparison is intended to measure how variability impacts complaints.

The delta between the baseline average for all years of treaty application against years of climate and non-climate complaints is shown in Table 20. Overall, basins tended to be in slightly dryer periods, by an average -0.53 on the PDSI, when any type of complaint occurs, although some basins did not follow this trend (8 of 23 basins) and were actually wetter during complaint years. For years when a climate related complaint was filed, all basins, except the Fenney, were universally drier, by an average of -1.62 on the PDSI. For those years when non-climate complaints were registered, the PDSI was also lower than the average, by -0.56.

Table 20 Average drought index at the basin level for periods of conflict and non-conflict. Note that the basin averages differ from the treaty level since there are multiple treaties for some basins.

	Average Drought Index				Delta From the Average Drought Index Since the Treaty Was Signed		
Basin	**All Years Since the Treaty Was Signed**	**For Years with Any Complaint**	**For Years With A Climate Complaint**	**For Years With Non-Climate Complaints**	**For Years with Any Complaint**	**For Years With A Climate Complaint**	**For Years With Non-Climate Complaints**
Aral Sea	-1.88	-0.51		-0.51	1.37		1.37
Colorado	0.40	-1.77	-0.80	-3.85	-2.17	-1.19	-4.24
Columbia	0.09	-1.04	-0.95	-1.12	-1.12	-1.04	-1.21
Danube	-0.63	-1.99		-1.99	-1.36		-1.36
Douro/Duero	-1.18	-2.83	-2.52	-2.99	-1.65	-1.34	-1.80
Fenney	-0.78	-0.54	-0.54		0.24	0.24	0.78
Ganges-Brahmaputra-Meghna	-0.26	-0.54	-0.46	-0.56	-0.28	-0.20	-0.29
Guadiana	-1.44	-3.82		-3.82	-2.38		-2.38
Helmand	-0.47	-4.53	-4.98	-4.38	-4.06	-4.51	-3.91
Incomati	-2.25	-4.93		-4.93	-2.68		-2.68
Indus	-0.51	-0.60	-1.72	-0.56	-0.09	-1.21	-0.05
Jordan	-0.28	-1.32	-1.35	-1.32	-1.03	-1.06	-1.03
Kunene	-1.25	-2.03		-2.03	-0.79		-0.79
La Plata	0.10	0.55		0.55	0.45		0.45
Minho	-0.54	-0.20		-0.20	0.35		0.35
Maritsa	-1.82	-4.14		-4.14	-2.32		-2.32
Nelson-Saskatchewan	-3.02	-3.41	-3.41	-3.36	-0.38	-0.38	-0.34
Nile	-1.37	-0.85		-0.85	0.52		0.52
Nestos	-3.54	-1.71			1.82		3.54
Orange	-1.24	-0.60		-0.60	0.63		0.63
Rio Bravo/Rio Grande	0.20	-1.51	-1.51	-2.70	-1.71	-1.71	-2.89
Tigir/Euphrates	-0.66	-0.94	-6.11	-0.44	-0.28	-5.46	0.21
Zambezi	-3.17	1.51		1.51	4.68		4.68
All Basins Averaged	-1.11	-1.64	-2.21	-1.82	-0.53	-1.62	-0.56

Drought and conflict data were also compared to determine whether or not drought impacts the severity and number of complaints at the annual scale. A comparison of the severity of complaints for each basin that had any type of complaint shows that there is only a slight difference between BAR values during periods of relative drought and non-drought (-1.49 and -1.68, respectively). The slight difference indicates that periods of non-drought may in fact have slightly more severe conflict. For the quantity of complaints, 43.7 percent of complaints were during absolute drought and 38.4 percent were during relative drought. Considering that basins were in absolute/relative drought only 24 percent of the time, complaints of all types were more likely during periods of drought. The increase of complaints during periods of drought is even more apparent for climate complaints, where 58 percent of complaints were during periods of absolute drought, and 47 percent were during periods of relative drought. For both climate and general complaints, a slightly higher percentage of complaints were during periods of absolute drought when compared to relative drought, indicating that absolute drought thresholds may be more of an influence on complaints than relative drought. Overall, drought did not appear to impact the severity of complaints, but does have an impact on whether or not a complaint is lodged.

5.5.3 Power and conflict

Similar to the analysis for drought and conflict in Chapter 5.5.2, a more in-depth analysis was conducted to determine how differences in power between riparians affect the likelihood of complaints being filed. The regression equations (both Model 1 and Model 2) predicted a minimal impact from differences in power on the dependent variable. The purpose of this section is to investigate the individual inputs that were used to calculate the power variable and confirm the power variable's minimal impact on complaints by a direct analysis that ignores all other independent variables.

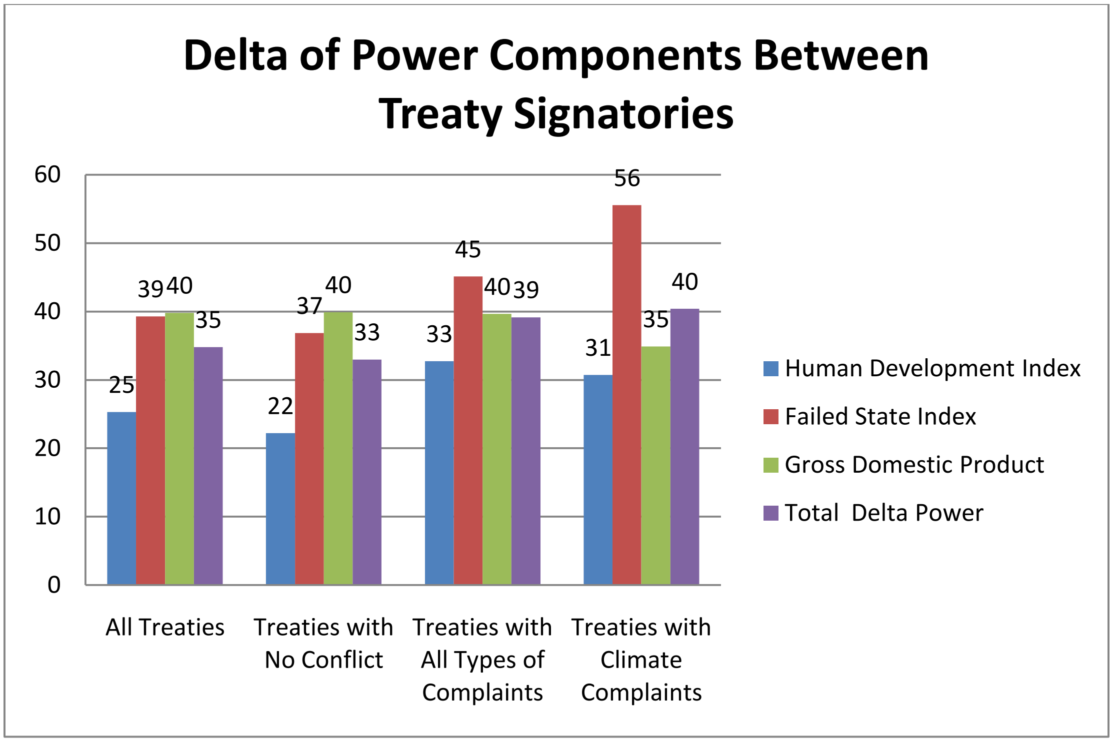

Figure 10 Difference in power between signatories according to type of treaty complaint. The Failed State Index has the largest relative difference between treaties with and without climate complaints.

Similar to the regression analysis results for the power variable, Figure 10 shows that there is very little difference in overall power between treaties with and without conflict, with a limited increase of 18 percent from treaties with no conflict (total Delta Power difference of 33) and treaties with climate-related complaints(total Delta Power difference of 40). However, a review of the various components reveals some interesting results. For treaties with climate complaints, there is a large increase in the delta of the Failed States Index between riparians (34 percent difference) compared to treaties with no complaints, and there is a similarly large increase (32 percent) in the conflict/no conflict delta for the Human Development Index. This could be an indication that large differences in the FSI and HDI between countries may be a sign or cause of additional stress between riparians leading to increases in the occurrence of complaints, including those that are climate related. Also of interest is that compared to other components, the delta GDP showed minimal differences between riparians with and without conflict. Sometimes used by itself as a corollary of power, these results indicate that GDP may not have the best predictive capacity for measuring differences in power that impact water relations.

5.5.4 Comparison of Impact of Drought, Power, and Treaties on Conflict

Treaty scores were plotted against power and drought indices and compared across different complaint groups to detect trends and differences between treaties with and without complaints. The results for drought indicate that for treaties with complaints, basins with higher drought standard deviations tend to have stronger treaties. Treaties with no complaints have very little difference in treaty strength when plotted against drought standard deviation. When treaty scores are plotted against PDSI scores, or the relative intensity of drought in the basin, treaties with complaints show a trend of stronger treaties in areas with more intense drought. Although the R^2 values are very weak, for treaties with conflict the combination of these two graphs indicate that treaties in basins with high drought variability and intensity tend to be weaker treaties according to the regression Model 1, but have a greater number of total components as measured by the Literature Review score.

Figure 11 Treaty scores plotted against drought indexes (absolute and standard deviation) for each category of complaint

Also with weak R^2 values, Delta Power scores indicate that for treaties with no complaints, stronger treaties result from relationships that have a smaller Delta Power, or in other words from riparians that are closer together in GDP, FSI, and HDI. For treaties with complaints, riparians with a larger Delta Power have stronger treaties according to the according to the regression Model 1, but have fewer number of total components as measured by the Literature Review score.

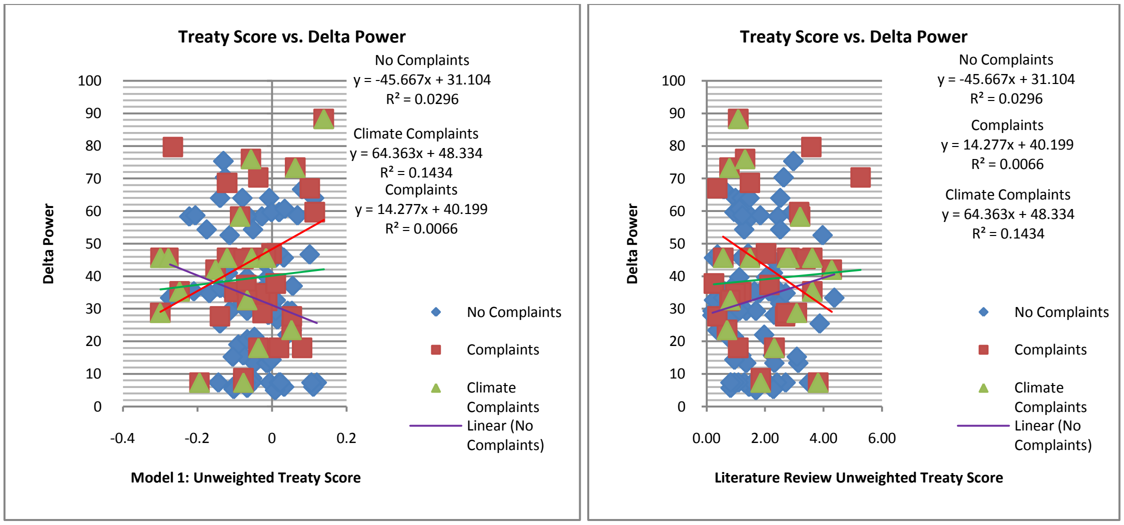

Figure 12 Treaty scores plotted against Delta Power. The low R^2 values indicate tenuous relationships between treaty scores and Delta Power.

The slopes indicate that there are tenuous relationships between treaty scores and drought as well as power relationships, but the interpretation of the above analysis depends on which treaty analysis method is utilized. The Literature Review provides an additive mechanism score and its results indicate that treaties with conflict have the largest number of mechanisms when compared to treaties with no conflict. MLR accentuates the differences in mechanism design based on the premise that conflict is an indicator of an unsuccessful and consequently weak treaty. Depending on the method used, the interpretation will produce opposite conclusions.

5.6 Discussion

The discussion of the MLR and Literature Review analysis is presented according to its relevance to each hypothesis. A more in-depth discussion that incorporates these findings across the full spectrum of treaties along with the specific results from each case study is included after the case studies.

Hypothesis 1: A state experiencing a period of increased hydrologic stress in the form of drought or additional variability will have a change in the likelihood of complaints or *state grievances involving a shared water resource, compared to a state that is not experiencing hydrologic stress.*

Drought (both frequency and severity) does not determine which treaties will have climate related complaints. Drought does not occur any more frequently in basins that have reported climate related conflict than it does in other basins: treaties with climate complaints are in absolute and relative drought less often, have a lower overall drought severity, and have less variability than treaties that have no conflict. Therefore, drought is not the primary cause or determiner of whether a treaty is going to have climate related conflict.

For treaties that do have climate related conflict, drought seems to be a driver of increases in frequency, but not severity of conflict. Complaints are shown to be more likely during periods of greater drought and hydrologic stress. Implications of this analysis are that treaties with climate complaints are more susceptible and sensitive to changes in climate. In this way, the presence or absence of a climate complaint in any given year can be used as an indicator of stress to the treaties' capacity to manage hydrologic fluctuations.

Hypothesis 1 is therefore not verified in general, but shown to be applicable for a subset of treaties that have already displayed a propensity for conflict. The relationship held true for all types of conflict (both climate and general complaints), but was complicated by the strong correlation between treaties with a higher rate of conflict and the presence of climate-related complaints.

Hypothesis 2: Water sharing agreements that have mechanisms in place, namely specificity, uncertainty, enforcement, communications, flexibility, integrativeness, and scale, will have less conflict and fewer grievances, including those that are climate related. Each mechanism contributes equally to the treaty's utility in managing hydrologic stress, and the overall institutional resiliency of a treaty can be summarized by adding the number of mechanisms included in the treaty.

According to the Literature Review scores and an evaluation of drought and complaint histories, the most robust treaties have a higher instance of both climate and general conflict. A comparison of the number of mechanisms per treaty for treaties with climate complaints, any type of complaint, and no complaints indicated that treaties with more mechanisms had an increased likelihood of having complaints. Treaties with climate complaints in particular were shown to have more mechanisms than other treaties. These results indicate that treaties with no complaints in fact had fewer mechanisms and are ostensibly less robust than those with climate complaints.

Treaties were generally considered as a sum of their mechanism parts when evaluating this hypothesis, but correlations between mechanisms were also considered since strong correlations between mechanisms would also seem likely to have a synergistic impact beyond just the additive affect of each mechanism. It would be expected that treaties with stronger correlations (and thus more synergy) would be found more often in treaties without complaints. However, treaties with no conflict have less pronounced correlation between mechanisms.

Hypothesis 2 is not verified by the analysis since the weaker treaties with the fewest mechanisms tend to have the least amount of conflict. The relationship between specific mechanisms and the presence of complaints, as well as possible explanations for the findings regarding Hypothesis 2, are discussed below.

Hypothesis 3: All mechanisms have added benefit, but some mechanisms are more important to providing increased institutional capacity to manage drivers of conflict such as hydrologic stress, as well as stress from differences in political power, national stability, and economics that, if left unmitigated, could otherwise lead to conflict.

For the MLR model, the coefficients obtained from regression analysis indicate that an increase in *flexibility*, *scale*, and *enforcement* within a treaty result in less conflict or complaints and the negative coefficients for *communications*, *specificity*, and *integrativeness* tend to indicate more conflict. The MLR analysis indicates that certain mechanisms may be an indicator of an increased likelihood of a complaint being filed. Hypothesis 3 is shown to be partially true in that the results indicate that some mechanisms are more important than others in mitigating conflict, but the hypothesis is also not verified since some mechanisms have negative coefficients and numerically detrimental impact on complaint occurrence.

A final point of discussion is the similarity in the unweighted, weighted, and fully weighted treaty strength ratios. The unweighted methodology uses the literature to determine which mechanisms contribute to treaty strength, whereas weighted totals assign additional emphasis on certain treaty parameters. The fully weighted method then gives additional emphasis to certain mechanisms. Each method progressively gives more emphasis to the findings from the literature review. However, the relative difference in treaty mechanism scores did not vary significantly across the multiple methods. To measure the differences in treaty scores for different methodologies, for each method the percent difference in treaty scores between treaties with no complaints and treaties with climate complaints was calculated (average score for treaties with complaints/average score for treaties without complaints). The unweighted method had a 30 percent and the fully weighted method had a 24 percent difference, with the weighted methodology at 26 percent. The relatively small 6 percent difference in average treaty scores between the unweighted and fully weighted methods indicates that any of the three methods can be used for calculating treaty strength, with the expectation that results will be similar and the unweighted method slightly increasing the differences in scores between the different complaint categories.

In summary, climate-related complaints are typically found in areas that also have other types of conflict. Climate complaints are precipitated by periods of drought for treaties that have a history of conflict, but the frequency and severity of drought does not determine whether or not a treaty will have climate-related conflict. In general, there are five summary observations that can be made about climate complaints: 1) they tend to occur in areas with ambient tension and general conflict regarding water; 2) drought does not determine which basins have climate complaints. However, for those basins where complaints occur, they tend to happen during periods of drought; 3) the severity of the climate complaints is not higher compared to general, non-climate related complaints; 4) treaties that have complaints are on average more robust (have more mechanisms) than treaties without complaints; 5) treaties with *flexibility*, *scale*, and *enforcement* mechanisms result in fewer complaints, whereas *communications*, *specificity*, and *integrativeness* tend to indicate more complaints. Each of these points from the treaty results raises additional questions and are examined further in the case study analysis. The case studies provide real world examples and fodder towards possible explanations for these findings that are presented in the discussion and conclusions in Chapter 6.3 following the case studies.

6 Case Studies-Application of the Results

Several of the questions raised from the results from the quantitative analysis are perhaps best approached by considering how the results are reflected in specific case studies. Each case study can provide several opportunities to test or validate a theory. In this study, baseline data used in the 146 treaties are expanded even further in five case studies to explain in greater detail the changes in the causal variables over time. These cases also consider causal variables across geographic subunits (sub-basin, national, etc) within a single basin, thereby allowing comparison across multiple units.

Considering specific basins at multiple temporal levels also allows for a better test of the posited effects that hydrologic variation has on the basin, with the impact filtered through the treaty. Hydrologic stress, or drought, is not necessarily a cause of conflict and a treaty does not necessarily mitigate conflict across all possible cases. A finding that conflict occurred in some basins without hydrologic stress will possibly confirm that there are many different potential causes outside of drought. Looking at a single basin and observing the variation in the degree of drought allows us to draw credible causal inference.

A large number of spatially and temporally diverse observations from a single basin also minimizes other variables and allows for better comparison. A common criticism of comparisons across basins is the difficulty in identifying variables outside the model being tested (Kahl, 2006; p. 62). That is, in a single-basin study the variables other than those that are considered in this study (drought, treaty mechanisms, and ‘power’) are closer to the ideal of zero variability. Our study across multiple basins using the standardized treaty results allows for the generalization of the findings and provides validity outside of a single basin.

6.1 Basin Selection Criteria

Case studies are used to examine the importance of and the vulnerability of failure of transboundary water allocation treaties in the future. Within the case studies, the importance of the seven mechanisms is explored to determine their role in managing different levels of hydrologic stress and if the relative mechanism importance coincides with the Literature Review and regression analysis. Selection of case studies was first based on the presence or absence of climate related complaints. Treaties that had climate complaints in the past were judged to merit further study since they perhaps provide more insight into the relationship between the reasons for filing a complaint and the presence/absence of a treaty mechanism. It also provides an opportunity to evaluate if these treaties have a higher likelihood of conflict reoccurring than those treaties that had no such inclinations in the past--due to their treaty design and the basin's projected changes in climate.

Within the 146 total treaties studied in the initial phases of this analysis, 20 treaties in 11 basins have climate complaints associated with them. Of the 20 treaties with climate-related complaints, 16 are water allocation treaties, and only two each concern hydropower and flooding. Basins with climate complaints associated with water quantity include: Nile, Ganges-Brahmaputra-Meghna, Douro, Helmand, Indus, Jordan, Colorado (combined with Rio Bravo/Rio Grande), Nelson-Saskatchwan, Columbia, Nestos, and Tigris-Euphrates. Climate-driven hydropower-related allocation complaints occurred in the Columbia and Nile, and flooding-related complaints occurring in the North American basins of the Columbia and Nelson-Saskatchewan.

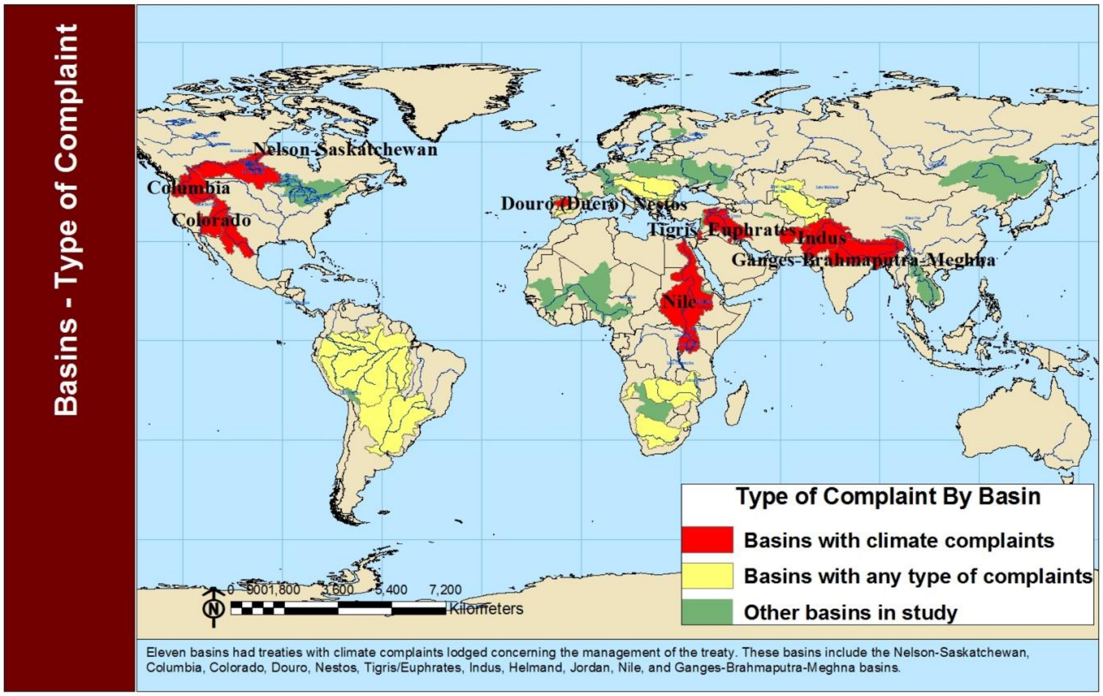

Figure 13 Basins according to type of climate complaints

All together, 85 climate-driven complaints or problems to deliver allocations were found. Of these, a majority (54 total complaints) are associated with five water quantity treaties that are more conflictive than the rest. Another cluster of 10 treaties are less-conflictive, where each only has one or two complaints. Based on the above historical data combined with the changes the basin is projected to undergo with climate change, five of the 12 basins with climate related complaints were chosen for further analysis as case studies. The five basins include the Nile, Tigris/Euphrates, Indus, Helmand, and Jordan with a total of seven treaties with climate complaints. A summary of the treaty drought, power, complaints, MLR, and Literature Review scores used in the analysis is shown in Table 21.

Table 21 Summary of treaties used as case studies.

	1950 Helmand	1960 Indus	1955 Jordan (Johnston)	1994 Jordan (Israel/Jordan)	1995 Jordan (PA/Israel)	1953 Nile	1987 Tigris-Euphrates
HDI Delta Between Riparians	93	7	34	36	83	102	28
FSI Delta Between Riparians	42	87	18	27	118	117	56
GDP Delta Between Riparians	85	32	18	24	27	46	53
Average of 3 Indices Delta Between Riparians	73	42	24	29	76	88	46
Treaty BAR--All Complaints	-1.4	-1.8	-1.7	-1.5	-1.8	-1.0	-1.4
Treaty BAR--Non-Climate Driven Complaints	-1.5	-1.8	-1.8	-1.2	-1.5		-1.5
Treaty BAR--Climate Driven Complaints	-1.0	-1.3	-1.0	-1.8	-2.0	-1.0	0.0
Number of Complaints	5	112	19	24	4	1	45
Number Climate Complaints	1	4	1	10	2	1	1
Drought Standard Deviation Since Treaty Was Signed	2.2	1.2	2.2	2.7	2.7	1.7	2.4
Average Drought Index (PDSI) Since Treaty Signed	-0.5	-0.5	-0.4	-1.0	-1.0	-1.4	-1.8
Drought Index - Change From Average During Complaint Years	-4.2	-0.6	-0.5	-1.5	-1.3	-0.4	0.2
Literature Review Unweighted Treaty Total	0.78	4.28	0.70	3.08	1.32	1.08	0.57
Model 1 Regression Unweighted	0.06	-0.15	0.05	-0.30	-0.06	0.14	-0.02
Model 2 Regression Unweighted	0.22	-0.60	-0.25	-0.91	-0.35	0.27	-0.31

The treaties and basins selected for further study did not have all of the data that would ideally be available. An ideal case study would have certain data prerequisites concerning both treaties (e.g. quantity of allocation and where and when the water is to be delivered) and the natural availability of water resources both in the past and future. This would enable us to define a critical level of water allocation that might be vulnerable and to estimate the risk of this level not being met. For example, the probability of failure to meet a treaty water allocation could be determined by using flow data combined with the agreed allocated water quantity for hydropower or other use (treaty flow), the agreed location, the time of allocation (e.g. "between October and March each year"), and a record of the climate-driven complaint or failure (event) (Zentner et al., 2008). As discussed previously, for most agreements there is a lack of this type of detail that limits our ability to determine whether streamflow data are available at the right location along the river and whether the variability it represents may be altered by an upstream dam or other use. Additionally, flow data itself if often limited even when the location is known. This data scarcity carries over into the case study analysis and the drought index is used to assess a value that corresponds to the real value of the agreed allocated water quantity for hydropower or other use (treaty flow). While this allows for a unified method of analyzing the probabilities of failure in the past and its change in the future in the widest sense, much of the location and time-specific analysis is not possible.

6.2 Basin Specific Analysis of Treaty Design and Future Hydrologic Stress

In each case study, a short history of the origination of the treaty is presented. The hydrology and political background is followed by a summary of the drought index and climate-related complaints where the general relationships between drought and the complaint are analyzed. The importance and influence of the treaty mechanisms for the management of each complaint is compared with the regression/Literature Review based strength/institutional resiliency scores. Finally, an outlook section discusses the projected changes in climate expected for the basin and the overall strengths and weaknesses of the treaty for managing those changes.

6.2.1 Nile River Basin

The Nile has ten riparian countries-Egypt, Sudan, Ethiopia, Uganda, Tanzania, Kenya, Democratic Republic of Congo, Rwanda, Burundi, and Eritrea. Three of the ten (Egypt, Sudan, and Ethiopia) are far more important than the remaining seven from the standpoint of Nile water hydrology and potential political conflict or cooperation over Nile water issues. The importance of the Nile, especially for Egypt and Sudan, likely cannot be overstated. Ninety-five percent of Egyptians live in the Nile Valley and depend on the river for virtually all of their fresh water. Egypt is probably more dependent than any other country in the world on freshwater that comes from outside its borders. The Nile is also crucial for Sudan; 77 percent of Sudan's fresh water comes from outside its borders, most of it via the Nile system (FAO Water, 2010). Increasingly, upstream nations have begun (or have plans) to depend on Nile waters for hydropower and agriculture production.

The treaty that is the focus of this case study is specific to Lake Victoria and the Owen Falls Nalubaale Dam in Uganda. The 1953 treaty, between the colonial United Kingdom and Egypt, provided for the participation of Egypt in the construction of the Owen Falls Dam, and the use of Lake Victoria as a storage reservoir of water for Egypt. Additionally, Egypt's financial contributions and the compensation for damage incurred as a result of the rising level of the lake is outlined. It was also stipulated that Egypt would continually have an engineer onsite to ensure that the interests of Egypt were taken into account (Mwesigye, 2006). Having an Egyptian engineer onsite was a likely influence regarding later joint decisions on treaty implementation, including release and utilization schedules. Uganda is mentioned in the treaty and it has management requirements, but it was represented by the UK and was thus not a signatory in 1953.

The 1953 Owen Falls case study treaty stands alone, but is shaped by the broader history of treaties and relations between Sudan and Egypt, and the other upstream riparians. In 1929, Britain signed the Nile Basin Treaty with Egypt, pledging on behalf of its colonies not to undertake any works to reduce the volume of the Nile. It stipulated, "no irrigation or power works or measures are to be constructed or taken on the River Nile or its tributaries, or on the lakes from which it flows in so far as all these are in the Sudan or in countries under British administration, which would entail prejudice to the interests of Egypt." In 1959, three years after Sudan's independence, the treaty was revised by Egypt and Sudan amending the 1929 agreement on the division of Nile. It gave 75 percent of the waters to Egypt (55.5 billion cubic meters (BCM)) and 25 percent to Sudan (18.5

BCM). The agreement refers to "full utilization" and "full control of the river," even though it involves only the two states. Egypt considers the 1959 treaty, as well as the 1953 treaty regarding Lake Victoria, binding on the other Nile Basin countries.

Table 22 Key features of the 1953 Nile Basin Treaty

Important Mechanisms for Climate Complaints	*Scale*
Primary Agreement (TFDD ID)	79
Signatory	Egypt, Uganda (via UK)
Treaty Description	Exchange of notes constituting an agreement between the government of the United Kingdom of Great Britain and Northern Ireland and the government of Egypt regarding the construction of the Owen Falls Dam in Uganda. Lake Victoria was to be used for the storage of additional water but would reduce flow to the Owen Falls Dam.
Date signed	1/5/1953
Years Enforced	55
Issue Type	Hydro-power/Hydro-electricity
Comments on Non-water Linkages	Egypt pays Uganda £980,000 (loss of hydroelectric power) and also flood compensation

Relations between Sudan-Egypt and the other upstream nations have been precarious due to this series of treaties, which are almost unanimously viewed as inequitable by the international community since they partitioned the whole of the Nile to Sudan and Egypt (Al-Raqahy, 1990; Cascao, 2008, 2009; Whittington, Wu, & Sadoff, 2005). According to McCaffrey (2007), there are no provisions for non-signatory nations to exploit Nile waters without Cairo's permission. Egypt's position is that any alteration of the existing treaty must be accomplished through the treaty protocols and with the consent of all parties. Egypt has defended its position by referencing its "natural and historic rights" and the "priority of appropriation," claiming that any efforts to minimize the treaty by its "involuntary signatories" can be considered an attack on "inviolable Egyptian rights" (McCaffrey, 2007).

6.2.1.1 Background

6.2.1.1.1 Hydrology

The Nile River stretches for over 4,000 miles and the basin covers 13 million square miles, making it slightly larger than India (Klare, 2001). The Nile flows from south to north and is formed by two major tributaries: the White Nile and Blue Nile. The Blue Nile has its source in the highlands of Ethiopia, by Lake Tana. The White Nile flows generally north through Uganda and into Sudan where it meets the Blue Nile. Egypt, Sudan, and Ethiopia account for 85 percent of the territory that constitutes the hydrologic boundaries of the basin. Sudan contains 63 percent of the basin, while Ethiopia has only 12 percent and Egypt 10 percent (TFDD, 2008).

The basin has a wide range of climatic environments that often blend together and can change suddenly spatially. There are three primary climatic classifications as defined by Köppen that make up the majority of the basin (FAO-SDRN Agrometeorology Group, 1997; TFDD, 2008; S. Yoffe et al., 2004). In the first climate region found primarily to the north, over 90 percent of Egypt and the majority of northern Sudan is classified as dry, with a desert climate and hot annual temperatures greater than 18 °C (Köppen classification of Dry, BWh). This climatic region includes about 36 percent of total area of the basin. The second region, encompassing central Sudan and portions of Eritrea and Ethiopia for a total of about 15 percent of the basin, is dry, semi arid grassland steppe with hot annual temperatures greater than 18 °C (KöppenKöppen classification of Dry, BSh). The third climate region of tropical isothermal monsoon with a short dry season and average temperatures greater than 18 °C (Köppen classification of Tropical Ami) is found primarily in southern Sudan, most of Uganda, and portions of northwest Ethiopia over a total of 19 percent of the basin.

Ethiopia's mountains are the major source of Nile water. Of the water reaching the Aswan Dam in a normal year, 86 percent originates in Ethiopia: 59 percent via the Blue Nile; 14 percent via the Bar/Akobo/Sobat; and 13 percent via the Tekeze/Atbara (Rushdi, 1990). While the Nile moves much less water than Africa's other major river systems such as the Congo, Niger, and Zambezi, demand for water in the Nile Basin is significantly higher than Africa's other river basins. The Nile's annual output is equal to only 14 percent of the Mississippi's annual discharge (Whittington, 2005 and author's calculations).

The hydrology for Lake Victoria is somewhat removed from the rest of the basin and is sensitive to local rainfall since most of its water comes not from upstream flows, but from rain that falls directly over the lake. For this reason, natural water level fluctuations from year to year are mostly dependent on seasonal changes in rainfall near the lake (NASA, 2010). Ground-truth data regarding the water budget are often not sufficient or readily available since the relevant countries do not make them public or are of questionable veracity. Local climatic conditions and catchment inflow combine with human management (via dam outflow) to control Lake Victoria's water balance.

6.2.1.1.2 Politics

Thomas Homer-Dixon has suggested that conflict is most probable when a downstream riparian is highly dependent on river water and is militarily and economically strong in comparison to upstream riparians (Homer-Dixon & Blitt, 1998). Egypt and Sudan and the rest of the upstream riparians fit this definition. Egypt depends on the Nile and is far stronger militarily, politically, and economically than any of the upstream nations including Sudan, Uganda, or Ethiopia.

The 1959 and other treaties discussed previously resulted in a virtual Egyptian and Sudanese monopoly of Nile water. Egypt and Sudan did not consult with or take Ethiopia's concerns into consideration during negotiations. According to McCaffrey (2007), Ethiopia "officially informed Egypt and other riparian states in 1956 and 1957 that it reserved its right to use Nile water for the benefit of its people." Over the years, Ethiopia has continued to object with variable intensity that the treaties between Sudan and Egypt and their other unilateral management decisions are about water that mostly originates in Ethiopia.

Although Egypt and Sudan agreed to the 1959 allocation of Nile water, Sudan remains uneasy about the outcome of the agreement. Some in Sudan believe that the 75 percent to 25 percent division of water was inherently unfair, while others are concerned that exclusion of the eight other riparians from the agreement has complicated Sudan's relations with those riparians (Mukhtar, 2010).

In 1999, nine riparians (with Eritrea in observer status) created the Nile Basin Initiative (NBI), a partnership to jointly develop the basin using the substantial socioeconomic benefits from emergent international donors that are encouraged by cooperation. From the beginning, the NBI was meant to eventually develop into a Nile Basin Commission (NBC) with greater authority to manage the Nile waters (NBI, 2010).

The next planned step in this development is the ratification of the Cooperative Framework Agreement (CFA), which provides the legal and institutional framework through a robust and binding sharing agreement (Al-Raqahy, 1990). The CFA requires ratification by six of the nine member states for it to be binding and, as of 26 July 2010, five nations (Ethiopia, Kenya, Rwanda, Tanzania and Uganda) have signed the CFA indicating their intent of ratification (The Current Analyst, 2010). The CFA does not include volumetric water allocations, but rather uses principles of international water law to determine rights. However, Egypt and Sudan are not willing to sign an agreement that does not explicitly recognize their 'historical and acquired rights' to the Nile waters under the earlier agreements. Consequently, they have been unwilling to sign and have been delaying the development of the agreement. With only one more signature required to push the CFA into the ratification stage, Egypt and Sudan are exerting economic and diplomatic pressure, specifically on the unsigned nations of Burundi and Democratic Republic of Congo, to influence their decision and prevent the treaty from coming into force (Global Arab Network, 2010; People's Daily, 2010; Zawya, 2010). Even after the CFA is signed, the six signatory nations are not bound by the agreement and are not obligated to ratify it. The ratification process itself could take several years and is likely to be contentious.

Other political changes that will likely influence Nile water allocations include the possible emergence of an independent South Sudan in 2011, which would impact any new agreement as well as the development of several projects, such as the Jonglei Canal. The Jonglei Canal was intended to move a substantial amount of White Nile water around the worlds' largest freshwater swamp (the Sudd) in southern Sudan (McCaffrey, 2007). By reducing evaporation loss in the Sudd, the 224 mile long canal would make available almost five BCM of water, divided equally between Sudan and Egypt (J. V. Sutcliffe, 1984). Most southern Sudanese believe the project was only intended to benefit the north, emphasizing the underlying pastoralists versus settler tension. Attacks by the Sudan People's Liberation Army (SPLA) on the the project headquarters in 1984 stopped work after 70 percent of the canal had been dug (Abdel-Ghani-Sa'oudi, 2001). The Government of South Sudan has been non-committal with regards to continuing construction of the Jonglei Canal, but renewal of the excavation of the canal will almost certainly require the approval of a new southern government (Klare, 2001; Sudan Tribune, 2009).

6.2.1.2 Complaint and Drought Index Summary

Since 1954, discharge at Lake Victoria has been controlled by the Ugandan Jinja Owen Falls Nalubaale Dam system located at the only lake outlet in Jinja, where it forms the Victoria Nile. An "Agreed Curve" was developed for the operation of Nalubaale Dam (agreed upon at the same time as the 1953 agreement and revised in 1964) to dictate how much water should be released from Lake Victoria from the dam's turbines and sluices, based on a 10-day basis of the measurements of the lake water level (NASA, 2010). After the lake level rose about 2.5 m in 1961–1964, the "Agreed Curve" was revised based on models of power demand and Egypt's agriculture requirements (J. V. Sutcliffe & Petersen, 2007).

The 1953 treaty has only one recorded complaint, which is related to decreased flows and drought conditions. In March 2006, the following event with a -1 BAR scale occurred:

> “Conflict has mounted between Nile Basin states due to widespread drought conditions resulting from low regional rainfall. Ugandan officials have reduced the flow from Nile headwaters to allow reservoirs to refill. Water shortages have created conflict between countries seeking greater access to the Nile and its tributaries for planned irrigation and hydroelectric projects” (TFDD, 2008).

Since the treaty was signed and until the period of interest for this study when the complaint was filed in 2006, the Nalubaale Dam most often operated according to the “Agreed Curve” and kept water levels near the stipulated levels at the Jinja gauge. While not explicitly stated in the TFDD record, the above event likely relates to sharp decreases in Lake Victoria’s water level over the 2002-2006 time period. For several years leading up to the event, the region had been in severe drought and lake water levels dropped more than 1.1 m below the 10-year average (Figure 14). Prior to this time, any departures from the “Agreed Curve” were small and were followed by compensatory releases (J. V. Sutcliffe & Petersen, 2007).

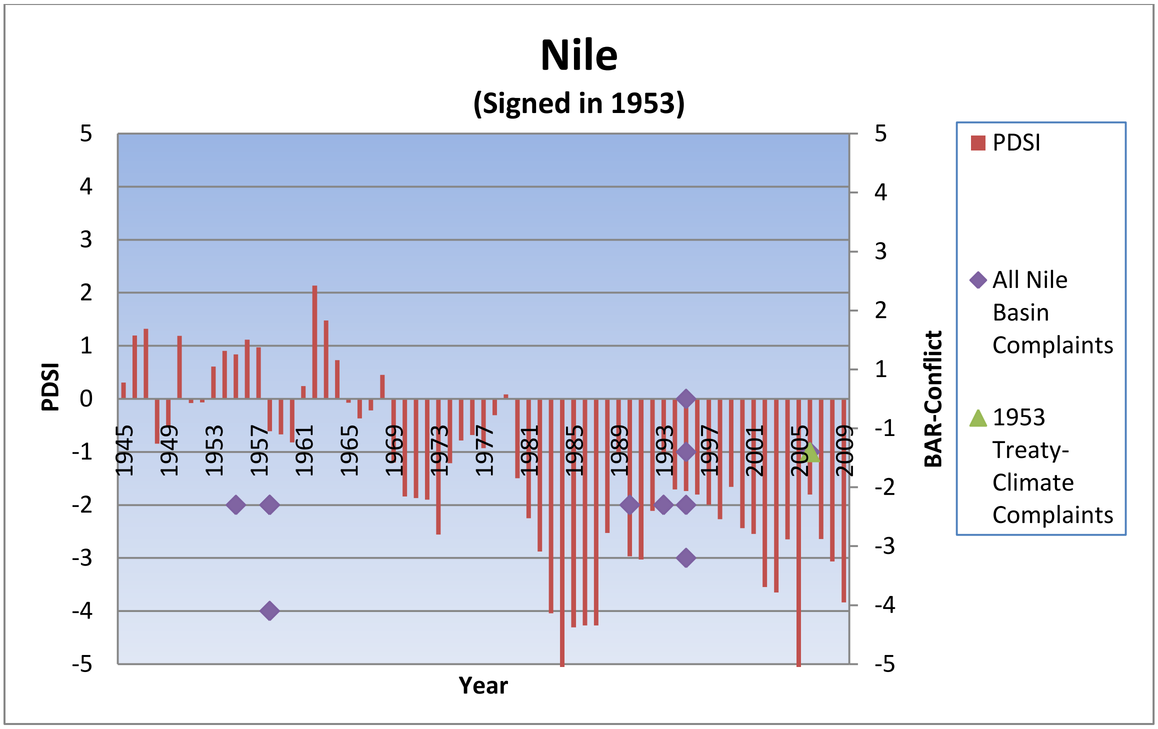

Figure 14 Nile Basin complaints and drought index (PDSI) history. The drought in 2005 was partially responsible for lower Lake Victoria levels, prompting the climate complaint.

Fluctuations in climate certainly played a part in the 2006 event, which came just after a severe four year period of drought, culminating in an estimated PDSI of -5.3 in 2005, which was the second most severe drought index recorded for the basin since 1945. The drought standard deviation (1.7) was similar to the average for all basins in the study (1.8). The average drought index since the treaty was signed (-1.4) was slightly more severe than the average for all treaties (-0.9). For all events relating to all three treaties in the basin, the average PDSI was 0.4 lower than during non-event years.

While much of the decrease in water levels may have been drought related, Uganda's management of the releases from the Owen Falls Dam almost certainly had a role as well. The release schedule may have been complicated by the 1999 construction of a second hydropower facility, the Kiira Dam (Swenson & Wahr, 2009). According to a February 2006 report from Daniel Kull, a hydrologist with the UN's International Strategy for

Disaster Reduction in Nairobi, had the dams operated according to the "Agreed Curve" since the new dam was constructed, lake levels would have been 45 percent higher (Kull, 2006). In other words, the drought would have caused only 45 percent of the water loss actually seen and the remaining 55 percent of the decrease was due to over-releases from the Owen Falls Dams. This indicates that Uganda was not following the 50-year-old international agreement designed to protect the lake's waters. Ugandan officials objected to and denied Kull's report, but other studies came to the same conclusion that an increase in releases, to varying degrees, played a part in decreased lake levels. Mangeni (2006) concluded that the main cause of the lake level decline must have been the operation of the dams and the increase in releases. Swenson (2009) references recently released measured estimates of dam discharge that exceeded that specified by the "Agreed Curve" by 20–30 percent. Still others, such as Mubiru (2006), argued that lower levels were due to drought conditions, and that the over-releases were an insignificant proportion of losses by lake evaporation. Regardless of cause, trade and tourism suffered as commercial ships struggled to navigate shallow waters and to find docking stations. Over 30 million people in Kenya, Uganda, and Tanzania that depend on Lake Victoria for their livelihoods were agitated over supposed water sharing violations between the countries (Pierce, 2006).

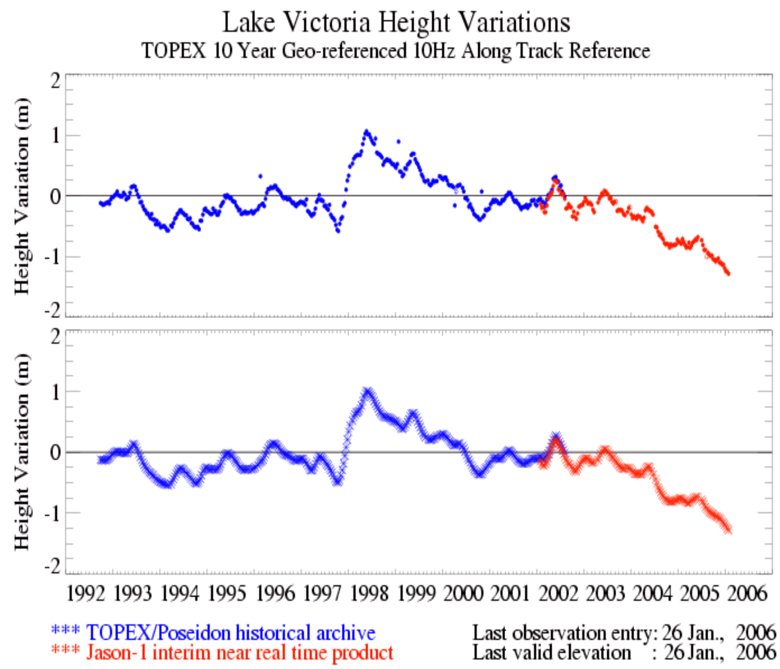

Figure 15. Lake Victoria water level fluctuations. A report from a UN hydrologist indicated that Uganda, and not drought, was primarily responsible for the drop in lake levels (USDA Foreign Agricultural Service, 2010).

6.2.1.3 <u>Treaty Influence on Water Management and Complaint</u>

The 2006 complaint was not between and does not directly relate to any interaction between Uganda and Egypt, the key participants in the 1953 treaty. There is no record of Egypt objecting to Uganda's operation of the dam and their relations apparently remained the same. Only Uganda's relationship with other nations bordering the lake was negatively impacted. For the signatories of the treaty, either there was no issue worthy of complaint or the treaty functioned to prevent or mitigate a negative reaction. Two years after the complaint, in 2008, Uganda stopped supplying the Egyptian Engineer on site with data, but this occurrence is likely unrelated to the event (Sydney Morning Herald, 2010).

When considering the treaty mechanisms, the 1953 treaty appears strong with a 0.14 score (compared to a -0.05 average for all treaties) according to the Model 1 regression analysis that has a positive emphasis on *scale*, and a negative emphasis on *communications*, *integrativeness*, and *specificity*. From the Literature Review, which emphasizes the number of mechanism components, the treaty is relatively weak, with a score of 1.08 compared to 1.84 for all treaties. The treaty is especially lacking in *flexibility* and *specificity* components. Some scores, including *specificity* and *flexibility*, would be improved if subsequent, more functional additions to the treaty from the joint engineering committee had been included in the analysis. For example, the creation and revision of the "Agreed Curve" and the application of compensatory releases were not included in the original treaty, but instead were part of the treaty implementation and thus were not included in the mechanism calculations.

Lake Victoria flow management issues associated with the treaty have been handled between Uganda and Egypt, without consulting other nations, despite the impact that such decisions might have on the other riparians. Part of this may be due to a lack of effective communication mechanisms, treaty or otherwise, specific to and inclusive of other nations bordering Lake Victoria. For the Basin as a whole, until the NBI came into being in 1999 there was no mechanism for Egypt and Uganda to communicate with the other Nile Riparians on a regular basis regarding any type of water issues. Within the NBI, other Nile Basin states have a mechanism to meet together regularly and can more effectively communicate and coordinate on projects (NBI, 2010). However, the management of Lake Victoria has not yet permeated into the NBI discussions. In the case of this event, the NBI communications mechanism was not used to share flow and release data and the treaty information relative to the "Agreed Curve" was not shared outside of the two signatories of the 1953 treaty. The effectiveness of the NBI is questionable since countries, for the most part, continue to proceed with projects without reference to other members. Egypt, Sudan, and Ethiopia, in particular, ignore the other riparians. The NBI has still not provided an overall plan for managing water in the basin, and Egypt and Uganda continue to manage the Lake Victoria water levels according to the treaty and independent of the other riparians.

As evidenced by the above discussion, the complaint can be most readily attributed to the lack of a key component in the *scale* mechanism; namely from its limited, bilateral nature that does not include or recognize all relevant nations. One component of the *scale* mechanism is the inclusion of interests of non-signatory riparians and reference to the rights and interests of non-signatory states. Kameri-Mbote (2007) notes that not only are other nations under-represented in the Nile agreements, but there remains a need to include stakeholders beyond the national governments. By addressing that aspect of the *scale* mechanism, local users would be able to influence the distribution of benefits governed by interstate agreements while continuing to "buy in" to basin-wide initiatives, reducing the chances of conflict. Practical means to enhance *communications* and *enforcement* between Uganda and the other lake-sharing nations would likely have been addressed by a better *scale* strength as well, allowing for more transparent data and easier recognition and resolution of the non-compliance. The need to fully include all interested parties in the *scale* mechanism, as is attempted in some multilateral treaties, is often achieved in many other basins by several, overlapping bilateral treaties on the same issue. However, in this case Lake Victoria and the White Nile Basin lack additional treaties that together could have served as an adequate medium for positive interaction.

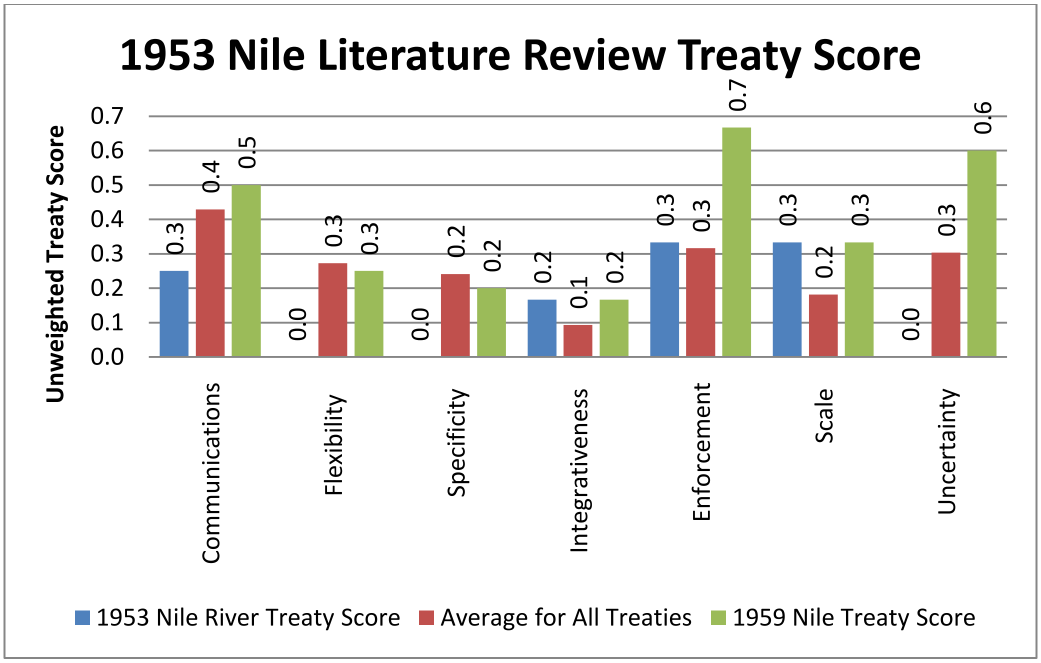

Figure 16 Nile Basin scores according to the literature-review based analysis. The 1953 Nile Treaty is weak, with only minimal mechanisms to manage the limited scope of the treaty.

Scale is calculated as the most important mechanism by both of the regression analysis models that incorporate data from all treaties in the study. Specific to the 1953 treaty, *scale* has a relatively high score and would apparently be a positive factor in the treaty application. However, the *scale* mechanism is made of five components and one key component (the inclusion of all non-signatory signatory riparians) is missing in the treaty. Without a good *scale* mechanism that in some way includes all parties, the other six mechanism components, no matter how strong, would not have been applied towards this complaint. Also of key importance to this complaint, and the second most important component overall according to one regression model, is communication. Although not explicitly stated in the treaty, efficient communication networks were established between Uganda and Egypt. As a positive impact, Egyptian engineers placed on site at the Owen Falls Dam likely enhanced *communications* and may have helped prevent Egypt from filing a complaint since they were aware of both the water levels and the release schedule at the dam. However, the lack of public information on dam releases, dam operations and river flows made it difficult for the other Lake Victoria countries to judge the impact of the hydroelectric projects on the Victoria Nile.

Another consideration is the impact that the strengths and weaknesses of the 1959 agreement had on the 1953 treaty in general and on the 2006 complaint specifically. The problem of scale also is evident and of primary importance in the 1959 Nile Basin Treaty since no riparians other than Egypt and Sudan are explicitly considered.[28] Egypt's exclusion of other nations certainly did not provide another means for communication and may have helped foster an unwillingness to share lake data. As a positive influence on communication, the 1959 treaty established a Permanent Joint Technical Committee, that provided oversight with engineers in both Sudan and Egypt, which may act as a conduit for transferring Lake Victoria information from Uganda to Sudan via Egypt, helping to mitigate any complaints from Sudan. The 1959 treaty lacks a provision for amendment and a mechanism for solving differences which could have been useful in the 2006 complaint situation if for no other reason than to promote peaceful solutions to regional water problems. Finally, the treaty that involves the majority of the Nile Basin water provides no agreed regimen governing Nile usage for all riparians. As a result, the 1959 treaty acts as an impediment that increases the difficulty and lowers the potential for an integrated plan that could have prevented the 2006 complaint by optimizing and jointly developing the Nile waters.

6.2.1.4 Analysis of All Nile Basin Complaints

Nile Basin complaints relative to all treaties in this study, including those outside of the 1953 treaty, were reviewed to determine the issues and causes of the complaint. As part

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[28] The 1959 Treaty created the Permanent Joint Technical Commission for dispute resolution between Sudan and Egypt. It also has a mission to review claims made by other riparians, but the commission has never done so and thus remains largely ineffective as a dispute resolution mechanism (Cooley, 2009). Given the large number of objections from upstream riparians over the 1959 treaty, the lack of claim-review indicates that either other upstream nations view the commission as biased or that the commission chooses to not review the claims.

of the review, each complaint was compared against the seven treaty mechanisms to determine which mechanism is of primary and secondary importance to managing the complaint (due to either the presence or absence of a mechanism in a treaty). For example, in the following Nile event from July 1995, *integrativeness* was deemed the primary mechanism since land and military disputes were tied to the Nile 1959 treaty:

> "Sudan Interior Minister Brigadier General Khayr has stated that any attack by Egyptian forces on the Sudanese police force in Hala'ib triangle will be considered a clear violation of border agreements between the countries. He added that if such an attack takes place, Sudan will be free of its obligations to other agreements between the two countries, including an agreement on sharing Nile waters" (TFDD, 2008).

When considering all basin complaints, *integrativeness* was the mechanism most often relevant. Of the 12 total events for three Nile treaties (1929, 1953, and 1959), *integrativeness* was a primary or secondary factor in five complaints. *Communications* (four) and *enforcement* (three) were also important. For the *integrativeness* mechanism tally, complaints where any factors outside of those specific to the scope of the treaty were primary to the complaint and were included in the total. This broadened the scope to include not only sectors typically associated with water treaties, such as hydropower, flooding, or fisheries, but also all types of politics and relations. In effect, the *integrativeness* tally represents how often factors with secondary focus to water quantity impact complaints.

6.2.1.5 Outlook and Projected Impact on Water Resources From Climate Change

There are numerous studies on the impacts of climate change on the Nile, but these findings are often conflictive and very little consensus has been reached on how changes in precipitation and evaporation will influence runoff. Some studies and simulations indicate that the Nile River is expected to experience increased streamflow. Beyene et al. (2010) predicts an increase in runoff from 2010-2039, before a steady decline through the end of the century, as a result of both precipitation decline and increased evaporation. Nohara (2006) predicts an annual increase of 12.7 percent due to increase in runoff in watershed regions. Other studies indicate minimal changes. Elshamy (2009) found that for the Blue Nile, changes in total annual precipitation range between −15 percent to +14 percent, but more models report reductions (10) than those reporting increases (7). Also for the Blue Nile, Kim (2008) predicts that the area is likely to become wetter and warmer in the 2050s, resulting in a lower occurrence of Nile low-flow periods and a decrease in drought frequency. Bates et al. (2008) summarizes this lack of consensus by stating that for the Nile basin, “there is no clear indication of how Nile River flow would be affected by climate change, because of uncertainty in projected rainfall patterns in the basin and the influence of complex water management and water governance structures.”

Qualitative values capturing present and projected water variability for the portion of the Nile in each country are summarized in Table 24. As discussed in Chapter 4.3.4, these assessments are based on data provided by Strzepek. Strzpek calculated a coefficient of variation (CV) for precipitation and runoff, which is defined as the standard deviation divided by the mean of all annual values within a given time period. The dry, middle, and wet scenarios are based on the two extreme and the median scenarios of the 22 different general circulation models (GCMs) that were used in the climate models for the Fourth Assessment Report of the IPCC (IPCC, 2007). Using data from these three GCMs, a CV for ‘precipitation’ and ‘runoff’ summarizing the time periods of 2030 and 2050 were used to categorize variability for each country within the basin as low, medium, or high. A historic baseline of variability was also calculated.

For the countries party to the 1953 Treaty (Uganda and Egypt), projections indicate little to no increase in variability through 2030, with Uganda having a high level of variability in 2050 according the dry scenario. Of all the countries in the basin, none are projected to have an increase in variability by 2030 and only four (Sudan, Uganda, Central African Republic, and Democratic Republic of Congo) are projected to have increased variability by 2050. These four nations are not primary contributors to the basin’s water. Despite the seemingly rosy picture, there is likely to be increased evaporation in downstream nations like Egypt from higher temperatures that perhaps offsets the increased projected precipitation in upstream nations like Ethiopia. In this scenario, the upstream nations' potential resources would increase while downstream access could remain the same or decrease.

Table 23: Modeled runoff variability using projected changes in climate change under certain scenarios for the riparians of the Nile.

		Future Variability Change Class					
Riparian	Present Variability Class	2030-Dry	2030-Middle	2030-Wet	2050-Dry	2050-Middle	2050-Wet
Burundi	Low	Low	Low	Low	Low	Low	Medium
Central African Republic	Low	Moderate	Low	Low	High	High	Medium
Egypt	Moderate	Low	Low	Low	Low	Low	High
Eritrea	Low	Low	Low	Low	Low	Low	High
Ethiopia	Low	Low	Low	Low	Low	Low	Low
Kenya	Moderate	Low	Moderate	Low	Low	Low	Medium
Rwanda	Moderate	Low	Low	Low	Low	Low	Medium
Sudan	Low	Low	Low	Low	Moderate	Low	Medium
Tanzania	Low	Low	High	Low	Low	Low	Medium
Uganda	Low	Low	High	Low	Low	Low	Medium
Democratic Republic of Congo	Low	Moderate	Low	High	Low	Moderate	Medium

The 1953 Treaty has a strong regression score and only one incidence of climate-related conflict, indicating that the treaty is capable of managing the projected minimal changes in water variability and overall resources associated with climate change. For the basin as a whole, the 1959 treaty is theoretically strong and efficient for the nations that are party to it, but it is hampered by a lack of key *scale* components, especially the inclusion of all relevant nations. It is increasingly likely that the utility of existing treaties on the Nile may need to be reconsidered since not all major stakeholders are included. The Nile Basin countries have moved towards this and agreed to unite in common pursuit of sustainable development and management of the Nile by establishing the NBI, and this is likely to lead to a CFA with allocations, or at least principles, that will be in opposition to the existing 1959 agreement. For the CFA to be ratified and practically applied without conflict, existing agreements will likely need to be altered. Additionally, management of Lake Victoria and the 1953 agreement may be incorporated into the CFA and eventually into the larger Nile Basin Organization that manages all Nile waters. If this process continues to incorporate the “equitable use” principles, previously under-represented stakeholders will be able to provide input into flow supervision and development projects along the river basin, which should help to mitigate events such as the 2006 complaint.

A key lesson in this case study is the interconnectedness of treaties in a basin and the need for the recognition and inclusion of all relevant nations. More than any other case study, the Nile sharing agreements seem to be in a state of flux due to both upstream demands for more equitable sharing and downstream political changes, which complicates the assessment of their resiliency under climate change scenarios. Despite complications from Egypt’s seeming intransigence and Sudan’s political fluidity, there is potential for the revision of existing treaties and application of new ones since all nine NBI countries seem to agree that a peaceful solution would allow international funds for development to be released once a legal framework is in place. Also, at least in the power sector, the interests of Egypt, Ethiopia, and the Sudan appear compatible, with some potential to increase *integrativeness*. However, even with these benefits, as per capita water availability decreases with continued population surges, political and national security interests may take precedence over the practical results and international ‘carrots’ that come from increased cooperation. In particular, Egypt may feel its agriculture, industrial, and political interests (from projects such as Toshka and El Salaam) may be threatened by any agreement and water-development projects that expand Nile water access to Kenya, Ethiopia, and Tanzania. Sudan’s possible southern independence and the availability of funding for upstream projects, especially since donor support for the NBI is set to expire in 2012, will be key issues in the near term that will shape the outcome of the NBI and the survival of existing arrangements.

6.2.2 Helmand River Basin

The Helmand River Basin covers most of the southwest portion of Afghanistan and a small portion of southeast Iran. The river is important to farmers and for hydroelectric power production in Afghanistan, and is also important to farmers in Iran's southeastern Sistan and Baluchistan province. The Helmand is one of five major river systems in Afghanistan, all of which have some transboundary component. Afghanistan is upstream and the source of the Amu Darya, Harirud, Helmand, and Kabul Rivers which are shared with Turkmenistan, Uzbekistan, Tajikistan, Iran, and Pakistan. Water availability and consumption patterns vary significantly among these rivers and basins. For instance, the Amu Darya Basin covers about 14 percent of Afghanistan yet holds about 60 percent of the country's water flow, whereas the Helmand Basin covers 40 percent of the land area and holds only 11 percent of the water flow (Bedunah, 2006).

While international water rights over these rivers has been contentious for over 100 years, Afghanistan is typically ignored in these disputes and most existing water allocations (such as those governing the Amu Darya Basin) reflect regional consideration of Afghanistan as a producer of water, but with no recognized claim to use it (Horsman, 2008). Only the Helmand River has a 1973 agreement that includes allocations for all basin riparians, though even that agreement has not been fully implemented. The other Afghanistan transboundary rivers that have regional agreements governing their use do not include Afghanistan.

The treaty that is the focus of this case study is a 1950 US-brokered agreement between Iran and Afghanistan to create the Helmand River Delta Commission (HRDC), with a mission to collect and study available data to be used as a basis for a future allocation agreement. The Helmand is loosely governed by a 1973 agreement between Iran and Afghanistan, which has allocations that were paved by the 1950 agreement.

Table 24 Key features of the 1950 Helmand Treaty

Important Mechanisms for Climate Complaints	*Integrativeness*, as well as *communications* and *enforcement*
Primary Agreement (TFDD ID)	72
Signatory	Iran, Afghanistan
Treaty Description	Terms of reference of the Helmand River Delta Commission and an interpretive statement between Afghanistan and Iran. The Helmand River Delta Commission was created and given the task to measure and divide the river flows between the two signatories.
Date signed	9/7/1950
Years Enforced	58
Issue Type	Water Quantity
Text of Water Allocations	Initially determined by commission; finalized in 1973 Treaty

The 1950 treaty resulted in the establishment of the HRDC, which was intended only as a fact-finding and advisory body. The commission was created to provide a baseline recommendation for a future agreement that determines how the countries allocate water for hydropower and other requirements. Sections *c* and *d* in the functions section of the agreement summarize the purpose and limited scope of the treaty.

- c. The Commission shall recommend the technical methods by which the share of the water of the Helmand River to which Iran may be entitled, pursuant to the terms of such mutual accord as may be reached, may be allocated to Iran at or below Band-i-Kamal Khan.
- d. The Commission shall present its findings and recommendations to the Governments of Iran and Afghanistan. The findings and recommendations of the Commission shall be advisory only.

The 1950 treaty does not bind the nations to specific allocations or any further action beyond the committee. The agreement did lead to the creation of the neutral HRDC comprised of representatives from Canada, Chile, and the United States. In 1951, the HRDC provided a recommendation of 22 m^3/s allocated to Iran that was not approved by the Iranian Government, who wanted a greater share of the Helmand's waters. However, the HRDC recommendation proved its utility by providing baseline data and a starting point for the 13 March 1973 Helmand River Water Treaty (Adle, 2005). The 1973 treaty increased the Iranian share to 26 m^3/s by permitting Iran to purchase another 4 m^3/s during nondrought years.

For this study, the 1950 treaty contents are used for analysis; but for practical application towards understanding complaints, both the 1950 and 1973 treaties need to be considered together. The 1973 treaty is the only formalized allocation arrangement for the basin and any recent conflict between the nations over Helmand water is typically channeled to and refers to the 1973 treaty. However, whether or not the treaty has been ratified remains unclear. The treaty was most certainly signed by both countries in 1973 by Iranian Prime Minister Amir Abbas Hoveida and Afghan Prime Minister Mohammad Musa Shafiq. A coup d'etat in Afghanistan that same year delayed implementation of the treaty (Adle, 2005). Some scholars such as Ettehad (2009), Abidi (1977), and Adle (2005) assert that the treaty was ratified in either 1973 or in 1977 by a new regime in Afghanistan. In a personal communication with the author, Mr. Tawab Assifi, who was an Afghan government advisor during the treaty negotiations, indicated that the treaty was signed and approved by the Afghan Government, President Daoud, and King Zahir Shah, then ratified by the then Parliament of Afghanistan.[29] Others such as Carpenter (2008), Mojtahed-Zadeh (2009), and Favre (2004) indicate that the treaty remains unratified.

Regardless of ratification status, the 1973 agreement was never fully implemented due to instability that peaked with events that occurred in 1979: the Soviet invasion of Afghanistan and the Iranian revolution. Neither country has abided by the treaty parameters, with Afghanistan often failing to provide the minimum flows and Iran not compensating Afghanistan for releases beyond the 22 m^3/s. Nevertheless, the 1973 quota has become the cornerstone for disagreement and even now Iran's discussions with the Karzai government, which have been inconclusive to date, are generally under the framework of the 1973 agreement (Deghan & Palmer-Moloney, 2009). The ongoing disagreement between Afghanistan and Iran over the suitability and applicability of the

[29] Mr. Assifi heads the Assisting Afghanistan to Revitalize Irrigated Agriculture organization, with emphasis on the Helmand region. Email communication on 3 October 2010.

1973 quota as the basis for river and conflict management perhaps best serves as an illustration of either ineffective implementation or the lack of a robust agreement, but also gives this case study an opportunity to examine the relationship between treaty influence and the recorded complaints.[30] For these reasons, in this study the 1950 Treaty regression scores are used as a proxy for all Helmand treaties when discussing the effectiveness of existing agreements towards managing conflict, even for those events

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[30] Extensive research was conducted in an effort to locate the 1973 treaty text and detailed findings from the HRDC. Several personnel from the US Department of State, Government of the Islamic Republic of Afghanistan, and the US Department of Defense were contacted, which eventually produced a copy of the 1973 treaty text, as well as numerous other relevant documents. Dr. Jean Palmer-Maloney at the US Army Corps of Engineers graciously provided many of these documents from the archives of the Covington and Burling Law Firm, which represented Iran's interests in the 1950s during negotiations with Afghanistan. These documents often refer to the border delineation in the late 1800's, illustrating the historical nature of conflict over both the land and water allocations. An overview of reviewed documents related to Iran/Afghanistan treaties/agreements on Helmand River water includes:

1. Treaty of Peace between Great Britain and Persia--4 March 1857
2. Goldsmid's Arbitral Opinion, 1872
3. Award of Arbitration--McMahon, 10 April 1905
4. Letter of R. Cline, British Legation, Tehran, 09 August 1929 to Ministry of Foreign Affairs, Tehran--re: last sentence of Goldsmid's award
5. Temporary agreement for Distribution of Water, 29 December 1938
6. Translation of undated Cablegram from Tehran
7. Memorandum (Seal of British Legation, Tehran) undated
8. Translation of Speech made by Mr. Monsef. Deputy of Parliament, 16 May 1947
9. Translation of speech made by Ministry of Foreign Affairs before the 'Majlis' on 17 May 1947
10. Letter to Minister of War from the Governor General of Baluchestan 22 March 1949
11. Memorandum on Goldsmid Report by A. Marchant
12. Memorandum, 18 Jan 1950, Historical Note on Goldsmid and McMahon Arbitration and Boundary Commissions and Subsequent Negotiations, by A. Marchant

outside of the treaties limited scope. Discussion of the 1973 treaty mechanisms is also included, but is limited by sparse treaty data.[31]

6.2.2.1 Background – Helmand

6.2.2.1.1 Hydrology

The Helmand Basin has the most area and contains Afghanistan's longest river, with the Helmand River running for 1,150 km. The Helmand River crosses the Dasht-e-Margow desert ("desert of death", likely named for the flat and waterless terrain) in Afghanistan before it reaches a region of seasonal lakes in the Sistan depression at the Afghan-Iranian border (Whitney, 2006). The Helmand River drains large portions of the southern half of the country, from the Sia Koh Mountains in Herat Province to the eastern mountains in Paktia Province and the Parwan Mountains northwest of Kabul, and finally to the Sistan depression between Iran and Afghanistan (Williams-Sether, 2008). Sistan is an 18,000 square kilometer depression within the lower Helmand Basin. It contains the large delta of the Helmand River and a series of shallow, semi-connected playas, wetlands, lakes, and lagoons at the western edge of the basin (USACE, 2010). There are several other small streams that contribute to the Sistan system, but "the combined discharge of all these sources (before irrigation diversion) is less than 20 percent of that contributed by the Helmand River" (Whitney, 2006). In the northern section of the Sistan, the Hamun Lakes form part of an almost 5,000 km^2 shallow wetlands system (Ettehad, 2009). Sistan is located in the easternmost portion of the Iranian highlands, but most of it falls politically under Afghanistan.

The exact flows and water resources in this basin is difficult to ascertain due to a lack of hydrological data. Monitoring in Afghanistan ceased after the Soviet invasion in 1979 and is only now in the process of being reestablished. Afghanistan had a modern stream-

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[31] Dr. Amin Tarzi at the Marine Corps University provided a copy of the treaty in Persian. Dr. Mehdi Mirzaee at Oregon State University kindly provided translation of the key points. A more detailed description of each article is provided by Abidi (1977).

flow gauge network of about 160 gauges in the late 1960's, but after 30 years of neglect the network was not operable until 2005 when rehabilitation began with three stations regaining operability (USACE, 2010). A summary of estimated flows parsed together from multiple studies indicates that the Helmand has a discharge of about 9.3 BCM/year, providing about four percent of Afghanistan's total water supply (Carpenter, 2008; Ette-had, 2009; Horsman, 2008; Wegerich, 2008; Whitney, 2006). In a normal hydrological year, the Helmand River flows at its fullest between March and June and provides about 80 percent of the waters that empty into the Sistan depression (Whitney, 2006). However, the Helmand has experienced dramatic fluctuations in flow in recent years.

The 400 km Arghandab River is the largest tributary to the Helmand River. The 320 km Tarnak River is the main tributary of the Arghandab River and, though not as long as the Arghandab, generally contributes more water to the Helmand (Carpenter, 2008). The management of a number of hydroelectric dams, including the Kajakai Dam, is complicated by extreme seasonal fluctuations in streamflow. Generally, the basin receives most of its rainfall in the four months of winter with almost no storage accumulation from infrequent rainfall the rest of the year. The rainfall pattern varies geographically, with an annual precipitation average about 75 millimeters per year over most of the southwest portion of the basin, and two to three times that in the mountains north of Herat and in the eastern Helmand Basin at Kandahar (Whitney, 2006; Carpenter, 2008).

Of the four primary climatic environments as defined by Köppen that make up the majority of the Helmand basin, three are of the dry climate zone type (FAO-SDRN Agrometeorology Group, 1997; TFDD, 2008; S. Yoffe et al., 2004). A dry desert climate with hot annual temperatures greater than 18 °C (Köppen classification of Dry, BWh) is found in about 34 percent of total area of the basin, mostly in southwest portion of Afghanistan and in Iran. A dry desert climate with cool temperatures typical of middle latitude deserts (Köppen classification of Dry, BWk) is found in 22 percent of the basin. A dry semi arid steppe with cool temperatures typical of middle latitude deserts (Köppen classification of Dry, BSk) is found in 17 percent of the basin. Towards the Hindu Kush mountains in the northeast portion of the basin, cold climate zones with a snowy climate, and either hot, warm, or short cool summers (Köppen classification of Cold, Da/Db/Dc) make up the majority of the remaining climate types, with over 25 percent of the basin.

The Helmand river basin has the highest amount of irrigation from groundwater sources in Afghanistan. Increased use of groundwater supplies has caused groundwater levels to drop in some areas, jeopardizing traditional spring and karez-fed supplies (USACE, 2010).

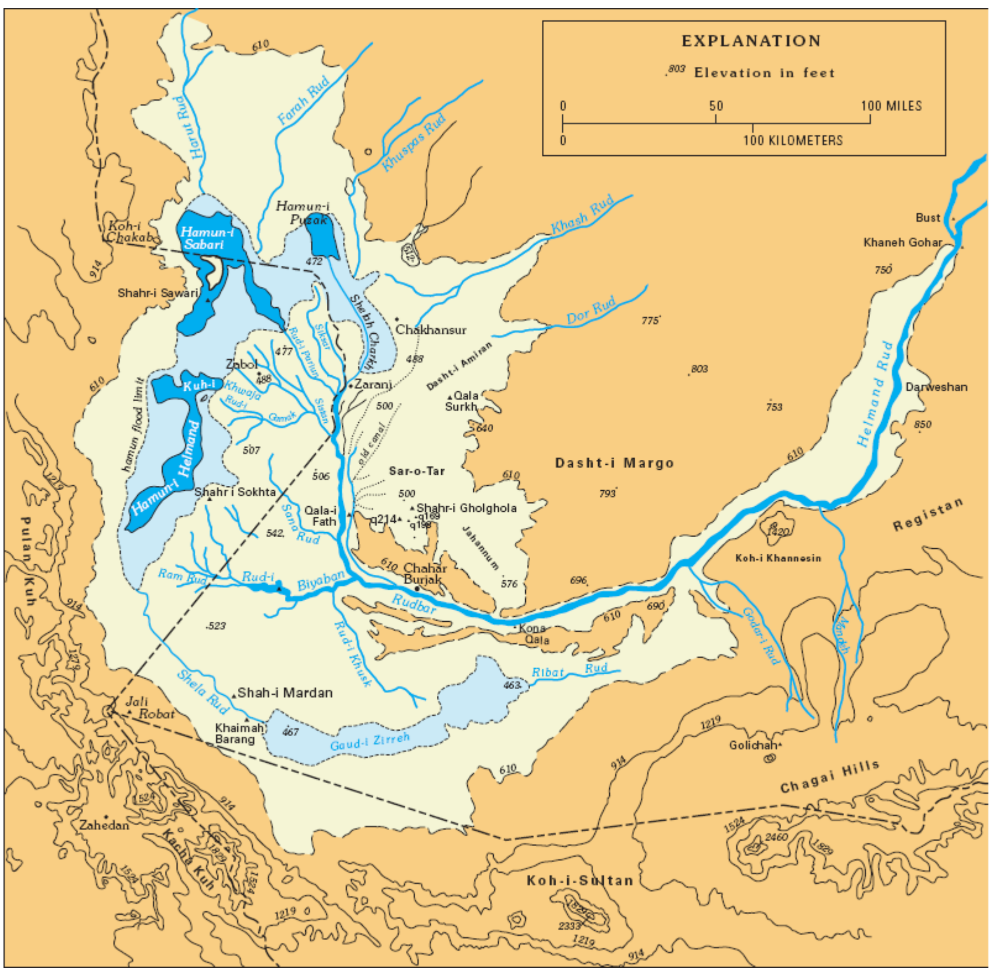

Figure 17 Sistan and Haman Lakes region of the Helmand Basin (Whitney, 2006; used with permission)

6.2.2.1.2 Politics

The Helmand River basin has been the source of intermittent and unresolved disputes between Afghanistan and Iran since at least the 1870's when the river was used as part of the border delineation by the British (Whitney, 2006). The frequent changes of the position of stream channels and important canals on the delta often cause havoc to the local populace, and an international furor was created in1896 when a channel change occurred along the designated border between Afghanistan and Iran (Adle, 2005; Whitney, 2006). Starting in the 1940's, Iran opposed the US-funded Helmand-Arghandab Valley Authority (HAVA) dams and other water diversion projects that were intended to provide Afghanistan hydroelectric power and increase agricultural productivity, but Iran feared would limit the natural flows of the river (USACE, 2010; Whitney, 2006). Although overtures were made to Iran with the 1950 treaty (which was intended to lead to an agreement with Iran over water allocations), Iran was not consulted regarding the myriad HAVA projects that were built on the Helmand River. There are two major dams associated with HAVA built during the era that are especially important for controlling flows. The Arghandab Dam (also known as the Band-i Dahla Dam) on the Arghandab River, is located north of the city of Kandahar. It was completed in 1952 with a storage capacity of 478.6 million cubic meters (MCM), and in 1953 the even larger 91 meter high Kajakai Dam on the Helmand River was completed with a storage capacity of 1.7 BCM, over three times greater than the Arghandab (USACE, 2010; Whitney, 2006).

While relations between Kabul and Tehran have improved since 2003, an agreement that both countries formally accept for managing the Helmand has not yet presented itself. Afghanistan recognizes its inherent power to control upstream waters and because of increased funding and new water infrastructure projects, it is finally able to capitalize on its water resources and feels no urgency to adhere to the 1950 treaty-based allocations recommendations or renegotiate the 1973 agreement.

Current sources of conflict between Iran and Afghanistan once again center around US and other international funding and plans to construct infrastructure to utilize and divert upstream Helmand waters. In fact, most projects under consideration today are to rehabilitate, re-evaluate and implement projects proposed several decades ago under the HAVA system. Many of these projects center on larger "intra-annual storage reservoirs because critical demands for irrigation (summer) and hydropower (winter) do not coincide," exacerbating the problems of large year-to-year water variability (USACE, 2010). Proposed and as-of-yet unfunded reconstruction projects countrywide total 7.3 billion USD, including projects worth 1.4 billion USD in the Helmand basin (Carpenter, 2008). The primary funding sources for the water sector are the World Bank and the Asian Development Bank, who are rehabbing several existing hydropower sites (Asian Development Bank, 2010; World Bank, 2010). Countrywide, about 30,000 wells have been installed and numerous irrigation canals are being rehabilitated (Carpenter, 2008). As of August 2010, no new large dams have been constructed, but several are planned, including at least two within the Helmand Basin. The large differences in power, using the three indices discussed previously in Chapter 4.2.4, show that Iran and Afghanistan have a delta of 73 (compared to 35 for all treaties) that heretofore may have been of primary importance to Helmand water discussions, but have perhaps been lessened by the US and other funding sources for reconstruction in Afghanistan.

Iran has also focused on Afghanistan's development plans on other transboundary rivers such as the Harirud, but it is especially sensitive to Afghan reconstruction efforts on the Helmand River which could impact the Sistan and Baluchistan Province. The province of Sistan-Baluchestan has the lowest human development index and is the most unstable region in the country (UNDP Iran, 2000). The region has been repeatedly hit by terrorist attacks, killing hundreds, blamed on Sunni groups by ethnic Baluchis in the province (AFP Global Edition, 2010). While Afghanistan stands to benefit from its Helmand reconstruction activities, Iran's concerns about decreased flows and fear of drought-driven instability has pushed them to take steps to hinder the upstream development effort. Iran's mostly unsuccessful efforts to harness or divert water for the region from Afghanistan has encouraged Iran to adopt "a mixed strategy of destabilization and cooperation" towards Afghanistan, including "providing support for the Taliban and direct action against water diversion targets" (Deghan & Palmer-Moloney, 2009;

USACE, 2010). Although not conclusive, Iran has been associated with explosives found on at least one dam in Afghanistan (Stimson Center, 2010a).

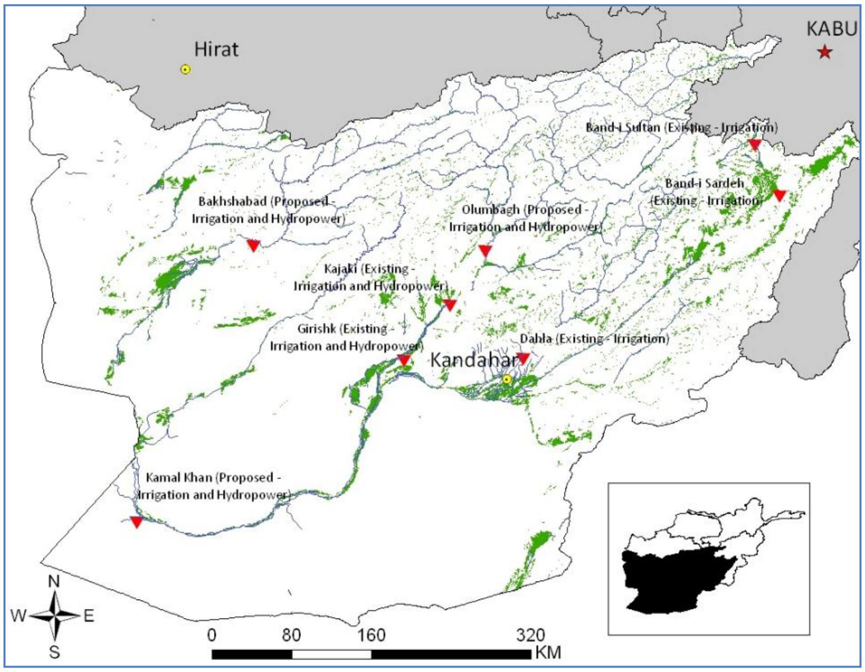

Figure 18 Map of the Helmand River Basin. Inverted triangles represent dams, yellow circles and red star represent cities, and green shading represents irrigated areas (USACE, 2010; used with permission).

The current International Security Assistance Force (ISAF) operations in Helmand and water’s central role in counter-insurgency strategies make the development of Helmand waters key for stability operations. Drought in 2008 caused one-third of Afghanis to be food-insecure and improved irrigation for the 80 percent of the population who rely on agriculture as a livelihood has been touted as key to overall security (FEWS, 2008). The United Nations estimates that with development of its water and irrigation network, Afghanistan could double its current cereal production of about 4.6 million tons with sufficient investments (IRIN News, 2008).

6.2.2.2 Complaint and Drought Index Summary

There are four TFDD complaints that are attributed to the 1950 Helmand Treaty, only one of which is classified as climate related. However, two other complaints directly relate to that complaint and the associated drought conditions that hit the Helmand and Sistan region from 1999-2005, creating the worst hydrologic conditions since at least 1945. Below normal precipitation, along with early snowmelt, resulted in poor harvests and food insecurity across localized areas of southwestern Afghanistan and southeastern Iran, according to National Oceanic and Atmospheric Administration (NOAA) precipitation data and analysis of irrigated areas by the U.S. Agency for International Development (USAID) and the U.S. Geological Survey (USGS) Famine Early Warning System (FEWS, 2008, 2010). Historically, droughts covering limited areas occurred every 9 to11 years, while nationwide droughts have a return period of about 20 to 30 years (Bhattacharyya, Azizi, Shobair, & Mohsini, 2004). The drought during this time period was unusual because of the combined effect of its severity, geographical extent, and length from 1999-2005. The drought in the Sistan area from 1998 to 2005 and decreased flows from the Helmand and its tributaries combined to cause the Hamun Lakes to disappear from 2001-2002 (Whitney, 2006). Traditional agriculture production diminished as a result of decreased water supplies from the Helmand, causing about one-half of the 1997 population to temporarily leave Sistan (Whitney, 2006).

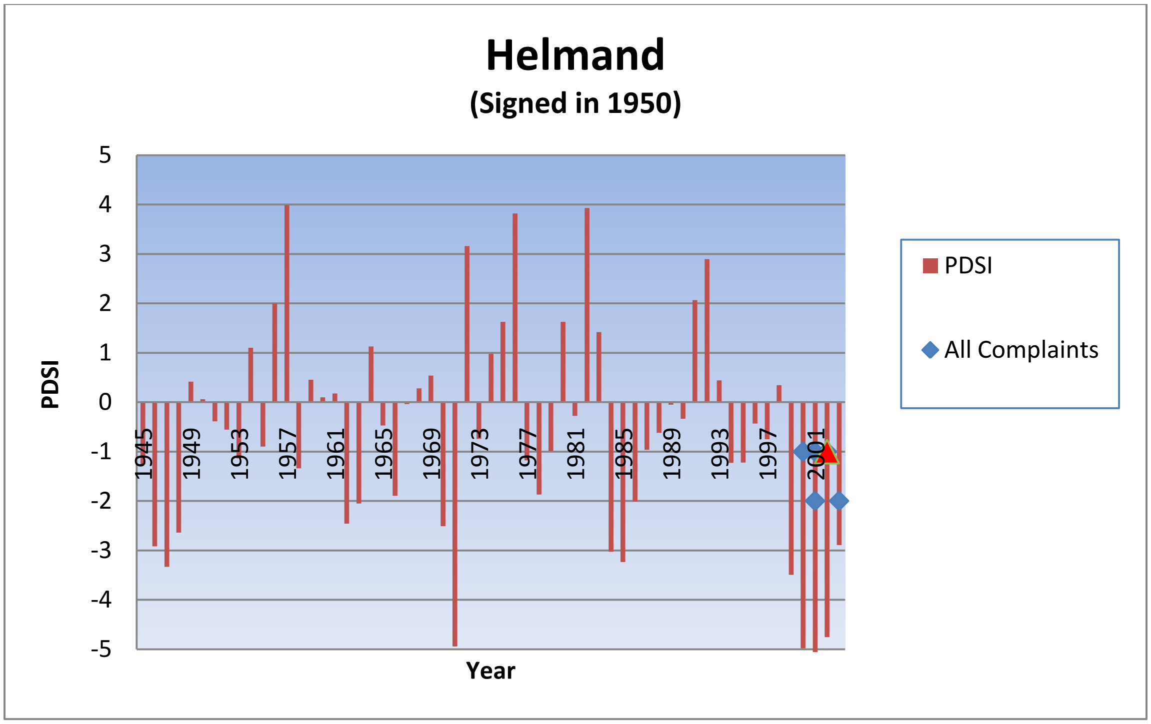

Figure 19 PDSI and both general and climate-related complaints for the Helmand Basin. Severe drought prompted and shaped the 2002 climate complaint.

Iran, either because it did not fully attribute the decreased flows to drought or for political reasons, wrote to the UN Secretary General, Kofi Annan, in September of 2001 charging that the Taliban had blocked the Helmand River, causing some 140,000 ha of land in the neighboring regions of Iran to dry up (United Nations, 2001). The initial complaints from Iran are recorded in the following two TFDD events from 2001, which are not labeled as climate-related since the Taliban was accused of being the primary cause of the decreased flows:

> "Hadi Nezhad-Hoseyniyan (Iran's permanent envoy to the United Nations) voiced protest in a letter to UN Secretary-General Kofi Annan, over the blockade of Hirmand [Helmand] river by Afghanistan."

> "Two foreign publications have in recent days reported the blockage of the waters of the Helmand River as it flows into lake Hamun. According to these two reports, with this action Taleban is trying to affect the efforts made by Iran at the Afghan Peace Conference held at the time of the Hajj in Saudi Arabia"(TFDD, 2008).

The letter to the United Nations prompted some delayed action; in spring 2002, the UNEP was informed that the lower reaches of the Helmand had experienced significant flows for 40 days and in early September 2002 a joint inspection of the Kajaki Dam was made by technical teams from Iran and Afghanistan. Afghanistan agreed to increase releases from their reservoirs and this water began reaching the Sistan area on 24 October 2002. However, only 15 days later the flows to the Sistan basin ceased due to water diversion that occurred somewhere before the border. These events prompted Iran to send another letter to the United Nations, dated 12 December 2002, that accused Afghanistan of not abiding by the 1973 treaty and referenced satellite data that showed that the amount of water in the upper reach of the Helmand River had considerably increased compared to earlier years. The second letter and start/stop of water reaching the Sistan area was recorded in another TFDD event, recorded as climate-related, in November of 2002:

> "Afghan Minister for Housing and Town Planning Mohammad Yusof Pashto has said his government had approved the restoration in the flow of Helmand River for 60 days to Iran and was surprised by the sudden disruption after a recent short flow" (TFDD, 2008).

Although the nature of the relations leading up to and surrounding these events was based on dam releases and diversions, later investigations by the UN showed that while releases were a contributing factor, drought was determined to be the main cause, as the Helmand River was flowing at as much as 98 percent below its annual average (UNEP, 2004, 2005; Whitney, 2006). For this reason, the November 2002 TFDD event was recorded as being climate-related in nature.

The TFDD complaints for the treaty are limited to a period of unprecedented drought from 2000-2005 and several authors have noted the correlation between previous episodes of drought and changes in relations that range from either more severe complaints or renewed treaty discussions. Suzuki (2006) states that the Helmand issues have been the main cause of dispute between the two countries for over a hundred years, noting that although not constant, disagreement has usually emerged during times of drought. According to Whitney (2006), "friction over water deliveries to Iranian Sistan …has become especially contentious during droughts." Abidi (1977) notes that the Helmand issue reemerged from a twenty year dormant state in 1971 and was precipitated by a year of exceptional drought. Drought-prompted increased relations in 1971 contributed to and culminated with the 1973 Helmand treaty.

6.2.2.3 Treaty Influence on Water Management and Complaint

The two nations' dealings during the TFDD complaints from 2001-2003 discussed above illustrate that the protocols and allocations outlined in both the 1950 and 1973 treaties were not applied within the basin. While the allocations of the 1973 treaty were perhaps a reason for Iran to file the complaint, the mechanisms of both treaties had very little to do with the processing and solution of the issue. Iran's complaints were filed with the United Nations and did not follow the dispute resolution protocol as outlined in Article X of the 1973 treaty, nor were joint meetings or unbiased committees used, which were called for in both the 1950 and 1973 treaties. The solution to Iran's complaints emerged not from the treaty mechanisms, but from both the UN decision and timely increases in precipitation and flows. These events, however, are not conclusive evidence that the 1950 and 1973 treaties were poorly designed. In this case, any positive influence from these treaties towards more effective management was perhaps overwhelmed by the internal political upheavals and stalled relations between countries, as well as an inability to determine the ground-truth situation stemming from inadequate flow measurement equipment in Afghanistan. As post-Taliban relations are now continuing to normalize and stability is closer to being achieved in Afghanistan, a re-evaluation of the 1950 and 1973 treaties is warranted to determine if their design remains feasible for the current and future hydrologic and political environment.

As discussed previously, the 1950 treaty helped to shape the 1973 Agreement, but has no specific allocations or mechanisms of its own that directly relate to the events in the TFDD. A review of the treaty mechanism scores from the literature as outlined in this study illustrates the limited nature of the treaty. The 1950 treaty has a cumulative Literature Review score of 0.78, compared to an average of 1.84 for all treaties. It is a shell of a robust, all-encompassing treaty, with limited mechanisms and scope. It lacks any aspects of *specificity*, *integrativeness*, or *flexibility*. Yet the 1950 treaty performed as it was meant to, with the creation of a committee and an allocation recommendation that has been referenced during negotiations since 1951. The success of the treaty perhaps is reflective of the treaties' specific mechanism strengths, as indicated by the MLR Model 2 score of 0.22 compared to an average of -0.18 for all treaties. The situational needs dictated the specific purpose of this treaty (to create a committee and further negotiations). Towards this function, the most important mechanisms would arguably be *scale* and *communications*, which are relatively strong in this treaty. Their emphasis in the Model 2 equation resulted in a stronger MLR score.

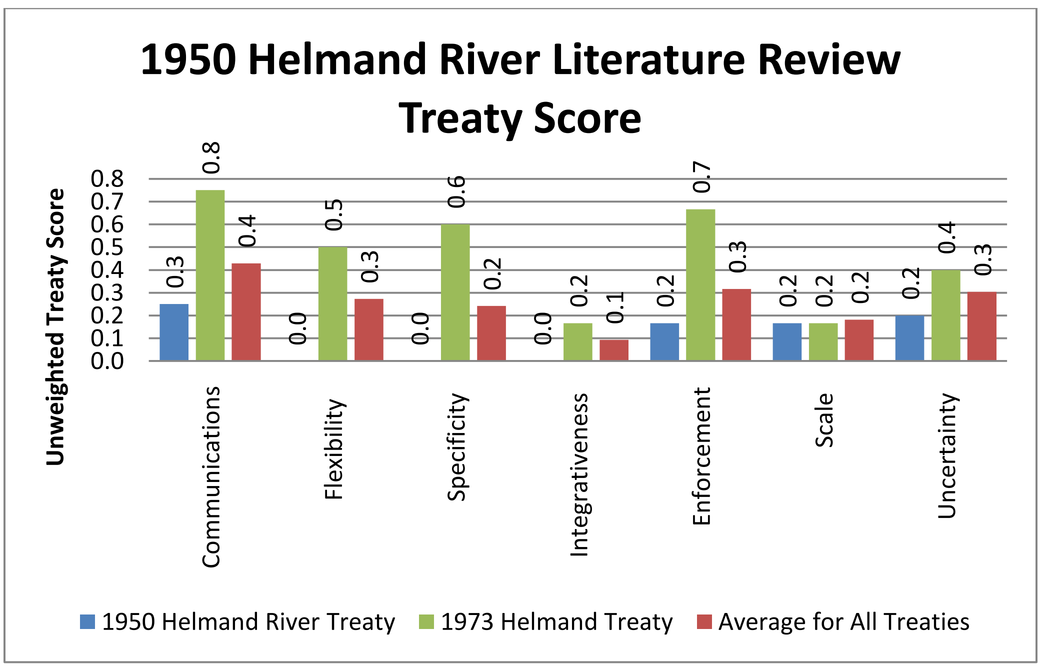

Figure 19 1950 Helmand River Treaty scores and comparisons. The 1973 Helmand Treaty is robust, but has faced implementation obstacles.

The 1973 treaty ratification status remains unknown and consequently it is not one of the 146 treaties used for statistical analysis. However, given its relevance, a copy of the treaty was obtained and analyzed for this case study. The translated treaty text and a comprehensive summary of the 1973 treaty from Abidi (1977) provide data from which general mechanism scores can be estimated. The discussion below uses the available treaty data and the seven study mechanisms to dissect the 1973 treaty and provide a rough summary of its strengths and weaknesses.

- *Specificity*: Compared to other treaties in this study, the 1973 treaty is extremely specific in its allocations. According to Article I, the volume of water from the Helmand River to be released by Afghanistan in a normal year was restricted to an average flow of 22 cubic meters per second. This was in accordance with the recommendation of the 1950 treaty-created commission. Article II gives specific volumes of water to be received by Iran during each month of the year, "ranging from 2.32 cubic meters per second in the dry months to 78.16 cubic meters per second during the flood period" (Abidi, 1977). The treaty also considers periods when flows may exceed the above designated flows. Under Article IV, Afghanistan agreed not to take any action which might "deprive Iran totally or partially of its agreed share of water," and retained all rights to the balance of the river water (Abidi, 1977). Iran further agreed to not to lay claim on more water than the treaty stipulates, "even if flows can be increased and Iran can use it in downstream Helmand Delta."
- *Communications*: Communication mechanisms are left to the water commissions, whose functions are laid out in the first protocol. This mechanism also combines with *flexibility/uncertainty* for managing periods drought. For example, Article X notes that if extreme drought causes flows to not reach the Helmand Delta and allocations to not be met, the commissioners will convene and "propose an agreed emergency tasks (plan) for mitigation or resolution to their governments."
- *Enforcement*: *Enforcement* mechanisms are flexible and specific, with escalating resolution mechanisms if problems are not initially solved by negotiations between the two countries. Article VII provided that each signatory has the freedom and responsibility to appoint its own commissioners to oversee and

implement the provisions of the Treaty. Article VIII stated that in the "event of differences in the interpretation or application of the provisions of the treaty, the parties were first to endeavor to obtain a solution through diplomatic negotiations or use of the good offices of a third part, but if neither course produced a solution, the differences were to be submitted for arbitration" (Abidi, 1977). Article VII also contains the agreed details about the manner of resolving differences, including the conditions and composition of any Arbitral Tribunal.

- *Flexibility* and *Uncertainty*: The treaty recognizes the possibility for, and provides the ability to manage, fluctuations in flow from year to year. Article III states that if flows decrease due to climatic factors, the required volumes can be reduced proportionally. On the negative side, the treaty did not consider the need to reconsider some of the basic treaty principles at some point in the future. Article IX states that the treaty represents "the complete and permanent agreement of the two countries, and that it was not to be subjected to any other present or future principle or precedent."
- *Integrativeness*: Quality issues were considered in Article V, which stated that Afghanistan would ensure that the water that Iran receives was not contaminated to the point of being untreatable by existing technical methods. Specific quality standards were not noted or expanded on in the treaty text. Another aspect of *integrativeness* was a consideration for erosion and construction along the river as discussed in Article VI, which stipulated that any type of "joint structures which were necessary for the purpose of stabilization of the bed of the Helmand River at places where the boundary line was located at the bed of the river, could be constructed only after the plans and specifications for such structures had been approved by both parties" (Abidi, 1977).

Given its frequent reference in water-related complaints between the two nations, it is surprising that the 1973 bilateral treaty is strong in most mechanisms that together produce a balanced approach to tackle water management in the Helmand Basin. It contains a mechanism for resolving differences with gradually increasing levels of severity. It has high *specificity* based on past flows at the monthly level, but also *flexibility* for periods of drought. These robust treaty mechanisms are reflected in the Literature Review average of 3.2, which is in the top ten percent and well above the average of 1.84 for all treaties in this study. However, despite the inclusion of all riparians, most aspects of *scale*, such as including the requirements of the local population, are not included. *Scale* is a weakness, and its emphasis in the Model 1 regression equation lowers the overall score to -0.27 compared to -0.05 for all treaties.

6.2.2.4 Outlook and Projected Impact on Water Resources from Climate Change

Climate models of the region predict that less water will flow through the Helmand Basin due to decreased rainfall, and more water will be lost to evaporation due to increased temperatures (Deghan & Palmer-Moloney, 2009). Lower precipitation could cause a 15 percent or greater reduction in runoff in Central Afghanistan by about 2057, according to some models (Milly, 2005). According to a USGS Helmand watershed water-balance model, a 10 percent reduction in precipitation would result in a 17 percent decrease in runoff (Vining & Vecchia, 2007).

Qualitative values capturing water variability for the portion of the Helmand in each country are summarized in Table 26.[32] For Afghanistan, which provides greater than 90 percent of the water in the basin, the extreme wet and dry scenario projections indicate an increase and up to high variability from 2030 through 2050. Afghanistan is projected to have an increase to high variability in four of the six scenarios, but the moderate scenario projects low variability similar to the historical pattern. Iran's variability is already moderate and, similar to Afghanistan, is projected to have an increase to high variability in four of the six scenarios.

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[32] For a more detailed discussion on the variability class determination, please see Section 4.3.4.

Table 25 Modeled runoff variability using projected changes in climate change under certain scenarios for the riparians of the Helmand Basin. Pakistan's contribution to, and portion of, the basin is very small and is not considered in this study.

		Future Variability Change Class					
Riparian	Present Variability Class	2030-Dry	2030-Middle	2030-Wet	2050-Dry	2050-Middle	2050-Wet
Afghanistan	Low	High	Low	Moderate	Moderate	Low	Moderate
Iran	Moderate	High	Moderate	High	High	High	Moderate
Pakistan	Low	High	Low	Low	High	Low	Moderate

Based on the Literature Review score and the application of the Model 1 regression equation, the 1973 agreement, if properly implemented, appears to have many features that could help mitigate conflict from projected climate change driven changes in variability. The treaty has a strong Literature Review based score well above the study average, and other than a weak *scale* mechanism has a relatively strong regression score. An established and well-designed water treaty accepted by both Iran and Afghanistan would be important to managing hydrologic fluctuations. Iran, for their part, refers to the 1973 treaty when they have requests to increase Helmand flows and for additional releases from dams on the Helmand and Arghandab Rivers. At the same time Iran references and utilizes the 1973 treaty, they have also been seeking a new agreement with Afghanistan (Samii, 2005).

Despite a lack of consensus over allocations, there have been indications of improved institutional capacity to manage disagreements in the Helmand, many of which are based on the 1973 agreement. Complaints stemming from climate and flow variability are still occurring, but *communications* and *enforcement* mechanisms may be mitigating stress and preventing escalation of the conflict to include UN or other high-level arbitration. For example, according to January 2009 press reports, Iran's foreign minister accused Afghanistan of halting the flow of the Helmand River into Iran. The Afghan foreign minister countercharged that Iran failed to meet its commitments of financial remuneration as stipulated in the 1973 Helmand waters agreement. After meeting to discuss the issue, discharge of water from the Kajaki Dam increased after the two commissioners reportedly reached a short-term release agreement (IPR Strategic Business Information Database, 2003).

While also an illustration of how dispute resolution mechanisms are being applied, the above example also highlights what may be a key weakness of the 1973 treaty. The absolute character of the stipulated allocations, as opposed to a percentage basis, appears to be a flaw in the agreement as it stands. The treaty, while providing for short-term *flexibility*, does not allow for long-term alteration of the allocations to account for climatic shifts in precipitation/flow. In the 37 years since the treaty was signed, and the 60 years since the 1950 treaty's commission findings, the treaty allocations may not accurately reflect the current flow regime and climatic conditions. In other words, the quantity and timing of the natural flow within the basin may have shifted. Without further data, it is impossible to know whether or not the treaty remains feasible. However, what is clear is the need for increased *flexibility* and *uncertainty* mechanisms that will consider that such changes and fluctuations may occur again in the future.

An improved *integrativeness* capability specific to development of the basin is especially important to shaping broader relations and guiding U.S. and internationally-funded reconstruction efforts within Afghanistan. NGOs recognize this need and are helping to both formalize the treaty and expand its scope. According to the UN, discussions on this treaty were reactivated after a hiatus of several decades with the reconvening of the Iran-Afghanistan Water Commission in September 2005 (UNEP, 2005). The commissioners currently meet on a quarterly basis to promote bilateral cooperation and the formation of subcommittees on dredging and flood control in the Helmand (Najafi, 2009). Additionally, since 2003 Iran and Afghanistan begun to cooperate on rehabilitation of Hamun Lake, working via trilateral sessions with the United Nations Environment Program (M. King & Sturtewagen, 2010).

Especially apparent in this case study are factors outside of the water sector that influence its management. Politics, internal instability, and economics not specifically tied to water are far more important for driving water relations between the two countries than any purely water-related issues. Certainly, hydrologic stress or altered requirements play a role, but the extent that action is taken regarding that stress is shaped by seemingly indirect factors. More than the projected changes in water variability stemming from climate change, the extent of development and increased water utilization in Afghanistan are likely to be the largest factor in determining the severity of flow-related complaints between the two countries. How well water agreements help to shape these factors in the end may determine whether future conflict occurs. The 1973 treaty contains such shaping capacity with above-average *integrativeness, scale,* and *communications* mechanisms, but to be effective the treaty will need to be accepted and implemented by both countries.

6.2.3 Indus River Basin

The Indus basin is shared by Pakistan, India, Afghanistan, and China. The Indus waters are especially vital to agriculture production in Pakistan and the Kashmir region. For India, the basin's hydropower potential is arguably its most important attribute. The sharing of the Indus River has been contentious for at least a hundred years, but became especially so after the partition of British India into Pakistan and India on August 14, 1947 (A. Dinar, Dinar, S., McCaffrey, S., McKinney, D., 2007). Multiple disputes prompted the World Bank to provide incentives and act as a mediary. After 10 years of back and forth negotiations the 1960 Indus Waters Treaty (IWT) was finally signed between India and Pakistan, as well as the World Bank. The IWT remains the only treaty to which the World Bank is a signatory (A. Dinar, Dinar, S., McCaffrey, S., McKinney, D., 2007).

Table 26 Key features of the 1960 Indus Water Treaty

Important Mechanisms for Climate Complaints	*Scale* and *Specificity*
Primary Agreement (TFDD ID)	114
Signatory	India, Pakistan, International Bank for Reconstruction and Development
Treaty Description	Indus waters treaty 1960 between the government of India, the government of Pakistan and the International Bank for Reconstruction and Development. Engineering plans were used first, then found lacking until political efforts could direct them. Third party-negotiators were necessary.
Date signed	9/19/1960
Years Enforced	48
Issue Type	Water Quantity
Water Allocation Method	Allocation of Entire Rivers
Text of Water Allocations	India: 100% of Eastern Rivers. Pakistan: 100% of Western Rivers.
Self *Enforcement* Mechanisms	Article V
Comments on Non-water Linkages	£ 62,060,000 as replacement costs of irrigation canals in regions formerly irrigating from Eastern Rivers. Money paid to India if the 31 MAR 1970 expiration date is extended for up to three years.
Conflict Resolution Mechanism	Council, then a Neutral third party

The treaty is complex, and is unique in its basic approach of segregating and allocating the basin according to the geography of the tributaries. Unlike most other treaties that use percentage or temporal arrangements, the IWT allocates the entire flow of the three eastern tributaries of the Indus River (Beas, Sutlej and Ravi Rivers) to India and the three western tributaries (the Jhelum, Chenab, and the main stem of the Indus Rivers) to Pakistan (McCaffrey, 2007). The exceptions are limited by provisions included by Pakistan that curb India's construction of storage reservoirs and diversion structures which could significantly impede the timing and quantity of water flow. The reservoir size restriction results in Western River power projects in India being of the run-of-the-river type, with allegedly higher construction costs and decreased cost-effectiveness of power generation from these projects (Warikoo, 2006). The treaty also includes provisions regarding the construction of a system of irrigation canals in Pakistan to replace its sources of water from the Eastern rivers. These provisions resulted in the Indus Basin Project (IBP), comprised of three storage reservoirs (Tarbela, Mangla and Chashma), six barrages, eight new inter-river link canals, and the remodeling of three existing link canals (Asianics Agro Dev International, 2000). Despite the full allocation of these tributaries, India and Pakistan remain interdependent and they continue to confront disputes that arise as they implement the IWT and develop the river. The few caveats that allow India limited domestic, non-consumptive, agricultural, and hydropower use of the Western Rivers (McCaffrey, 2007) tend to be the most contentious. In this case study, climate-related conflicts in the Indian and Pakistani parts of the Indus Basin that have occurred since the signing of the treaty are reviewed.

6.2.3.1 Background

6.2.3.1.1 Hydrology

The Indus River system is comprised of a 2,900 kilometer main stem that rises in Karakoram Himalaya of southwestern Tibet, and five major tributaries to its east including the Jhelum, Chenab, Ravi, Sutlej and the Beas. According to one study (Alam, 1998), the main stem of the Indus river carries about 115 BCM, which is a little less than half of the total supply of 217 BCM from all six rivers considered in the IWT. Together the Jhelum and Chenab combined carry about 32 percent of the total supply, and the Ravi, Beas and the Sutlej combined constitute about a quarter. Another study estimates that the average annual inflow of the Indus River and its tributaries to be approximately 189 BCM, of which 177 BCM is available to Pakistan (Kugelman & Hathaway, 2009). About 13 percent of the catchment area resides outside of India and Pakistan. The Indus and Sutlej rise in Tibet, while the main stem of the Indus is contributed to by three tributaries that originate within Afghanistan to the west-- the Kabul, Swat, and the Kurram Rivers. The Kabul River contributes as much as the Jhelum or Chenab tributaries, and more than each of the three smaller eastern tributaries that are part of the IWT. The Kabul River joins the Swat River in Peshawar valley, before meeting the Indus near Attock (Salman & Uprety, 2002).

Table 27 Catchment areas and runoff of the Indus River system

					Discharge BCM		
River	Station	Length/km	Average Runoff/BCM (MAF)	Catchment Area (km^2)	Summer	Winter	Percent of Total Discharge
Indus	Kalabagh	2,900	115 (93)	268,800	69.6	11.5	45%
Chenab	Marala	970	32(26)	29,500	24.4	4.6	16%
Jhelum	Mangla	725	28 (23)	33,400	22.3	5.6	16%
Sutlej	Rupar	885	17 (14)	48,000	14.3	2.5	9%
Beas	Pong	400	16 (13)	16,800	12.8	3	9%
Ravi	Madhopur	700	9 (7)	8,000	6.4	1.5	4%
Kabul	Warsak	700	21 (17)	67,600			12%
Total			217 (176)	404,500	149.8	28.7	178.5

Sources: (Alam, 1998; Dinar, 2007)

Highly variable flows on the Indus are primarily dependent on the monsoons, beginning in June, with peak flood levels reached in July-August (Alam, 1998). During the 4-month monsoon period, about three quarters of the total annual flow of the Indus occurs (A. Dinar, Dinar, S., McCaffrey, S., McKinney, D., 2007). However, also critical to the time distribution and magnitude of river flow are the seasonal and perennial changes to snowpack and glacier ice. The peak seasonal and daily flows do not necessarily coincide exactly with the occurrence of precipitation, but on the combination of storage (in the form of snow/ice), temperature, and precipitation that either adds to the snowpack or becomes runoff (Archer, 2003). Generally, “the lower the catchment elevation, the greater the proportion of precipitation” that is below the snow line and the more quickly flows are impacted by the precipitation as runoff (Archer, 2003; p. 201).

The basin has a wide range of climatic environments ranging from dry or temperate to cold and polar. The majority of the basin falls in the dry climatic classification as defined by Köppen (FAO-SDRN Agrometeorology Group, 1997; TFDD, 2008; S. Yoffe et al., 2004). A dry desert climate with hot annual temperatures greater than 18 °C (Köppen classification of Dry, BWh) is found in about 37 percent of the basin. A total of about 12 percent of the basin is dry with semi arid grassland steppe and hot annual temperatures greater than 18 °C (Köppen classification of Dry, BSh). About 9 percent of the basin is polar, with a tundra climate (Köppen classification of Polar, ET).

The combination of melting glaciers, permanent snow, seasonal snowmelt, and winter and monsoon rainfall result in a wide range of annual flows; for example, the stem of the Indus River can vary by between 75 to 118 percent of its average 115 BCM per year (Alam, 1998; p.32). The significant monthly and mean annual variability in both flow and precipitation within the basin results in both drought and flooding, sometimes in the same year. Of all natural disasters to affect Pakistan since 1973, flooding represents the top four, and seven of the top ten most destructive events in terms of loss of affected population (United Nations Office for the Coordination of Humanitarian Affairs - ReliefWeb, 2010).

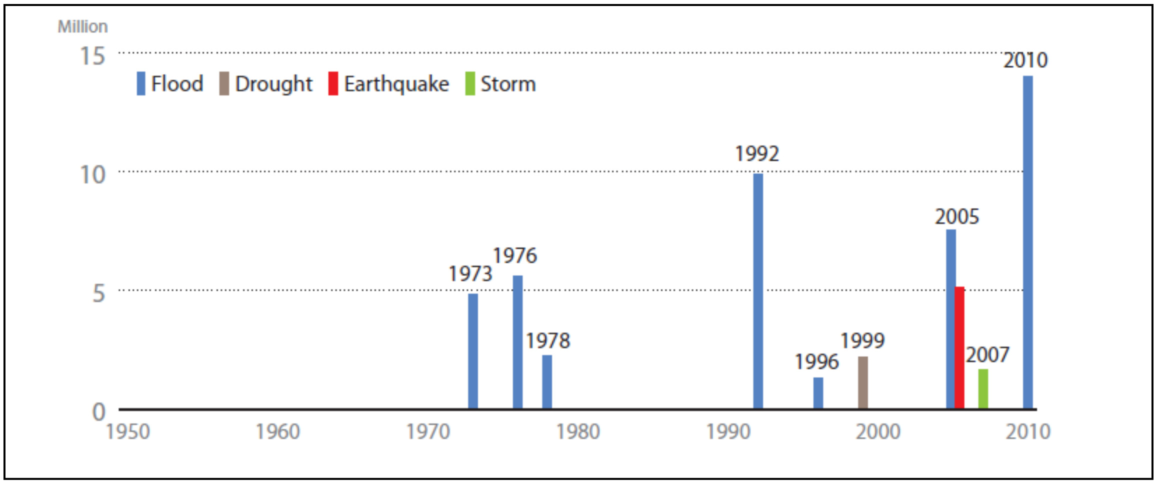

Figure 20 Natural disasters in Pakistan, by number of affected population. Flooding and drought account for eight of the ten disasters (United Nations Office for the Coordination of Humanitarian Affairs - ReliefWeb, 2010; used with permission).

There is a broad set of existing infrastructure within the basin for both irrigation and hydropower. The Indus Plain covers about 25 percent of Pakistan's total land area and contains the majority of the Indus Basin Irrigation System (IBIS), the world's largest contiguous irrigation system--comprised mostly of barrages and irrigation canals. Parts of the system resulted from the IWT requirement to transfer water from the western rivers to replace water lost from the eastern rivers (Asianics Agro-Dev. International, 2000; p.6). All told, 97 percent of Pakistan's surface water resources is used for irrigation and agriculture that directly supports the 65 percent of Pakistan's population that rely on irrigated lands for their livelihood (Kugelman & Hathaway, 2009; pg. 30).

6.2.3.1.2 Politics

Water has always had an important role in the relationship, but cooperation, rather than conflict, over its use has usually been the primary theme. Land disputes over Kashmir have been the key divisive element between India and Pakistan, resulting in three major and one minor war. The abundant water resources of Kashmir and their importance to both countries has always been an undercurrent to and helped define the land issues. Recent comments by Pakistan Army Chief General Kayani indicate that water's security-related importance has been elevated to perhaps second-to the territorial rights of Kashmir.[33] In early 2010, General Kayani noted that "the Pakistani Army will remain 'India-centric' until the Kashmir issue and water disputes are resolved," and he has since made similar statements about the importance of water in obtaining a long-term peace with India (India Times, 2010).

The core water issue is India's development of the western tributaries allocated to Pakistan, and the interpretation of the IWT articles that define the parameters of water use. Pakistan's stance is intended to prevent India's infrastructure development along the western tributaries from affecting the quality and quantity of water reaching Pakistan (N. Zawahri, 2008). India is intent on utilizing the hydropower capacity of the rivers. Often independent of the physical infrastructure and fluctuations in flow, water has increasingly been used as a convenient hot-button by both countries when political expediency demands elevated rhetoric towards the other nation.

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[33] General Kayani distinguished between land and water, but the land issue is also linked to Kashmir's abundant water resources.

Funding for water-related projects is a carrot nations, including the United States, have used to curry favor with Pakistan. March 2010 statements from the State Department indicating that water scarcity was “a central U.S. foreign policy concern” have been backed up by aid packages to Pakistan (Solomon, 2010). In July 2010, the US initiated a “signature water program” of funding for Pakistan, with a first phase total of $270 million for projects including municipal water and irrigation projects, the Gomal Zam Dam irrigation project, the Satpara Dam project, and Balochistan water storage dams (Kellerhals, 2010).

As a regional hegemon and the upper riparian, it is often noted that India seems to be in control of the ebbs and tides of the dispute. However, the Delta Power comparison in this study illustrates a more level playing field, with a difference of 42 compared to an average of 35 for all treaties. The GDP delta of 32 is less than the average of 40 for all treaties. This indicates that while India may have upstream control, Pakistan has the economic and political influence to not be cowed by an overly dominant India. What likely prevents Pakistan from fully realizing their influence is a lack of internal stability, as illustrated by a Failed State Index difference of 87 between the countries compared to an average of 39 for all treaties. The previously discussed US aid and international influence directed toward Pakistan is likely to further narrow both the FSI and GDP based power gap.

6.2.3.2 Complaint and Drought Index Summary

Since its signing in 1960, the Indus Treaty has weathered and continued to function during two separate wars between the signatories, in 1965 and 1971. Consequently, the treaty has been hailed as a beacon for water-related cooperation (Salman & Uprety, 2002). While the treaty has fostered exceptional cooperation between India and Pakistan, there have been intermittent conflicts over its interpretation and application. Conflict over the IWT has generally been politically driven, rather than from the “technical and engineering aspects of water management” (Sridhar, 2010).

The treaty has weathered at least 109 water-related complaints, only four of which were pertaining to changes in climate (TFDD, 2008). When compared to the other basins in this study, the Indus has both a lower variability (standard deviation of 1.2 compared to 1.8 for all treaties) as well as a lower average drought index since the treaty was signed (-0.5 compared to -0.9 for all treaties). All four climate complaints were filed after 2002, with two complaints lodged in both 2002 and 2004. The minimal climate complaints may be partially explained by a lack of drought in the basin since the signing in 1960 until 1998-1999, when drought hit the region. The 2002 climate-related complaints were lodged during the fourth year of the worst drought to affect the region since at least 1945. The PDSI during 2002 was -2.6, which came on the heels of a historically severe -4.13 drought year in 2000. Drought from 2001-2002 in Pakistan caused water shortages of up to 51 percent of normal supplies and affected an estimated 349,000 people, mostly farmers in Baluchistan (Ahmad & Hussain, 2004; International Research Institute for Climate Prediction (IRI), 2001). Many of the negative impacts from lower precipitation were mitigated by various measures undertaken by Pakistan, including increased exploitation of groundwater (Ahmad & Hussain, 2004; pg. 5). Drought conditions had eased by 2004 when the other climate complaints were filed.

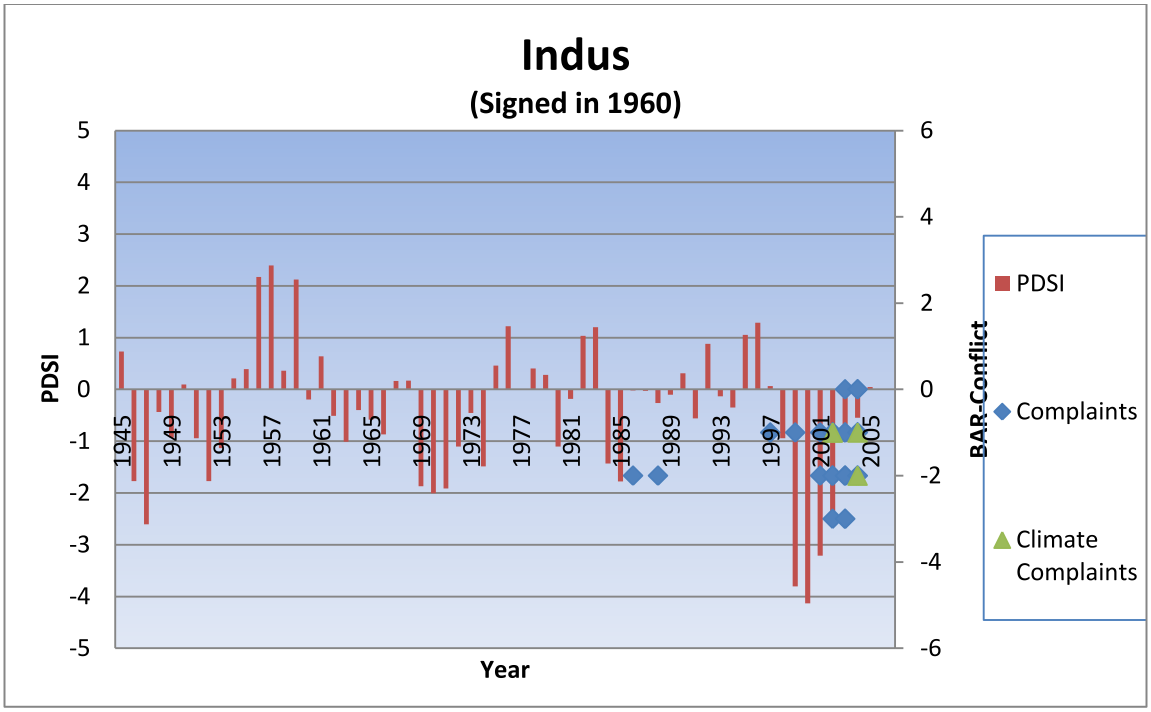

Figure 21 Indus Basin complaints regarding the 1960 IWT and drought index (PDSI) history. Climate complaints were largely not related to drought conditions.

While the four complaints had a climate component, none of the complaints were specific to flow allocations. Three complaints referenced a general renegotiation of the treaty in response to water stress, as exemplified by the 2004 incident below:

> “Pakistan's ruling coalition from the Punjab province have asked the government to buy water from India to tide over the acute crisis in their region. They also want the 1960 Indus Water Treaty to be renegotiated with India to get Sutlej water” (TFDD, 2008).

In 2004, flows had recovered from drought levels and the PDSI was -0.55, the same as the basin’s average over the 45-year period since the treaty was signed. Increased flows in 2004 resulted in the fourth complaint pertaining to flood control issues and damage in Pakistan that purportedly originated from upstream releases in India:

> "India released water the Satluj River, which caused damage to the standing crops on the banks of the river, and the collapse of make-shift bridges" (TFDD, 2008).

All of the complaints were resolved without the application of the *enforcement* mechanisms and they did not escalate to involve higher levels of government. The climate complaints represented a very small percentage of the total complaints for the basin (less than four percent). Drought conditions and the associated increase in water scarcity likely raised the importance of water relative to previous years, and thus may have been a contributing factor to some complaints. The complaints were relatively minor, were not accusations of treaty violations and were non-specific in nature relative to the treaty with no specific statutes mentioned. The origin of the complaints was arguably from political stress and reflective of overall relations rather than from fluctuations in climate.

6.2.3.3 Treaty Influence on Water Management and Complaint

Three of the four complaints considered in this case study had climate components that were seemingly not the primary cause for the lodging of the complaint. The secondary nature of climate as an issue coupled with the small percentage of climate complaints and the lack of political escalation indicates that hydrologic stresses are successfully being managed, mitigated, and deflected by the 1960 treaty. This capability is enabled by and reflected in the treaty mechanisms. When considering the treaty mechanisms using the Literature Review calculations, which emphasizes the number of mechanism components, the overall treaty score of 4.28 indicates an extremely strong treaty that ranks as the 3rd highest in the study. The regression analysis places a negative emphasis on *communications* and *integrativeness* (both of which are strong in the treaty) and a positive emphasis on *scale* (which is the second weakest mechanism), resulting in a Model 1 regression below average score of -0.15 compared to -0.05 for all treaties.

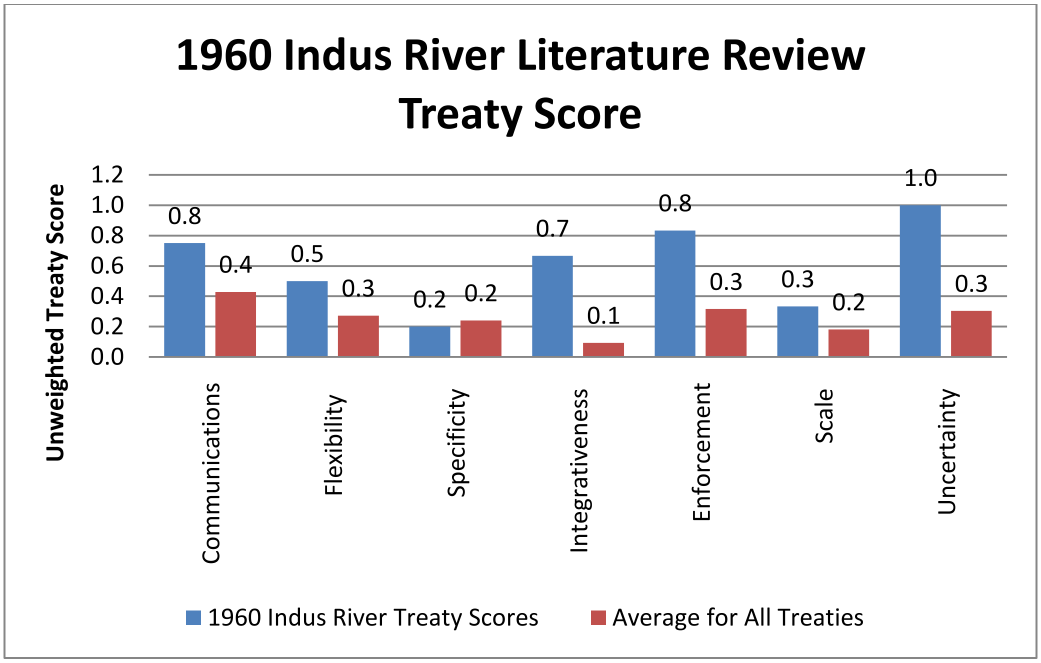

Figure 22 Indus Basin scores according to the literature-review based analysis. The IWT is extremely strong, ranking as the 3rd highest in the study.

With the exception of *specificity*, which is near the mean for all treaties, all treaty mechanism scores are above average, and are especially strong in *uncertainty*, *integrativeness*, *communications*, and *enforcement*. Meaningful discussions on how the four climate complaints were managed by each mechanism is limited by the scarce reporting of the circumstances surrounding these events. However, perhaps more relevant is a discussion of how the treaty has mitigated and prevented numerous complaints that almost assuredly would have resulted without the IWT, but that the complaints in this study may expose some chinks in the seemingly strong treaty that could become more apparent as climate stresses increase.

Specificity appears to be one of the weaker mechanisms in the treaty based on the mechanism count. One of the key *specificity* issues absent from the treaty is a specific flood control mechanism. The only complaint considered in this case study that had a central climate related component was the 2004 event regarding downstream flooding in Pakistan that supposedly originated from upstream releases in India. While only one climate event related to flooding was captured in the TFDD, flooding is certainly a primary issue within the basin. Treaty mechanisms intended to account for fluctuations in flow in general are limited, but especially do not reflect any intent to mitigate flood disasters, 67 of which have hit Pakistan since 1900 (compared to only one for drought; as defined by the United Nations Office for the Coordination of Humanitarian Affairs) (United Nations Office for the Coordination of Humanitarian Affairs - ReliefWeb, 2010). Since spring flooding in the basin is an annual likelihood even during years of overall drought, it surprising that the treaty does not contain more robust mechanisms that are specific to the management of flooding problems.[34] Cooperation over flooding that does occur is ad-hoc or built into other mechanisms, such as *communications*, and is not part of an integrated flood management plan. For example, the Indian Government views the sharing of flood data for undertaking advance flood warning measures as ‘a gesture of goodwill’ rather than as an IWT requirement (India.gov, 2010).

While the treaty is specific in some regards, much of the interpretation is left to the ‘spirit’ of the treaty, which both sides define differently.[35] However, some of the perceived *specificity* weakness is somewhat deceiving due to the unusual allocation design based on tributary locations rather than on a quantitative basis. The full allocation of rivers negates many of the usual requirements to manage and enforce variability of flow. Although the origins of the provision were based on a lack of trust, the complete allocation of tributaries nullifies many of the typical causes of conflict and has helped to minimize confusion and differences over flow requirements that could have arisen with climate fluctuations. However, the same distrust also resulted in the provisions for storage and other limited-

[34] Flooding is only mentioned as a consideration for construction on the shared rivers. Article IV states, “In executing any scheme of flood protection or flood each Party will avoid, as far as practicable, any material damage to the other Party, and any such scheme carried out by India on the Western Rivers shall not involve any use of water or any storage in addition to that provided under Article III.”

[35] The treaty states its intent to promote “a spirit of good will and friendship, the rights and obligations of each in relation to the other concerning the use of these waters and making provisions for the settlement and cooperative spirit.”

use restrictions for every project that India might have on the western rivers. When they do occur, complaints tend to originate from the sections of the treaty where allocation is not absolute, such as Indian construction intended to utilize the western rivers for non-consumptive uses as defined in the treaty.

A strong *integrativeness* score is based on the inclusion of non-water linkages including territorial issues, fishing, and navigation. Although not part of the *integrativeness* mechanism calculations, the World Bank incentives of massive aid to both Pakistan and India to build storage and conveyance not only provided incentives to sign the treaty, but also expanded the scope to include economics and agriculture since the development carried out in both India and Pakistan provided temporary increased agricultural production (Mustafa, 2007). The broad mission of the Permanent Indus Commission (PIC) (a joint management body which was initiated as part of the treaty with representatives from each country) allows the joint management body to oversee a number of relevant sectors. Article VIII created the PIC to "establish and maintain cooperative arrangements for the implementation of this Treaty, to promote co-operation between the Parties in the development of the waters of the Rivers, and to study and report to the two Governments on any problem relating to the development of the waters of the Rivers." The PIC has freedom to "determine its own procedures," which allows for the consideration of a wide range of issues. For example, the PIC could potentially use the IWT's water quality provisions to address water pollution problems (Miner, Patankar, Gamkhar, & Eaton, 2009). The PIC, however, has thus far limited its scope to those topics specified in the IWT, and has not addressed issues such as groundwater use, long-term projected changes in flow resulting from climate change, or water conservation (Miner et al., 2009; pg. 212).

Scale is one of the weakest of the treaty's mechanisms. The treaty focuses on the water-distribution and international relations between India and Pakistan, but does not include Afghanistan, which is increasingly using the basin water resources, including the shared Kabul River. It also does not adequately address domestic and interprovincial water issues. Such issues are becoming more important in India and especially in Pakistan. The question of distribution of water and other resources is often a contributing factor to domestic instability in both countries. Like all instability, there is a multiplicity of contributing and interrelated causes. Separatist movements in both India and Pakistan have latched onto the water issue, with Pakistan's militant groups utilizing India's ostensible control of Pakistan's water supply to gain support for their extremist agendas (Jafrani, 2010). Within Pakistan, sharing agreements between the provinces have led to much debate and protesting. Despite a domestic 1991 Water Accord intended to more equitably share the Indus waters between four provinces in Pakistan, lingering distrust has limited cooperation and prevented potentially mutually beneficial construction (Pakkisan.com, 2010). Perhaps the best example is the proposed Kalabagh dam on the Indus River in Sindh province. In 2006, the dam sparked protests in Balochistan, North West Frontier Province, and Sindh provinces. While all three provinces view its construction as a Punjab ploy to increase their influence, the Sindhs believe the proposed dam will lessen their water supply, "while Balochistan and the North West Frontier Province fear inundation"(UNPO, 2010). The project was put on hold, but is again being discussed with the recent flooding throughout Pakistan; Prime Minister Gilani noted that if construction had been completed as planned, "the deaths and destruction in the floods could have been averted," and noted that its construction would take place if consensus could be reached (Daily Times, 2010). For India, balancing the interests of Jammu and Kashmir province with the national strategic goals has not always been successful. Jammu and Kashmir has complained to the central government about the application of the treaty, calling it unfair to their province. In 2002, the province even went so far as to pass a resolution in their Legislative Assembly that called for an annulment of the IWT (Chandran, 2009). They contend that the rights to their rivers were sacrificed to Pakistan without their consent, which has consequently stunted development and resulted in insufficient hydropower production capacity to meet their needs (Warikoo, 2006). Of the province's requirement of 1,600 MW, the area reportedly only generates about 450 MW and must purchase power from outside the province to meet its demands (Sridhar, 2010).

The national level focus without consideration of local needs in the *scale* mechanism is likely to be more of an issue as development continues and localized water scarcity increases.

Strong *communications* mechanisms have provided an avenue for regular dialogue between the two countries, but the impact has been constrained by the securitization of water. The treaty requires the regular exchange of data to be accomplished with the PIC commissioner as the primary channel for communications (Salman & Uprety, 2002; R. Singh, 2005).[36] While the PIC is intended to facilitate the sharing of data, it is hampered by both India and Pakistan labeling much of their water data as secret (R. Singh, 2005). The data that are shared are viewed with skepticism and under the assumption that much is being withheld (Salman & Uprety, 2002). Pakistan's Indus water commissioner noted "although there is no evidence that India is withholding water, they are withholding information required under the 1960 treaty"(Jafrani, 2010). If Pakistan and India had more trustful relations, "there would be a mutually-verified monitoring process which would assure that there is no change in the flows going into Pakistan" (Briscoe, 2010). The lack of unbiased data achieved through communications and joint monitoring prevents a comprehensive view of the total water supply and demand for each country.

The treaty's *enforcement* and dispute resolution mechanisms have been largely successful in limiting complaints from reaching levels that require outside intervention. *Enforcement* has been the primary issue for the majority of all low-level complaints that have been

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[36] Salman (2002) notes that data exchange is to include the subjects of "daily gauge and discharge data relating to flow of the rivers, extractions/releases from reservoirs, and canal withdrawals, leakages, and deliveries."

filed within the basin.[37] The IWT has a complex progression of dispute resolution mechanisms, with the base level being the PIC. Only one time has a dispute escalated to levels higher than the PIC. The issue was regarding India's US$1 billion, 450MW Baglihar Dam on the Chenab, which Pakistan first objected to in 1990 (N. A. Zawahri, 2009).[38] The issue of Baglihar's construction was initially discussed in the PIC before being raised to the level of foreign secretaries, and was finally sent for Neutral Party arbitration in 2002. A Swiss civil engineer, Dr. Raymond Lafitte, was appointed as the Neutral Expert in May 2005 and provided his ruling in February 2007 (Miner et al., 2009). Lafitte determined that the dam construction could go forward, with only limited changes. Of the major points of contention, Lafitte recommended slight alterations in favor of Pakistan on most of them (such as a 3-meter height increase in the location of the turbines), but ruled for India regarding their use of a gated spillway. The binding judgment by Lafitte was accepted and hailed as a triumph by both countries. India claimed their design was validated, with only minor changes, and was proclaimed in embassy headlines such as:

> *"Baglihar Dam cleared by neutral expert*, and stating that the overall design of the Baglihar dam being built by India on the Chenab as a run-of-river plant 'has been upheld by Prof. Raymond Lafitte, the Neutral Expert (NE) appointed by the World Bank to consider Pakistan's objections to the Baglihar project, in his decision delivered today in Berne to the representatives of India and Pakistan"(Embassy of India Washington DC, 2007)

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[37] All Indus complaints filed in the basin, including those outside of the 1960 treaty, were reviewed to determine the issues and causes of each complaint. As part of the review, each complaint was compared against the seven treaty mechanisms to determine which mechanism is of primary and secondary importance to managing the complaint (due to either the presence or absence of a mechanism in a treaty). When considering all basin complaints, *enforcement* was the mechanism most often relevant. Of the 118 total events, integrativeness was a primary or secondary factor in 74 complaints. Communications (52) and flexibility (23) were also important.

[38] Pakistan questioned six criteria regarding the dam, including: maximum flood design, a gated versus an ungated spillway, spillway gate level, water level, pondage, and level of power intake (Miner et al., 2009).

Pakistan claimed that the ruling confirmed that India had violated the treaty, with this headline from the Pakistan Tribune:

> "*World Bank validates Pakistan stand on Baglihar Dam*', followed by a pronouncement that Lafitte had 'made it clear in (his) verdict that India has been found guilty of breaching the Indus Water treaty of 1960' "(PakTribune, 2007).

It is tempting to view the Baglihar decision as a demonstration that India and Pakistan can successfully use the *enforcement* mechanism for the equitable settlement of differences through a neutral expert without causing deterioration in relations (Zawahri, 2008). The Baglihar ruling was indeed a successful utilization of *enforcement* (as explained in Article IX) for the specific purpose of the construction of the Baglihar dam, but the broader implications of the ruling and question of success for the future of the agreement are far less clear. Pakistan is almost certainly unsatisfied with the additional control India gained over the Western rivers with the ruling, and the judgment has not stopped the accusations of Indian upstream flow manipulation (ANI, 2008). India, meanwhile, is using the decision as a template for increased dam construction, with numerous new projects on the Western rivers. While technically permissible within the reinterpretation of the IWT by the neutral expert, these dams' could give India a cumulative one-month storage capacity (Briscoe, 2010; Solomon, 2010). The ability to halt flow justifies Pakistan's fears and strains the limits of what they desire from the IWT since the reservoir restrictions built into the treaty in 1960 were intended to protect against India's upstream control.[39] With Baglihar, many of the attributes of the treaty that Pakistan relied on, such as the very specific construction parameters and the long-term viability and equity of the *enforcement* mechanism, are called into question. John Briscoe notes that the decision "left Pakistan without the mechanism – limited live storage –

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[39] These fears are least partially based on previous experience. Shortly after independence in 1948, India used its own upstream infrastructure on the eastern rivers (Ravi and Sutlej) to deprive Pakistan of irrigation supplies for about 0.7 million hectares (mha). After a month of flows being cut off, India "was able to extract full water rights concessions for the rivers before releasing water downstream" (Asianics Agro-Dev. International, 2000).

which was its only (albeit weak) protection against upstream manipulation of flows in India" (Briscoe, 2010).

While it took 45 years for the IWT to utilize the outside expert clause in its *enforcement* mechanism, it is not likely to take nearly that long for the next use. In 2010, Pakistan reportedly initiated the formal arbitration process regarding India's Kishanganga Dam hydroelectric and diversion project proposed along the Kishanganga River (Wright, 2010). Pakistan claims that the diversion will illegally transfer water from one tributary to another, adversely impacting downstream agriculture and their own under-construction project, the Neelum/Jhelum Dam.

6.2.3.4 Outlook and Projected Impact on Water Resources from Climate Change

While projections of changes in climate within the basin vary and changes will not be spatially uniform, generally models indicate that precipitation can be expected to increase, but will be overwhelmed by diminished meltwater from snow and glaciers that will ultimately result in significant flow decreases on the Indus by the end of this century. Many academics have confirmed that meltwater contributes more to the overall flow of the Indus than rainfall and thus the effect of climate change on the snow and glacial component is the primary driver of projected flows. Immerzeel (2010) emphasizes the importance of snow and glacial melt to the overall water supply in the Indus Basin, estimating that "discharge generated by snow and glacial melt is 151 percent of the total discharge naturally generated in the downstream areas." Singh et al (2006) modeled the meltwater runoff from a highly glacierized Himalayan basin and determined that for the study's small basin the contributions of glacier melt and rainfall in the total runoff are 87 percent and 13 percent, respectively. He concludes that on the long-term scale, greater melting of glaciers, such as those that supply the Indus, during the coming years is likely to lead to the depletion of available water resources and decrease overall water flows. Using various glacier models and scenarios, Immerzeel (2010) estimates an 8.4 percent decrease in mean upstream water supply from the upper Indus by 2050 due primarily to decreased meltwater, despite a 25 percent increase in mean upstream rainfall. Increased rainfall was also predicted by Akhtar et al (2008), who modeled portions of the Upper Indus Basin and estimates temperature and precipitation increases by the end of the 21st century, indicating a higher risk of flood problems under climate change.[40] Bhutiyani (2010) found that temperatures in the Northwestern Himalayas already show significant increasing trends in winter. Glacial melt is likely to first increase flows, then cause flows to decrease to below current levels. Immerzeel (2010) projects that initially glacial melt will increase summer and late spring discharges, but eventual meltwater decreases will lead to reductions in agriculture production (around the timeframe of 2046 to 2065) that will decrease the number of people that can be fed in the basin by 26.3 million.[41]

Qualitative values capturing water variability for the portion of the Indus in each country are summarized in Table 29. The two most important countries in this study are India and Pakistan by virtue of their borders containing the majority of the basin area and as the two signatories to the 1960 IWT. Both countries have either decreases or similar water variability through 2030. India’s already low variability is likely to continue in all but the 2050-wet scenario, which shows an increase from low to moderate. By 2030, Pakistan’s variability is predicted to decrease from moderate to low before returning to moderate in all 2050 scenarios. Afghanistan’s variability is likely to improve from current high levels according to all scenarios.

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[40] Akthar used the SRES A2 scenario simulated by the PRECIS Regional Climate Model and a range of glacier coverages (0, 50, and 100 percent) to estimate future discharge.
[41] Immerzeel (2010) used outputs from five general circulation models (GCMs) for the SRES A1B scenario over the period 2046 to 2065.

Table 28 Modeled runoff variability using projected changes in climate change under certain scenarios for the riparians of the Indus.

		Future Variability Change Class					
Riparian	Present Variability Class	2030-Dry	2030-Middle	2030-Wet	2050-Dry	2050-Middle	2050-Wet
Afghanistan	High	Moderate	Moderate	Moderate	Low	Moderate	Moderate
China	Moderate	High	Low	Low	Low	Low	Moderate
India	Low	Low	Low	Low	Low	Low	Moderate
Pakistan	Moderate	Low	Low	Low	Moderate	Moderate	Moderate

However, even if variability does decrease in coming years, fluctuations in flow will continue to be a factor in IWT relations, especially in times of flood and drought that tend to bring water issues to the forefront and amplify otherwise hidden problems. How effective the IWT mechanisms are at mitigating and managing potentially strained relations that might originate from flow variations will almost certainly be shaped by the broader relations between the two countries. Previously, many groups in Pakistan have associated (and laid blame for) water-related disasters with India regardless of whether or not the fluctuations in water availability were the result of natural climate permutations. For example, the August 2010 flooding in Pakistan resulted from unprecedented precipitation as reported by Pakistan's own Meteorological Department:

> "The Pakistan Meteorological Department report said that within one week in late July, KPK (Khyber Pakhtunkhwa Province in Pakistan) received 9,000 millimeters of rainfall - ten times as much as the province normally receives in the course of an entire year"(United Nations Office for the Coordination of Humanitarian Affairs (OCHA), 2010)

The precipitation data would seem to indicate that the majority of the flooding, if not all, was the result of increased precipitation within Pakistan and in the region of the IWT's three western rivers. The restrictions that the IWT places on India's construction on these rivers limit their potential to both mitigate and cause downstream flooding. Yet, the political nature of water events led to finger-pointing towards upstream, and even overhead, involvement:

> "… a rash of reports in the Pakistani media blam(ed) India, principally, for the massive floods, purportedly because New Delhi had deliberately diverted waters from dams in the Indian state of Jammu and Kashmir, and from the ones it "controlled in Afghanistan." Some reports also charged that the US was manipulating weather patterns over Pakistan"(Rajghatta, 2010).

While the above report does not reflect the official Pakistani government position towards Indian involvement in the flooding, it does show how water has become a political issue for those advocating Pakistan's hardline policies towards India. Official government policy and response towards India in times of water-related natural disasters is likely to be shaped by the political situation and influence of the hardline parties which will help dictate the extent to which IWT mechanisms are implemented.

The combination of the high mechanism scores from the Literature Review and only four climate-related incidents (despite generally sour relations between the signatories) indicate that the IWT is a strong treaty with high institutional resiliency that is likely capable of managing and mitigating complaints stemming from changes in climate. However, some weaknesses are apparent and worth discussing. The treaty is geared towards ensuring that new infrastructure conforms to treaty parameters rather than issues associated with variations in flow. Since the Indus tributaries themselves have been fully allocated, the coordinated measurement and management of flows are a lesser part of the treaty emphasis. While the countries are not likely to file complaints over flow allocations, projected flow increases due to glacial melt and additional flood threat may overwhelm the IWT's limited flood management capacity. Flood-related weaknesses in the *specificity* mechanism that were the source of the one clear-cut climate complaint may become more pronounced with a higher risk of flood problems under climate change.

The IWT is strong and efficient for relations between the India and Pakistan, but may be hampered by the lack of *scale* components that include local stakeholders and other relevant nations. International tensions are shaped and aggravated by domestic ones, and the IWT mechanisms are not designed to ameliorate local and regional tensions (Stimson Center, 2010b). Tributaries originating in Afghanistan, which have been more of an afterthought in the management of the overall basin and are not included in the IWT, will gain in importance as its flows decrease in variability while increases in variability will be seen from flows originating in the Himalayas. The lack of local and regional consideration in the *scale* mechanism may become more of an issue after 2050 when glacial resources are projected to diminish and populations in both countries could double.[42]

6.2.4 Tigris/Euphrates River Basin

The Tigris-Euphrates-Shatt al Arab is shared between Iraq, Iran, Syria, Kuwait and Turkey. Almost all the waters of the Euphrates and a large portion of the waters of the Tigris originate in Turkey and flow through Syrian territory before entering Iraq.

Relations regarding the rivers were generally peaceful and cooperative in nature until the 1960's when Turkey, Syria, and Iraq began developing the Tigris and Euphrates Rivers, including water storage, irrigation, and hydropower dams. In particular, the construction of the major development project known as the Southeastern Anatolia Project (or GAP) of Turkey (and to a lesser extent the Euphrates Valley Project of Syria, for irrigation) have served to increase tensions (Akanda, Freeman, & Placht, 2007; Aysegul Kibaroglu & Olcay, 2000). GAP is the largest development project ever undertaken by Turkey, and includes the construction of 22 dams and 19 hydroelectric power plants on the Euphrates and Tigris rivers in the Kurdish part of Turkey (Handcock, 2004). The GAP, if completed

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[42] Populations are expected to double by 2050 in Pakistan, according to the UN. http://esa.un.org/unpp/ According to India's Ministry of Health and Family Welfare, if India continues at the current pace it will double its population in the next 50 years. http://timesofindia.indiatimes.com/india/India-to-surpass-China-in-terms-of-population-by-2050-Govt-report/articleshow/6153912.cms#ixzz0z3wQ2AaY Both sites accessed 27 July 2010

as planned, provides Turkey extensive control of up to 40 percent of the Euphrates water currently flowing into Syria and 80 percent of the Iraq's Euphrates flow (Handcock, 2004). Syria and Iraq are understandably concerned over GAP and fear that reduced river flows will damage their own agricultural and energy projects. Presently, Turkey and Syria are continuing with their major development projects (including GAP), while Iraq has plans of its own. Iran's recent development projects on the Sirvan and Karun Rivers without an agreement with Iraq further complicates Iraq's allocations.[43] For the Euphrates River, the estimated percentages of water projected to be necessary for each country's development work are: Iraq 65 percent, Turkey 52 percent, and Syria 32 percent. These figures add up to 149 percent demand for the total Euphrates waters (Akanda et al., 2007).

All three countries realized early after the announcement of the GAP development plans that coordination and cooperation were necessary to manage the Tigris-Euphrates waters effectively. However, there was much conflict over allocation rights and data accuracy, with estimates of irrigable land and soil water requirements in each riparian country allegedly being skewed by the national experts that produced them (Aysegul Kibaroglu & Olcay, 2000, p.; pg.316). In 1983, Turkey, Iraq, and Syria established a Joint Technical Committee (JTC) to resolve such data disputes. The JTC aided in bringing the parties together, and two formal bilateral agreements to manage use were established in the late 1980s and early 1990s (although the JTC may have aided the agreements, conflict also necessitated their development). Soon after this, unfortunately, there was an impasse and no further progress was made in a multilateral management plan. The group has not met since the early 1990's.

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[43] As part of the Algiers agreement, Iran and Iraq equally divided the flows of the Bnava Suta, Qurahtu, and Gangir Rivers. Flows of the Alvend, Kanjan Cham, Tib, and Duverij are divided based on a 1914 commission report on the Ottoman/Iranian border "and in accordance with custom."

The treaty that is the focus of this case study is the Protocol of 1987 established between Turkey and Syria, which guaranteed an average annual flow of 500 m^3/s from Turkey to Syria. This treaty and its allocations had important regional implications and formed the baseline for later sharing agreements, including the Protocol of 1990 between Syria and Iraq, "which guaranteed that 58 percent of the Euphrates waters coming into Syria from Turkey would be released to Iraq by Syria" (Aysegul Kibaroglu & Olcay, 2000).[44]

Table 29 Key features of the Protocol of 1987

Important Mechanisms for Climate Complaints	*Specificity* and *Integrativeness*
Primary Agreement (TFDD ID)	999
Signatory	Syria, Turkey
Treaty Description	Protocol on matters pertaining to economic cooperation. This treaty concerns a measuring scheme, with fixed quantities recouped in the following period.
Date signed	7/17/1987
Years Enforced	21
Issue Type	Water Quantity
Text of Water Allocations	While filling Ataturk Dam, Turkey releases minimum 500cms on average annually at the Syrian border. If a monthly average falls below 500cms, Turkey will make up the difference the next month.
Water Allocation Method	Fixed quantities recouped in the following period.
Comments on Non-water Linkages	There are multiple areas of cooperation mentioned in this treaty, such as the linkage of electricity grids.

6.2.4.1 Background

6.2.4.1.1 Hydrology

The Euphrates and Tigris Rivers are respectively the first and second longest rivers in southwest Asia west of the Indus. Together, these two basins include an area of over 967,000 square kilometers (Kavvas, Chen, Anderson, & Ohara, 2010). Both rivers originate from precipitation that falls in the mountains of southeast Turkey, which

[44] As part of the 1990 protocol, Syria gets 42 percent of the water of the Euphrates River allowed to pass through the border between Turkey and Syria according to the 1987 agreement. Iraq gets the remaining 58 percent.

provides approximately 90 percent of the Euphrates flow (with Syria contributing 10 percent of total flow) and approximately 40 percent of the Tigris (with Iraq contributing 51 percent and Iran 9 percent) (Aysegul Kibaroglu & Olcay, 2000). Of the total flow of approximately 54 BCM leaving Turkey annually, 26 BCM flows to Syria as the natural outflow of the Euphrates and 21.3 BCM flows to Iraq as the Tigris (FAO Water, 2010). The flow regimes of the Euphrates and Tigris are seasonally dependent, with high discharge from March to June, and low discharge from July to October (MacQuarrie, 2004).

The Tigris has several significant tributaries, such as the Ilisu, Garzan, and Batman Rivers that combine for an average annual flow of 22 BCM at the border with Syria (Bilen, 2009; Kavvas et al., 2010). From the Turkish mountains, the Tigris River flows to the southeast, forming the border between Turkey and Syria for 30 km before entering Iraq. Originating in the Zagros Mountains, the Sirvan becomes the Diyala River in Iraq and meets the Tigris near Baghdad. The Tigris collects 25 to 29 BCM per year from its tributaries that originate in Iran and Iraq, totaling a yearly average flow of 50 BCM per year (MacQuarrie, 2004). Kibaroglu (2008) estimates that Iran contributes between 9.7 and 11.2 BCM through the northern tributaries and another 20 to 24.8 BCM to the Shatt al Arab waterway via the Karun River. Eventually, after flowing for 1,840 km, the Tigris joins the Euphrates River to form the Shatt al-Arab (Bilen, 2009).

The flow of many of the Tigris tributaries is irregular, and consequently many regions within the Tigris basin have historically been subjected to flooding. The only point above the Shatt al-Arab where there is a significant hydraulic connection between the two rivers is 100 km south of Tikrit (Iraq), where the Samarra Barrage diverts water into Lake Tharthar (Bilen, 2009). This manmade lake was completed in 1988 and is designed to mitigate flooding problems in Baghdad by taking excess runoff from the Tigris and diverting it to the Euphrates River (MacQuarrie, 2004).

Figure 23 Tigris-Euphrates Basin (UNEP/DEWA/GRID-Geneva, 2000; used with permission)

Originating in Turkey at the confluence of the Murat and the Karasu Rivers, the Euphrates River flows for 2,330 kilometers (Bilen, 2009). The Euphrates basin includes area from four countries: 28 percent lies within Turkey, 17 percent within Syria, 40 percent within Iraq, and 15 percent within Saudi Arabia. However, due to the drainage and precipitation patterns, Turkey contributes the lion’s share of the water (31.4 of 35

BCM, or 90 percent), with Syria contributing the remainder (Kavvas et al., 2010). Iraq and Saudi Arabia make no significant contributions to the Euphrates flow.

The flow in the Euphrates is highly seasonal and the temporal distribution often does not coincide with the irrigation requirements of the basin. The high drought standard deviation since the 1987 treaty was signed (2.4 compared to 1.8 for all treaties) illustrates the annual flow variability that can cause extreme shortfalls. The monthly flow of the Euphrates fluctuates between 16 and 530 percent of the monthly long-term average (Bilen, 2009). The Tigris annual flow variations are similar to the Euphrates.

The basin has a climatic environment composed primarily of dry, temperate, and cold regions. The majority of the basin falls in the dry climatic classification as defined by Köppen (FAO-SDRN Agrometeorology Group, 1997; TFDD, 2008; S. Yoffe et al., 2004). A dry desert climate with hot annual temperatures greater than 18 °C (Köppen classification of Dry, BWh) is found in about 33 percent of the basin. A total of about 16 percent of the basin is dry with semi arid grassland steppe and hot annual temperatures greater than 18 °C (Köppen classification of Dry, BSh). Temperate regions throughout the basin that include dry and hot summers with the warmest temperatures greater than 22 °C (Köppen classification of Temperate, CSa) make up about 24 percent of the total area. About 10 percent of the basin is cold, with a snowy winter and warm summers with temperatures greater than 22 °C (Köppen classification of Cold, Db).

The annual and seasonable variability make dams and reservoirs of primary importance to managing the Euphrates and Tigris Rivers. Some of the key dams on the Euphrates are: the Keban, Karakaya, and Ataturk Dams in Turkey; the Tabqa Dam in Syria; and the Haditha Dam in Iraq. The Ataturk Dam is one of the 10 largest dams in the world, with a total storage capacity of 48.7 BCM (Aysegul Kibaroglu & Olcay, 2000; MacQuarrie, 2004). For comparison, as of 2006, Turkey had 208 large dams with a total reservoir capacity of almost 157 BCM (FAO, 2009). According to measurements by Sahan (2001), if the GAP is fully implemented, the waters of the Euphrates will “decrease from the 30

BCM /year at the Syrian border before GAP to 16 BCM/year, and at the Iraqi border from the earlier 16 BCM/year to between 5 to 9 BCM/year."

6.2.4.1.2 Politics

Turkey views the 1987 and 1990 protocols as non-binding and relatively "soft" agreements, defining the rivers as "transboundary" and not international. Turkey's interpretation gives them more freedom on how to use the waters since it feels it has no legal obligation to share. Whether or not Turkey has altered its behavior meet treaty requirements is debatable. Turkey has mostly kept their obligations after 1990, but this may have more to do with the fact that "500 m^3/sec represents one-half of the Euphrates' average annual natural flow, which is Turkey's future consumption target" (N. Zawahri, 2006; p. 1048).

Each riparian tends to develop its water use plans unilaterally without considering the total water availability and without regard to the needs of the other riparians. This has caused a latent and occasionally pronounced condition of conflict over the Euphrates and Tigris rivers between Turkey, Syria and Iraq. The impetus for soured hydro-relations tends to be extreme drought or dam construction, resulting in reduced flows. The completion of the Keban and Tabqa Dams caused serious tensions among Iraq, Syria and Turkey in the 1960's and 1970's (N. Zawahri, 2006). In the beginning of 1990, the filling of the reservoir behind the newly constructed Ataturk dam started and caused the Euphrates flows to Syria to cease, prompting Syria and Iraq to protest.

> "Turkish President Turgut Ozal diverted the Euphrates river away from Syria and Iraq to fill the Ataturk dam that will power his nation into the 21st Century and help turn arid areas green. Baghdad and Damascus, which rely heavily on the Euphrates for hydro-electric power and irrigation, have expressed concern over the diversion" (TFDD, 2008)

Zawahri (2006; p. 1049) notes that "from 12 January until 13 February 1990, Turkey unilaterally stopped the Euphrates river at the Ataturk dam. The 119 m^3/sec that crossed the Turkish border came from minor tributaries feeding the Euphrates below this dam." The Turkish Ministry of Foreign Affairs later stated that Syria and Iraq had "been timely informed that river flow would be interrupted for a period of one month, due to technical necessity" at the November 1989 JTC meeting, and that Turkey had taken pre-emptive action to release more water for accumulation in downstream nations' reservoirs (Kaya, 1998). Yet, Syria and Iraq were apparently caught off-guard and accused Turkey of causing considerable harm; Iraq felt prompted to threaten to bomb upstream Euphrates dams (Kaya, 1998). Once the Ataturk Dam reached its operating capacity, flows across the border increased and the incident was resolved.

The rivers have occasionally been used as part of larger political action. One source of both tension and cooperation in the basin are national policies towards the Kurds (Handcock, 2004).[45] Threats of water restrictions, whether real or perceived, run across such religious and cultural boundaries. For example, an article from the Amsterdam Firat News Agency states:

> "19 May 2008 - Kurds are unable to utilize the Euphrates River that passes through Southwest [Syrian] Kurdistan. From this river, which has been forbidden to Kurds, water is being transported to Arabs by opening canals stretching to some regions of Raqqa, Derzor, and even as far as Aleppo. Water is being provided to all the Arab villages, but the Kurds are being left without water."

Turkey has been attempting to enter the European Union, but has been repeatedly rebuffed due to its poor human rights record, largely regarding the Kurds (Akanda et al., 2007).

Unless there is some outside motive or incentive, Turkey has almost complete *carte blanche* to manage the rivers as best benefits them. Turkey is in a state of hydrologic power and has no real water-based incentive to change the status-quo. Sahan (2001) notes that "Turkey dominates the international relationship over water resources in this area"

[45] Turkey's worry over the Kurdistan Workers Party (PKK) that was largely operating out of Syria in the late 1980s and 1990s almost led to war between the two nations. In 1998, Turkey accused Syria of supporting and harboring the PKK and only after Egyptian intervention did Syria agree to stop supporting the PKK (Akanda, 2007).

since it is the upstream country, has by far the highest GDP, and “strong international support in political and economic issues” (Sahan, 2001). According to the Delta Power derived from the three indices discussed in Chapter 4.2.4, Turkey and Syria have a Delta Power of 46, compared to an average of 35 for all treaties. Up until now, Turkey has probably played it somewhere in-between the positive and negative extremes of Zeitoun’s description of a hegemonic position: “From its position of superior power, the hydro-hegemon may choose to enforce either a ‘negative’ form of dominant hydro-hegemony, or a positive form of hydro-hegemonic leadership, whereby all riparians benefit” (2006; p.47).

Relations regarding the rivers have been tense, but openings for increased dialogue and cooperation may be emerging. Due to recent regional drought conditions in 2008-2009 and their subjugated hydro-status, Iraq and Syria have incentive to cooperate so that they have some standing and control over water quantity and quality. The U.S. presence in Iraq, while likely not providing incentive for cooperation, has caused political upheaval which may be conducive to change; the new Iraqi government is looking for a new water arrangement.

6.2.4.2 Complaint and Drought Index Summary

Since its signing in 1987, the Euphrates Treaty between Turkey and Syria has had over 45 complaints documented, only one of which was climate-related (TFDD, 2008). The minimal drought complaints may be partially explained by a lack of drought in the basin since it was initially signed in 1987 until 1999. The sole complaint lodged after 1999 was climate-related, and of the 45 total complaints it is the only complaint filed during a period of drought. The climate-related complaint was lodged in 2000 during a second consecutive year of drought that registered as the most severe since at least 1945. The PDSI in 2000 was -6.1, compared to an average of -1.4 since the treaty was signed in 1987. Overall, the basin has a large drought standard deviation of 2.4 since the 1987 treaty was signed compared to 1.8 for all treaties since their signing.

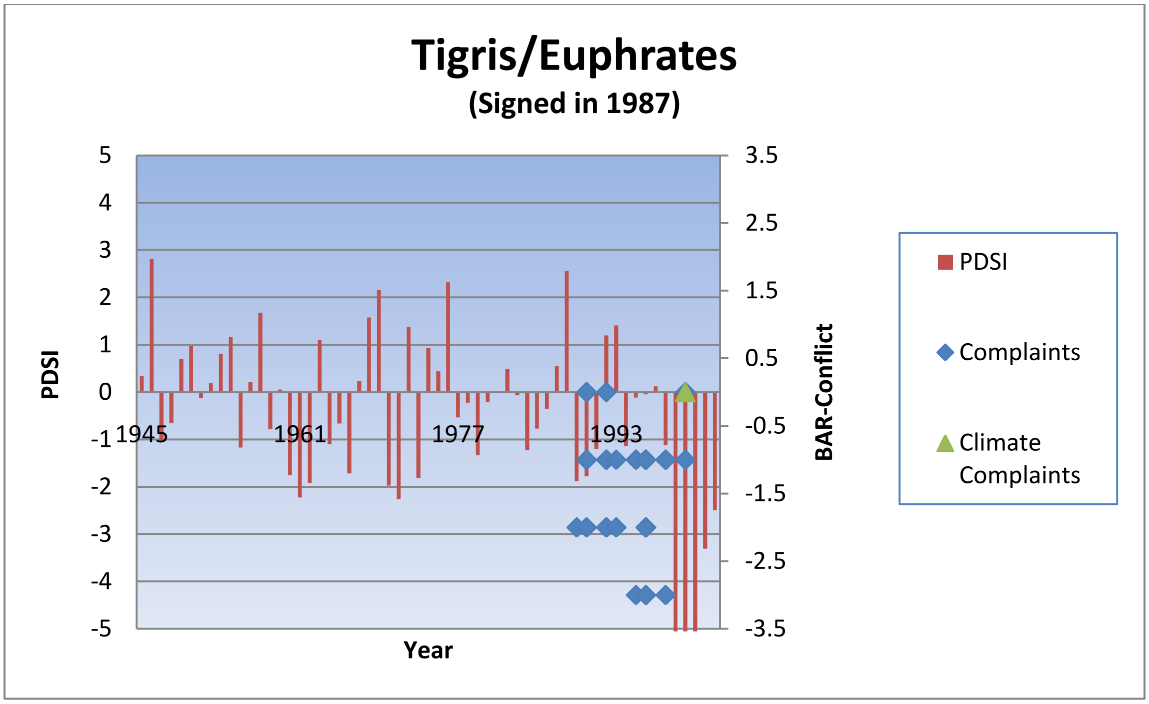

Figure 24 Complaints regarding the 1987 agreement and basin drought index (PDSI).

In 1999 and 2000, the upper reaches of the basin received only 55 percent of the average flow and reservoir levels reached as little as one fifth of their capacity (Warner, 2008). According to Zawahri (2006), Turkey did not meet the 500 m^3/sec allocation, as stipulated in the 1987 agreement, from late in 2000 until mid-2001. Syria's protests elicited a response of 'I cannot make the rain' from the Director of the DSI (General Directorate of State Hydraulic Works) (Zawahri , 2006). The August 2000 TFDD record of this complaint is stated as:

> "A shortfall in energy production has forced Turkey to stop supplying Syria with water beyond an agreed level, a senior Turkish official said. The decision was prompted by a decrease in the water level in the dams on the Euphrates river caused by an unusually dry season, which prevented hydroelectric plants from working at full capacity" (TFDD, 2008).

The 2000 complaint resulted not only from decreased supplies during severe drought, but also from the primary reason the GAP project was initiated: hydropower. Southeastern

Turkey generally has mild summers and severe winters, causing the hydropower production requirements to be highest in the winter when cold weather hits and household heating demands rise. During the fall and winter of 2000, warmer weather reduced heating and electricity demands resulting in less water being released by Turkey. Later in 2001 an abnormally warm summer increased electricity demands and pushed Turkey to produce more hydropower that consequently released more water to Syria (Warner, 2008). Zawahri (2006) quotes Caner Koncagul, the Turkish Ministry of Foreign Affairs, as saying, “weather patterns determine energy demands in Turkey. When the weather is warm, such as last winter (2001) there is less demand put on energy; as a result, there is less production of hydropower and therefore less water is released (downstream to Syria).”

6.2.4.3 Treaty Influence on Water Management and Complaint

To fully understand this treaty’s potential to manage conflict and variable hydrologic conditions, it is first necessary to examine its origins. The 1987 treaty stemmed from communications and political interaction surrounding the JTC, established between Turkey and Iraq after the Joint Economic Commission in 1980 (Kibaraglu, 2008; Bilen, 2009). Syria joined the JTC in 1983, after which and until 1993 a total of 16 meetings were held between Turkey, Syria, and Iraq (Kibaraglu and Warner, 2002). The JTC was primarily a fact-finding and communications mechanism to further a nebulous mandate that Bilen states as “…to decide the methods and procedures which would lead to a definition of the reasonable and appropriate amount of water that each country needs from both rivers (Tigris and Euphrates)” (2009). The JTC was essentially intended to create an allocation baseline from which negotiations of future agreements could begin. As part of the JTC, hydrologic, dam construction, and planned irrigation schemes were discussed (Bilen, 2009). The JTC, however, had no real power associated with it. Unilateral and uncoordinated water development continued, leading to still unresolved diplomatic issues over the usage of transboundary waters.

With the impetus of construction of the Ataturk Dam nearing completion and the filling of its reservoir looming, on 17 July 1987 Syria and Turkey decided to formalize their sharing arrangement and sign a protocol regarding flow on the Euphrates. At a Joint Economic Commission meeting with the participation of the Turkish and Syrian Prime Ministers, Turkey and Syria signed the Protocol of Economic Cooperation that states, "during the filling up period of the Atatürk Dam resevoir and until the final allocation of the waters of the Euphrates, Turkey would release 500 m^3/second of water," as an annual average to the Syrian border and compensate for the deficit in the following month if any month's average falls below this specified quantity (Turkish Ministry of Foriegn Affairs, 2009).

As can be discerned from the treaty text "until the final allocation," the 1987 protocol was regarded and designed as a temporary arrangement. As such, many of the mechanisms typically included in long-term water sharing agreements are absent in this treaty. Consequently, when the 1987 treaty is considered independent of the overall relations and arrangements between Syria, Turkey, and Iraq it appears to be an extremely weak treaty. The Literature Review score, which emphasizes the number of mechanism components, is 0.57 compared to an average of 1.84 for all treaties. It contains no mechanism components that address *scale*, *integrativeness*, *flexibility*, *uncertainty*, or *communications*. It does have a strong *specificity* mechanism, as well as a weak *enforcement* mechanism. Given that the regression analysis has a negative emphasis on *specificity*, it is not surprising that the treaty has a low regression score of -0.31 for Model 2, compared to an average of -0.18 for all treaties.

The high *specificity* score for this treaty stems from the inclusion of allocation and temporal components. Indeed, the treaty provides specific flow requirements and what could be considered a *flexibility* mechanism by allowing for a make-up period during the following month if flow thresholds are not met. Both of these mechanisms came into play with the 2000 event, but did not help to provide a solution to the complaint. The impact of the *specificity* mechanism was clearly evident. Syria and Turkey both agreed on the specific treaty parameters and they were uniform in their assessment that flow had dropped below the thresholds. However, this understanding prompted no real action and without any other mechanisms in place it may have been more of a liability than a management asset. Despite no *communications* mechanism, diplomatic discussions between the countries continued, but not at the technical level where practical solutions could have been realized. Syria became increasingly upset with the low flows, but with no *enforcement* mechanism in place they had no clear recourse. Turkey did not feel compelled to provide any alternative solutions, and without a clearly defined *flexibility* mechanism in place may not have had a clear way to do so. A lack of *integrativeness* meant that hydropower requirements were not taken into account, leading to Turkey's choice to fulfill their electric power needs first before considering Syria's downstream requirements. Finally, after the flows resumed, the lack of an *uncertainty* and *communications* mechanism were evident in the unclear reckoning of the discharge that crossed the border and Turkey's requirements to provide later compensation.

Many of the inadequacies of the 1987 Protocol could likely be overcome, or mitigated, by an effective JTC. The JTC is intended to deal with all water issues among the basin riparians and to "help to ensure that the procedural principles of consultation and notification are followed as required by international law" (Kaya, 1998). In this way, the JTC could provide additional strength to the *communications, enforcement*, *flexibility*, and *uncertainty* mechanisms. After the last official meeting in the 1990's and until recently, there is no evidence that the JTC has been a factor in relations, including during the 2000 event. The JTC, when it has met, is a forum for discussion, but does not wield any direct power to enforce existing treaties.

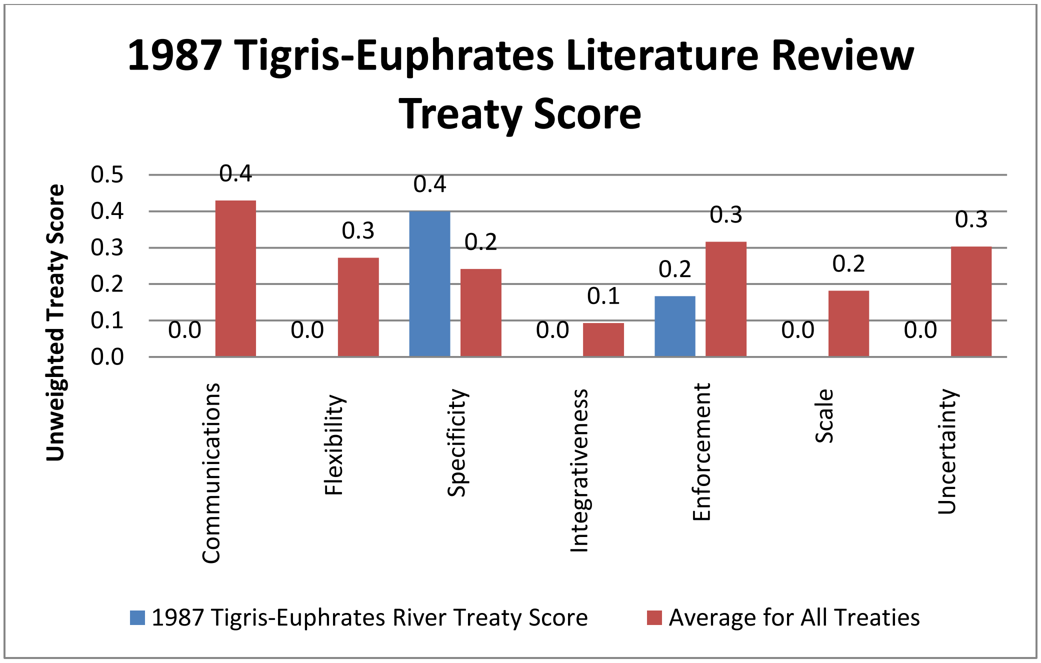

Figure 25 Tigris-Euphrates basin scores according to the literature-review based analysis. The 1987 treaty is relatively weak in all categories except *specificity*.

6.2.4.4 Outlook and Projected Impact on Water Resources From Climate Change

Recent projections from the IPCC indicate that precipitation in the Eastern Mediterranean that encompass parts of the basin will decrease by up to 20 percent (Bates, 2008), but specific projections of Euphrates flow are not provided. While acknowledging the difficulties in estimating discharge from rivers in arid areas like the Euphrates basin because of the sensitivity to water usage by irrigation and dams and high natural inter-annual variability, several researchers have conducted more detailed regional climate modeling that describe a negative climate impact on the Euphrates. Nohara (2006) indicates a 38 percent decline in annual mean discharge from the Euphrates, with the modeled impacts especially apparent during the high-water season.[46] Analysis from Evans (2009) indicates that the southernmost basin areas will experience a small increase in precipitation, but that the largest change is a decrease over portions of the basin in

[46] Nohara used a weighted average of 19 coupled atmosphere–ocean general circulation models based on the Special Report on Emissions Scenarios (SRES) A1B scenario.

Turkey, Syria, and Northern Iraq, with significant decreases seen in Western Syria and Turkey by mid-century.[47] While not addressing overall quantities, Bozkurt (2010) predicts shifts in the timing of Euphrates flow because of increased temperatures which limit snow cover and cause earlier spring melt in the eastern Anatolia region.[48]

Table 30 Modeled runoff variability using projected changes in climate change under certain scenarios for the riparians of the Tigris-Euphrates. Saudi Arabia and Jordan have minimal contributions to the basin and are not considered in this study.

		Future Variability Change Class					
Riparian	Present Variability Class	2030-Dry	2030-Middle	2030-Wet	2050-Dry	2050-Middle	2050-Wet
Iran	Low	Low	Low	Low	Low	Moderate	Moderate
Iraq	Low	Moderate	Low	Low	Low	Moderate	Moderate
Jordan	Moderate	Moderate	Low	Low	Low	High	High
Saudi Arabia	Low	High	Moderate	Moderate	Low	Low	High
Syria	Low	Moderate	Low	Low	Low	Low	Moderate
Turkey	Moderate	Moderate	Moderate	High	Low	Moderate	Moderate

Qualitative values capturing water variability for the portion of the Tigris-Euphrates in each country are summarized in Table 31.[49] For the countries who were party to the 1987 Treaty (Syria and Turkey), projections indicate that Syria's low variability is likely to continue in all but the 2030-dry and 2050-wet scenarios and that Turkey's moderate variability is likely to improve or stay the same in all but the 2030-wet scenario. Iraq's variability is predicted to increase in three of the six scenarios. Turkey, with its additional storage capacity with GAP, will likely be able to manage increased variability, but their release schedule will likely shift and be determined by their own hydropower and agricultural needs. Similar to the 2000 incident, Turkey's releases may have less to do with water availability and may be more of a result of temperature-driven hydropower demand. Temperatures in the basin are predicted to increase by up to 6^{o}C by the end of

[47] Evans uses 18 global IPCC models under the SRES A2 scenario.
[48] Bozkurt's climate change projections are based on SRES A2 scenario.
[49] For a more detailed discussion on the variability class determination, please see Section 4.3.4.

the 21st century, which will likely lower energy demand and decrease the amount of water released to downstream nations in the winter (Bozkurt, 2010).[50] Downstream Syria and Iraq will likely struggle with their own increased variability, while at the same time facing management challenges associated with Turkey's shifting release schedule.

The mechanism analysis indicates that the 1987 treaty has significant weaknesses that limit its institutional resiliency and ability to manage existing and predicted fluctuations in climate. A review of the practical application of the treaty confirms its design weaknesses. A limited *enforcement* mechanism, with no monitoring or prior notification article, did not provide Syria enough recourse to challenge Turkey's unilateral adjustments to its release schedule and is likely to be an issue in the future. With predicted increases in temperature, Turkey may again choose to withhold releases to accommodate shifts in its hydropower requirements that could result in negative impacts on downstream Syria.

Specificity components are found in 122 treaties in this study, but unlike the 1987 agreement most other treaties tend to account for specific requirements by including other mechanisms to increase adaptability. The high correlation between *specificity* and *flexibility* (Chapter 5.2) that exists in other treaties with climate complaints indicates that other treaties have accounted for the additional design requirements that high *specificity* requires. For the 1987 treaty, the high *specificity* score is a liability to relations without the supplementary *flexibility, communications,* and *uncertainty* mechanisms that could allow for Turkey and Syria to recognize and adapt to changes in available flow.

The mechanisms within the 1987 treaty are relatively weak and much of its potential to manage future stress depends on the JTC. The prospects for a strong JTC improved when meetings resumed in March 2007 after a nearly 14-year hiatus (Dogan, 2009). In February of 2009, the JTC met and the three nations agreed to share past, present, and future information regarding meteorological patterns and water quality in the Tigris and

[50] Based on the SRES A2 scenario.

Euphrates basins (Dogan, 2009). The three nations have also agreed to create a water institute consisting of 18 water experts from each country to work toward the “fair and effective use” of trans-border water resources (Yavuz, 2008). These meetings hopefully reinforce a weak *uncertainty* mechanism and a lack of a monitoring element that has caused not only the riparian states, but also scientists, to disagree about the mean annual discharge of both rivers, mainly due to their annual and seasonal fluctuations. The JTC still does not have *enforcement* capabilities for major issues, but has continued to be a conduit for complaint management.

Despite a weak treaty, the two nations have seemed to find ways to cooperate and manage any differences over water sharing that may bode well for the future. Recent JTC and other institute cooperation that extends beyond water issues highlights the potential for increased *integrativeness* capability, which is especially important in this basin. Water issues, while important, are often secondary to other issues with more political immediacy. Especially for Turkey, it is important to identify additional linked incentives that make water issues important enough to consider increased cooperation with downstream neighbors. Potential linked issues include cooperating with Iraq over oil and additional external funding that Turkey requires in order to finish GAP.[51] Since the World Bank and other international organizations do not support projects that are not based on an international agreement over shared water resources, increased financing for their project could provide strong incentive to increase cooperation (Akanda et al., 2007). Increased *integrativeness* is necessary not only for designing a more robust and long-term treaty that is capable of managing the hydrologic stress that is predicted in the basin, but also as an incentive for nations to finalize it’s signing.

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[51] Turkey has shown interest in allowing Iraq to utilize its port at Ceyhan as the terminus of a 450,000 barrel-a-day pipeline that carries about a third of Iraq’s total crude exports. http://www.hurriyetdailynews.com/n.php?n=iraq-turkey-renew-oil-export-deal-2010-06-17 Accessed 18 August 2010

6.2.5 Jordan River Basin

The Jordan River Basin includes areas of Israel, Syria, Lebanon, Jordan, Egypt and the Palestinian Territories. As the Jordan Basin and the Middle East as a whole are water scarce and have the majority of water conflicts, it is not surprising that the region is the most heavily studied in the world for water issues.[52] By as early as 1970, the region's available water resources were exceeded by the resources needed to meet its domestic, agricultural, and industrial needs; essentially, the "region 'ran out of water' and has since had to rely on creative solutions to adapt or import the food and other items needed for survival" (J. A. Allan, 2001). Water resources are particularly scarce for Israel (less than 300 m^3 of renewable water per person/year, Gaza and the West Bank (less than 100 m^3 per person/year) and Jordan (100 m^3 per person/year) (A. Jagerskog, 2003). Since the availability of renewable water in the basin is extremely low and both Jordan and Israel rely on the basin as their primary source of water, the determination of allocations in this region has a complicated, and sometimes acrimonious, history. Allocations are further complicated by rivers and groundwater that cross multiple national boundaries between countries that are often politically ill at ease with each other.

Three important water allocation treaties that have had climate-related complaints associated with them are assessed in this case study: the 1955 agreement from the Johnston Negotiations, which was never ratified, as well as treaties between Israel and both Jordan (1994 treaty regarding the Lower Jordan just below Lake Kinneret and the

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[52] Likely representing only a small fraction of the total effort, OSU's Middle East Water Collection maintains roughly 9,000 items on the subjects of politics and water in the Middle East. http://www.transboundarywaters.orst.edu/database/ A United Nations bibliography of books and journal articles published after 1993 has over 200 entries concerned with the political issues of water resources in the Middle East. http://www.un.org/depts/dhl/me_water.htm . A keyword search of the over four hundred entries in the OSU TFDD Water Cooperation and Conflict Bibliography revealed that approximately half of all entries deal with the region. http://osulibrary.oregonstate.edu/digitalcollections/tfdd/. All sources accessed 14 June 2010

Yarmouk River) and the Palestinians (regarding the sharing of water as part of the 1995 Interim Agreement).

Table 31 Key features of the Jordan Basin treaties considered in this case study

Important Mechanisms for Climate Complaints	*Specificity* and *Integrativeness*	*Communications* and *Enforcement*	*Uncertainty* and *Scale*
Primary Agreement (TFDD ID)	92	168	171
Signatory	Syria, Lebanon, Jordan, Israel	Jordan, Israel	Israel, PLO
Treaty Description	Johnston Negotiations	Treaty of peace between the state of Israel and the Hashemite Kingdom of Jordan, done at Arava/Araba crossing point. Annex includes table of dams of Yarmouk waters, their storage levels and capacities.	Israeli-Palestinian interim agreement on the West Bank and the Gaza Strip, with Annexes I to VII. Annex includes table of dams of Yarmouk waters, their storage levels and capacities.
Date signed	12/31/1955	10/26/1994	9/28/1995
Years Enforced	53-Never Enforced	14	13
Issue Type	Water Quantity	Water Quantity	Water Quantity
Water Allocation Method	Percentage	Fixed Quantities	Fixed Quantities
Text of Water Allocations	Syria: 132 MC (10.3%). Jordan: 720 MCM (56%). Israel: 400 MCM (31.0%). Lebanon:35 MCM. The three Arab states receive approximately 61 percent, and Israel approximately 39 percent.	Yarmouk-- Summer: Israel 12 MCM, Jordan gets the rest. Winter--Israel 13 MCM, Jordan gets the rest. Israel also takes 20 MCM for Jordanian storage in Lake Tiberias Jordan--Summer: Israel maintains current use, equal to Jordan's. Winter: Jordan 20 MCM of the floods Jordan also receives desalinated 10 MCM of approx. 20 MCM of saline springs. The two parties will cooperate to find an additional 50 MCM of drinkable water. Israel can take 10 MCM over and above its current groundwater withdrawals.	Israel recognizes Palestinian water rights. From Israel, Palestinians get additional water: Hebron, 1 MCM; Ramallah, 0.5 MCM; Salfit, 0.6 MCM; Nablus, 1 MCM; Jenin, 1.4 MCM; Gaza, 5 MCM. Palestinians provide themselves with 2.1 MCM to Nablus; 17 MCM (Eastern Aquifer) to Hebron, Bethlehem, Ramallah.
Comments on Non-water Linkages	US agreed to cost-share regional water projects if an agreement was reached. Small generating plants on the main canals to supply power for pumping. These power installations would not produce excess power for sale and are intended only to pump water to lands lying above the canal.		Israel bears capital development costs for new water deliveries
Conflict Resolution Mechanism	UN /Third party	Council	UN /Third party

The Johnston Negotiations, which led to the Johnston Plan for allocation between all riparians, occurred from 1953 through 1956, during which the United States, through Senator Eric Johnston, attempted the first international negotiations aimed at settling disputes over water rights in the Jordan Basin. Johnston's efforts to reach consensus regarding the joint use, sharing, and development of the watershed resources were approved but not ratified by all participating nations. The implementation of the treaty was derailed for a variety of reasons, including the lack of incentive for the Arab nations and a general political climate that was not conducive to cooperation, but the Johnston Plan did succeed in bringing the nations together to lay a baseline for allocations that has been generally adhered to and referenced during later complaints and treaty discussions (Wishart, 1990; pg. 536). The final allocations included annual allotments of 400 MCM to Israel, 720 MCM to Jordan, 132 MCM to Syria, and 35 MCM to Lebanon (A. Wolf & Newton, 2008).

Table 32 Johnston Plan water balance for the Jordan River system. Israel's portion is an average of the remainder after other allocations have been delivered.

	MCM per year				
	Flow/Recharge	Israel	Jordan	Syria	Lebanon
Original Johnston Plan For the Jordan River System (1955)	1,287	400	720	132	35

Though non-binding, the treaty has been used as a guide and followed by the riparian states as they proceed with basin development within their own countries. Perhaps most importantly, the discussions (though through Johnston's mostly virtual back and forth mediation between the capitals) fostered communication that has persisted to the present, with Israeli and Jordanian water officials meeting "several times a year, as often as every two weeks during the critical summer months, at so-called 'Picnic Table Talks' at the confluence of the Jordan and Yarmouk Rivers to discuss flow rates and allocations" (A. Wolf & Newton, 2008).

The 1994 Water Treaty was part of a larger "Treaty of Peace" between Israel and Jordan. The water portion of the 1994 Treaty between Israel and Jordan was at least partially built upon the Johnston Plan and states that Israel would provide approximately 50 mcm/year to Jordan from the surface water of the Jordan and Yarmouk Rivers and from the groundwater of the Arava Valley. The Israel Ministry of Foreign Affairs summarizes the water agreement as follows:

> "Israel and Jordan have agreed on allocations of water from the Jordan and Yarmouk Rivers and from Araba/Arava groundwaters. Israel has agreed to transfer to Jordan 50 MCM of water annually from the northern part of the country. In addition the two countries have agreed to cooperate to alleviate the water shortage by developing existing and new water resources, by preventing contamination of water resources, and by minimizing water wastage"(Israel Ministry of Foreign Affairs, 1994).

Specific water allocation rules between Jordan and Israel are stated in Article 6 and Annex II to the Peace Treaty signed by these two countries in1994. The general principle of water sharing of the Jordan River flow and the Yarmouk flow between Jordan and Israel is that one party gets a fixed quantity from a particular river and the other has the right to use the rest (Haddadin and Shamir, 2003). Article 6 regulates the sharing of a) the lower Jordan water, which consists mainly of outflow from Lake Kinneret and b) the flow of the Yarmouk, which is partially allocated to Jordan.

In 1995, one year after the peace treaty with Jordan, Israel signed an Interim Agreement with the Palestinian Authority (PA) that was intended to be a temporary arrangement until final peace negotiations could be conducted. The water portion of the 1995 agreement, part of Oslo II, promised additional water supplies for the "West Bank's Palestinian communities, with 23.6 mcm/year made available to meet the 'immediate needs of the Palestinians … during the interim period', while a further 41.4-51.4 mcm/year would be developed to meet the 'future needs' of West Bank Palestinian communities" (Selby, 2006). The water arrangements within Oslo II are contained in Article 40, which the World Bank summarized as accomplishing the following:

- "Set governance arrangements for a five year interim period, notably a Joint Water Committee (JWC) to oversee management of the aquifers, with decisions to be based on consensus between the two parties."

- "Allocated to either party specific quantities of the three West Bank aquifers underlying both territories - the share allocated to the Palestinian West Bank was about one quarter of the allocation to Israel and the settlements."
- "Provided for interim extra supplies from new wells and from Mekorot - an extra 28.6 MCM was to be allocated to Palestinian needs."
- "Estimated "future needs" for the Palestinian West Bank at 70-80 MCM" (World Bank, 2009).

6.2.5.1 Background

6.2.5.1.1 Hydrology

Eighty percent of this Jordan Basin is in Israel, Jordan, and the West Bank. Compared with other rivers of the world, the 230-km Jordan River is tiny, with a total natural discharge averaging around 1,600 MCM, more than 400 times less than China's Yangtze River (Mimi, 2003; A. Wolf & Newton, 2008).[53] Seasonal and annual variations are extreme, with only 3 to 4 percent of annual discharge occurring during the summer and autumn months, when water is needed most (Libiszewski, 1995). During periods of drought, flow can be reduced by up to 40 percent throughout the whole year (Libiszewski, 1995).

The majority of the Jordan basin is of the dry climate zone type (FAO-SDRN Agrometeorology Group, 1997; TFDD, 2008; S. Yoffe et al., 2004). A dry semi-arid grassland steppe with hot annual temperatures greater than18 °C (Köppen classification of Dry, BSh) is found in 29 percent of the basin. A dry desert climate with hot annual temperatures greater than 18 °C (Köppen classification of Dry, BWh) is found in about 24 percent of total area of the basin. A dry desert climate with cool temperatures typical of middle latitude deserts (Köppen classification of Dry, BWk) is found in 15 percent of the basin. A significant portion of the basin (21 percent) towards the east and northeast is

[53]China's embassy reports the Yangtze to have an annual average runoff of 951.3 BCM. http://np.china-embassy.org/eng/ChinaABC/dl/t167446.htm Accessed 7 September 2010

temperate, with dry and hot summers with the warmest temperatures above 22 °C (Köppen classification of Dry, CSa).

The Jordan River Basin has two important subbasins in terms of their contribution to water supply in the region and relevance to international water treaties: the Upper Jordan River and the Yarmouk River. The Upper Jordan River watershed is the most important source of water for Israel. It feeds Lake Kinneret (also: Lake Tiberius, Sea of Galilee), the main storage reservoir in the basin, from where Israel's distribution system, called the National Water Carrier, distributes water to the southern part of the country (Zentner et al., 2008). The main tributaries to the Upper Jordan are the Hasbani (also known as Snir or Senir), which originates in Lebanon, the Banias (also: Hermon) and the Dan, both of which originate from karst springs below Mount Hermon, and finally the Iyon (also: Ayun), which also originates in Lebanon (Zentner et al., 2008). About 450 MCM/year of Upper Jordan and Lake Tiberias waters are extracted and transported as far south as the northern Negev by the National Water Carrier (Mekerot, 2010).

Below Lake Kinneret, the Yarmouk River is the most important tributary to the Lower Jordan and is a primary source of water for meeting Jordan's national requirements. Figure 27 provides an overview of national borders, basin boundaries, and the most important tributaries with an annotation of their average annual streamflow quantities or average annual water use and allocations.

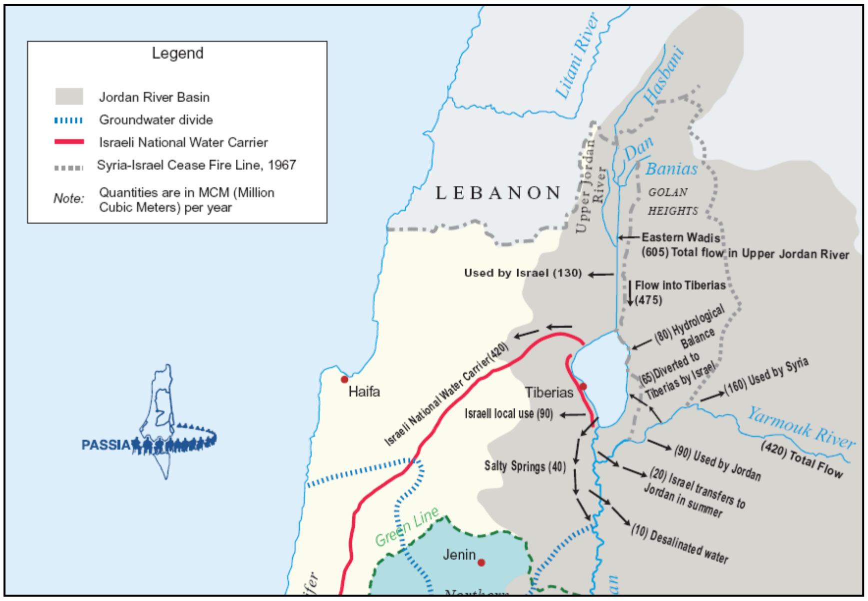

Figure 26 Jordan Basin key features and water contributions and allocations (Passia, 2010; used with permission).

The unimpeded annual flow of the Yarmouk River averages around 500 MCM/year, but varies from around 200 MCM/year in dry years up to 1,000 MCM/year in wet years (Itay Fischhendler, 2008a). The Yarmouk drains the Jordan Highland, characterized by “steppe vegetation on high, deeply cut limestone plateaus with an average elevation of about 900 meters, and discharges into the lower Jordan below Lake Kinneret”(Mongabay, 2010). Large elevation differences exist within the basin. The highest elevation in the watershed is 1,800 m above sea level, while the Jordan/Yarmouk confluence lies at 200m below sea level (Mongabay, 2010). USGS (1998) estimates average annual precipitation over the Yarmouk watershed to be about 423 mm and potential evaporation to vary from 1,600 to 2,300 mm per year. The Yarmouk watershed thus has a much drier climate than the Upper Jordan.

The natural flow of the Yarmouk has been altered by diversions, consumptive use, and numerous reservoirs before it reaches the Jordan. According to Green Cross Italy (2008), upstream Syria has built 37 dams on the Upper Yarmouk River with a total holding capacity of 211 MCM, of which 55 MCM are in violation of a water agreement signed by

Syria and Jordan in 1987. The same report by Green Cross Italy (2008) states that Syria's wells in the Yarmouk Basin negatively impact the base flow in the river, reducing it significantly.[54] In addition to Syria's withdrawals, in May 2003 Jordan and Syria began the construction of the Al Wehdah (Unity Dam). After the completion of the dam in November 2006, efforts to fill the reservoir and additional useage altered downstream flows. The countries planned that the reservoir would annually provide 30 MCM for irrigation and 50 MCM for the Jordanian capital Amman (Al Widyan, 2008; Ayadi, 2006; UNEP, 2009).

There are two key gauging stations on the Yarmouk relative to the 1994 treaty between Israel and Jordan. The Yarmouk is gauged at Maqaren (also: Maqarin) since 1964. The watershed area above this gauge is 5,950 km^2, and the elevation of the gauge is 12m above sea level (Zentner et al., 2008). Further downstream on the Yarmouk is the Adasiya gauging station with a catchment area of 6,790 km^2. Between Maqaren and Adasiya, a canal allows the diversion of water to Lake Kinneret (allocation to Israel and storage for Jordan, details in Table 34 in Chapter 6.2.5.2) (Zentner et al., 2008). According to the USGS (1998):

> "…annual volumes prior to 1967 were higher at Adasiyia than Maqaren, as expected for a condition prior to diversions. Since about 1971, annual volumes at Adasiyia have been much less than upstream at Maqaren during relatively dry years (when diversions can account for a large percent of the flow), but have been much higher than at Maqaren during wet years (when diversions account for only a small percentage of the flow). Similarly, the median monthly volume at Adassiyia is less than at

[54] As a side note to this case study, part of the initial attempts to use gauged data to determine treaty compliance in Section 4.2.4, the Jordan basin was selected as a case study area for having a long record of water studies. Nevertheless, the application of several methods encountered considerable data constraints. Due to strong modifications to natural flows by regulations, diversions, abstractions, etc. and only short and unreliable data from the Yarmouk, none of the different methods to model probabilities of failure to meet allocations could be fully applied. This led to the use of the PDSI data to estimate periods of hydrolgic stress and treaty non-compliance.

> Maqaren for all except the highest runoff months of January, February, and March."

The main groundwater within the basin comes from the Mountain Aquifer, which lies mostly underneath the West Bank. Estimates of aquifer potential vary from 600 MCM per year to 900 MCM, but an annual recharge of about 630 MCM is most realistic (Libiszewski, 1995). In the Mountain Aquifer underlying the West Bank, Israeli and Palestinian overconsumption has lowered the water table, reduced well pressure, and decreased spring discharge. Since the Palestinians in the West Bank have mostly shallow wells, "a falling water table is a more serious threat to Palestinians than it is to Israel" (Mark Zeitoun, 2008).

6.2.5.1.2 Politics

Politics and hydrology are closely tied together since shared waters are so important to Jordan, Israel, and the Palestinian Authority. Jordan relies on surface waters of the basin for 75 percent of its water and Israel for 30 percent (FAO Water, 2010). Israel receives more than 50 percent of its water from sources outside its pre-1967 borders, with more than 30 percent supplied by occupied territories (FAO Water, 2010). Land rights, perhaps the most volatile issue between the nations, is tied to water since the water that it holds often determines the value of the contested land.

Israel and the Palestinian Authority have signed three water allocation and management agreements including the Oslo I Agreement in 1993, the Cairo Agreement in 1994, and the Oslo II Israeli Palestinian Interim Agreement in 1995. The politics of groundwater is important to these treaties, especially the 1995 agreement between Israel and the PA where it is more relevant than surface water. Palestinians do not receive any water from the Jordan River and groundwater provides nearly all of their water supply.[55] More than 50 percent of Jordan and Israel's renewable supply comes from groundwater (FAO

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[55] Groundwater provides most of the Palestinians' water that is not provided/sold by Israel as part of the Interim Agreement.

Water, 2010). The Mountain Aquifer generally flows towards Israel in the west and north and discharges as natural springs outside of the disputed territories. The aquifer flow path creates an upstream and downstream riparian dilemma, with “Israel historically claiming more than 80 percent of downstream Mountain Aquifer resources” (World Bank, 2009).

The examples used in the rhetoric of ‘water wars’, where violent conflict between nations over the preservation or attainment of water is a primary military or political goal, inevitably include the Jordan Basin. And indeed water has been the impetus for several military conflicts in the region: of the seven total incidents in modern history where armed conflict was a factor, two were in the Jordan Basin (Wolf, 1998). The potential for conflict and the need for developing a water-sharing strategy for the whole basin was recognized with the creation of Israel in 1948. Unfortunately, several proposals to mitigate conflict, including the 1955 Johnston Plan**,** were not completely adhered to, leading to unilateral water development projects that added tension between the neighboring states of Israel, Jordan, and Syria.[56] Water-related infrastructure has been a military target during numerous skirmishes throughout the course of Israel’s history. Between 1951 to 1953 and from 1964 to 1967, political objections developed into several military confrontations including Israel’s attacks on Syrian water diversion projects and the occupation of the Golan Heights (Wolf 1998; Fishendler, 2008).

While there are elements of conflict, sometimes violent, between Israel and the Palestinian Authority and its other Arab neighbors, compared to the broader political situation the resolution of water issues can generally be viewed as a positive area of cooperation. Despite general cooperation, formal agreements have been difficult to complete as broader political hostility has complicated and caused discord during

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[56] Of the many controversial projects within the basin during the 1950’s and 1960’s, Jordan and Syria’s plans included the Greater Yarmouk Project that envisioned a canal running parallel to the river, a diversion plant to prevent the Jordan River headwaters from reaching Israel, and two dams, at Mukheiba and Maqarin (Unity Dam). Israel’s plans included the diversion of basin waters throughout the country by their National Water Carrier, which was completed in 1964 (Fishendler, 2008).

negotiations. It took nearly 40 years to come to an agreement with Jordan over their shared water. Between Israel and the Palestinians, water remains as one of five primary, unresolved issues for a final peace agreement--along with Jerusalem, territorial boundaries, settlements, and refugees (Mideastweb.org, 2010).

Much of the political interaction over water centers on both Jordan and Israel's securitization of the resource and their attempts to protect their jurisdiction over water resources. Israel wants Jordan River sources, both ground and surface waters, outside of its boundaries to flow relatively unobstructed. For example, at least part of its interest in the Israeli part of the Jordan Valley (including the Sea of Galilee) and Golan Heights is control of its quantity and quality of the water. For its dealings with Syria over the Golan Heights, the essence of a potential tradeoff in negotiations is "Syria gets the line, Israel gets the water" (Brzezinski, 2010). While the water of the Golan Heights (as one of the three primary sources of the Jordan River and about 20 percent of its flow as it enters Lake Tiberius) may not have been a primary reason for the Six Day War of 1967, the water associated with the land certainly seems to be a reason to maintain the Golan Heights.

6.2.5.2 Complaint and Drought Index Summary

There are a total of 108 complaints (11 of which are climate related) from the period of 1953 to 1999 associated with the three case-study treaties. All of the climate complaints are after 1994, with nine of the climate complaints filed during a severe drought that extended from 1998 to 2001. The climate complaints for each treaty and the influence of the relative PDSI are discussed below.

1955 Johnston Agreement: The treaty was not ratified by the Arab states and does not bind the nations to specific allocations or any real action. However, for many years it was the only formalized allocation arrangement for the basin and any conflict between the nations over Jordan water has typically referred to the 1955 treaty. There are a total of 19 TFDD complaints associated with the 1955 Treaty, but only one, in 1997, is climate-related. The PDSI of -0.3 during that year did not indicate dry conditions, with an index that was below the treaty average of -0.4 since it was agreed upon in 1955. In this case, the lower drought index likely indicates a slightly wet period with increased flows, leading to the complaint, by Jordan to Israel, that was geared more towards climate-related winter floods than decreased water availability (TFDD, 2008). The complaint was mild and it prompted no resolution or action taken to address winter flood management.

1994 Peace Treaty Between Israel and Jordan: The 1994 treaty has nine climate-related complaints and 24 total complaints; both totals are the highest of any of the three Jordan basin treaties in this case study. Though the water shares defined in the treaty are small with respect to the long-term average annual river flows, there are evidences of difficulties to meet the established agreements due to adverse climate-conditions with at least nine complaints since the signature in 1994. The TFDD has records of references to climate-related difficulties in the fulfillment of the treaty in 1994 and 1999. Two of the complaints were from 1994 and related to the treaty design and its ability to manage climate-related stresses, rather than from drought conditions that directly influenced the complaint. The 1994 complaints, while requiring no resolution and not prompted by hydrologic stress, nonetheless were related to treaty weakness regarding drought-management and were indicators of the problems that emerged with the 1999 complaints. The other seven of the climate complaints related to climate stresses are from 1999, which was the worst drought year on record, with a PDSI of -5.7 compared to an average of -0.16 since 1945. Table 34 summarizes the terms of the 1994 agreement regarding the Yarmouk River, as well as a summary of the 1999 events where the terms were challenged by one of the parties.

Table 33 Climate complaints challenging the 1994 agreement (TFDD, 2008).

Country	River	Date	Treaty/ Political Event	Specifications
Israel-Jordan	Yarmouk	26/10/1994	Treaty of peace between the state of Israel and the Hashemite Kingdom of Jordan	*Summer* (May15-Oct 15): Israel pumps 12 MCM, Jordan gets the rest. *Winter* (Oct16-May14): Israel 13 MCM, Jordan gets the rest as long as Jordan concedes to Israel an addition 20 MCM from the Yarmouk in winter in return for Israel conceding to transferring to Jordan during the summer period 20 MCM from the Jordan River. Both countries are entitled to excess flood water downstream of Adassiya Diversion (point 121).
		1994	Two events	Example: Complaints are in regards to treaty weakness. "The addendum does not cover distribution of water between the 2 countries in a drought year. Remarks give rise to fears of confrontation with Jordan on water issue in event of low precipitation in Lake Tiberias & al-Yarmouk reservoirs during dry winter."
		1999	Seven events	Drought Driven Complaints. Example: "Israel announces that due to drought it can only provide 40% of annual allocation of Yarmouk water. Jordanian Information Minister states that Jordan "rejects any change" in the terms of the treaty."

The seven 1999 events all are related to Jordan's complaints against Israel regarding their treaty-stipulated requirements to store 20 mcm of water in Lake Tiberius during the winter and then return it during the summer. In March of 1999, Israel said it was not able to collect the 20 MCM from the Yarmouk during the winter because of regional drought, which the Food and Agriculture Organization described as the **"**worst drought in decades" and "unprecedented" (FAO/FEWS, 1999). Indeed, the drought affecting the region between 1998 and 2001 was of unusual climatic and hydrologic severity, causing the levels of Lake Kinneret to fall to the lowest levels ever recorded and the annual flow of the Jordan River to reach its lowest levels in the 50-year hydrological record (Inbar, 2004). In April of 2009, the Government of Israel declared an official drought emergency, stating that the 1998/99 winter season registered the lowest amount of rain since 1850, and introduced a 40 percent cut in water allocation to farmers (Edie, 1999). The drought severely reduced food output in Jordan, which was already vulnerable to agriculture deficiencies due to limited financial capacity to increase food imports as a result of high unemployment and reduced GDP (FAO/FamineEarlyWarningSystem, 1999). The drought spurred Jordan to seek emergency assistance from the United Nations World Food Program (WFP) (Saleh, 1999).

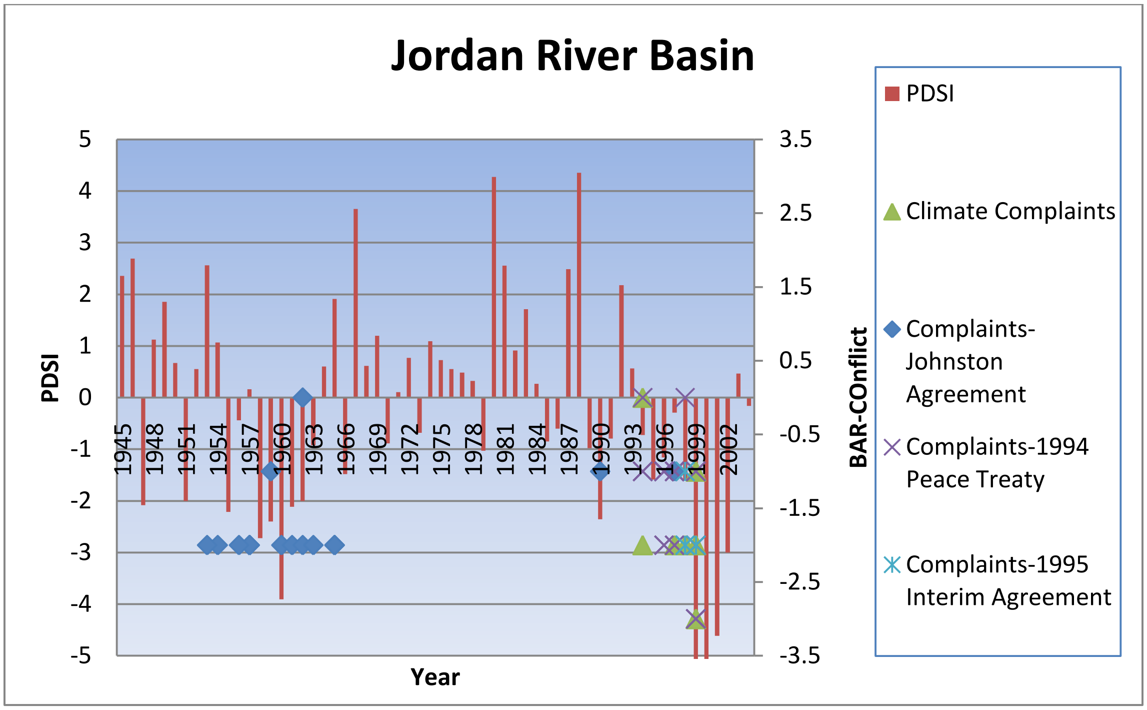

Figure 27 Jordan Basin complaints for each treaty and drought index (PDSI) history. The majority of the climate complaints occurred during severe drought in 1999.

Israel responded to the drought by suggesting a temporary 40 percent cut of water allocations to Jordan, although a formal announcement stating such was not made by higher levels of the Israeli government. Jordan insisted on obtaining its full share as stipulated in the treaty (Khatib, 1999). After reaching the upper levels of government, including the King of Jordan and senior Israeli cabinet members, the crisis was resolved when Israel supplied the full amount of water (J. A. Allan, 2002; A. Jagerskog, 2003).

1995 Interim Agreement between Israel and the PLO: This agreement has three total complaints, one of which has a minor climate-related component. The climate-complaint from 1998 was during a year of relative drought, with a PDSI of -1.6 compared to an average of -0.16 since 1945. The complaint notes that Palestine was facing a major water shortage; however, the core issue was less related to climate and more about the PLO's belief that Israel had plans to increase diversions from Lake Tiberius that could influence the amount of water received by the West Bank.

> "Israel plans to change the course of the upper Jordan River water which flows into Lake Tiberias have recently been exposed. Plan calls for diverting the water course before reaching Lake Tiberias…Engineer & deputy head of the Palestine Water Authority, Ka'wash, said diverting river's course means pre-determining negotiations and depriving Palestine from benefiting from its share of the Jordan River…All Israel measures are illegal, as no basin-party can undertake harmful unilateral action under international law" (TFDD, 2008).

The complaint appears to have been in regards to planned construction that eventually did not take place and is curious in that the Palestinians have no direct access to the Jordan along the West Bank as Israel declared a strip of land along the river a Closed Military Area (McCaffrey, 2007). It is unknown whether drought conditions were circumstantial or contributed to either the planned construction or the accusations of treaty violation. In either case, the issue was resolved without further disagreement or involvement of higher levels of government.

6.2.5.3 Treaty Influence on Water Management and Complaint

All three treaties had climate-related complaints associated with them, but the complaints for both the Johnston Agreement and the 1995 Interim Agreement were relatively minor and their origins and resolutions did not directly relate to the design or mechanisms within the treaties. Only the 1994 agreement between Jordan and Israel had complaints that directly related to the treaty. However, each of these treaties in some way is associated with each other and displayed overlap in the management of the complaints. While the below discussion is centered on the complaints associated with the 1994 agreement, the strengths and weaknesses of all treaties and their inter-relatedness with each other are discussed.

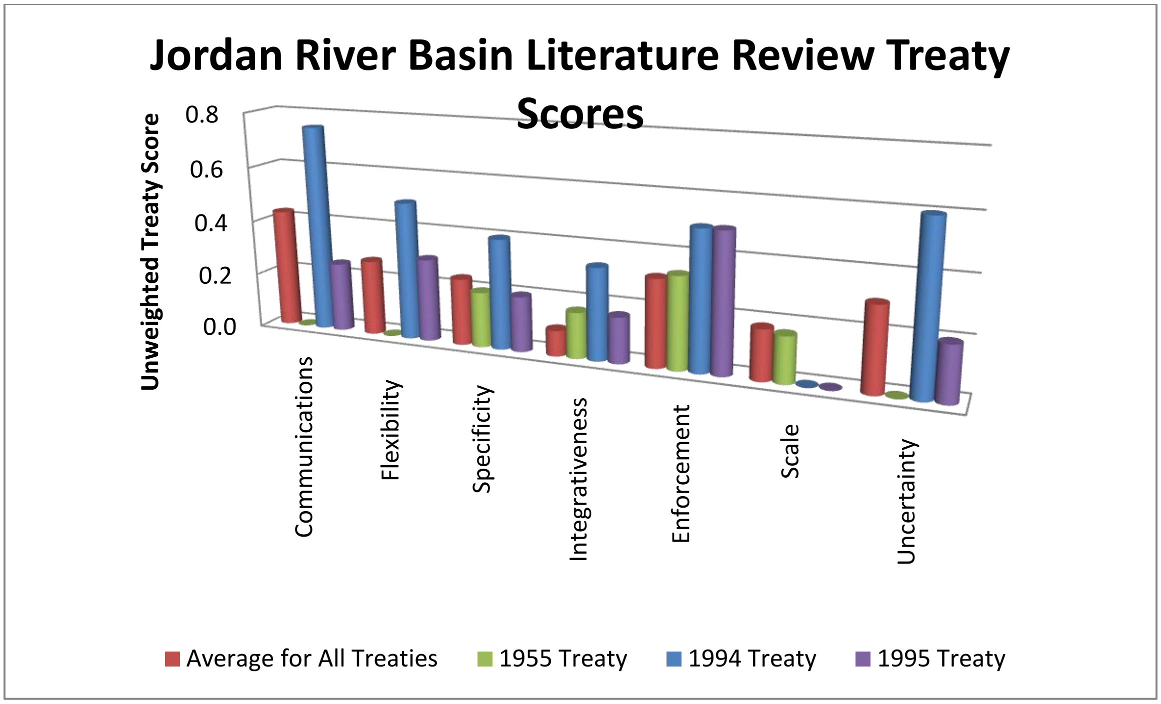

Figure 29 Jordan Basin scores according to the literature-review based analysis. Notice the low *scale* scores the 1994 and 1995 treaties.

Overall, the 1994 treaty had the strongest Literature Review score of 3.08 (compared to an average of 1.84 for all treaties in the study) indicating that it contains the most overall mechanisms. Of the three treaties, the 1994 treaty individual mechanism scores are equal to or higher than the other treaties for all mechanisms except for *scale*. While all three treaties were weak in the *scale* mechanism, lacking components such as the consideration of the requirements of the local population, only the 1955 Johnston Agreement attempted to include all riparians and the entire basin as part of its management purview. The other treaties of 1994 and 1995 were bilateral agreements that did not incorporate the requirements of all riparians and only included the shared waters of the relevant countries. Since the regression analysis especially emphasizes *scale*, along with negative emphasis on *communications*, *integrativeness*, and *specificity*, the Johnston Agreement was the strongest according to both regression models, with a Model 1 score of 0.05 compared to an average of -0.05 for all treaties.

Much of the strength of both the 1994 and 1995 agreements comes from the establishment of Joint Water Committees to manage and implement the treaty. While there are still issues over the equity of the decision-making powers, the Joint Water Committee (JWC) established by the 1995 agreement has integrated the PA into what was previously the Israeli-controlled water and sewage sector in the West Bank. The agreement states: “All licensing and drilling of new wells and the increase of extraction from any water source, by either side, shall require the prior approval of the JWC.”

Since there is overlap in the water resources for both treaties, the mechanisms and JWC for each treaty also have indirect influence on the other. For the Palestinian complaint in 1998 regarding planned construction on the Upper Jordan, the management and solution of the complaint should have been solely associated with the primary parties of Israel and the PA, and the mechanisms within the 1995 Interim Agreement. However, Jordan impacted the development of the complaint.

> “…Jordan Water & Irrigation Minister Haddadin said we are prepared to assist in settling problems of the Jordan River. We would have rejected the plan anyway had it been suggested to us, he added” (TFDD, 2008).

The accusations of planned construction, initiated by the Palestinians, were addressed by the Jordanian ministries. Ostensibly, this complaint should have been solely in the purview of the 1995 agreement, but in this case, there was overlap with the 1994 treaty. The *communications* and *enforcement* treaty mechanisms from both the 1994 and 1995 treaties, mainly in the form of the Joint Water Commissions and their associated ministries, likely played a role in mitigating further escalation of the conflict.

The 1955 Johnston Agreement paved the way for much of the success seen through the 1994 and 1995 agreements. However, the lack of *specificity* and *integrativeness* emphasis regarding several areas of water management, including flooding and groundwater, has filtered down and had repercussions that are exhibited in complaints with both treaties. The 1997 complaint referenced the lack of flood-management mechanisms in the 1955 Johnston Agreement, but has similar implications for the 1994 Peace Agreement. Neither treaty deals with flooding issues, other than from a water allocation perspective to fully utilize "excess floods that are not usable and that will otherwise be wasted," as stated in the 1994 agreement.

Along with flooding, the lack of groundwater issues within the agreement has had long-term impact on relations, especially between Israel and the Palestinian Authority, as discussed below.

The 1995 Interim Agreement is held up as a model in many discussions for its coordinated management and cooperation. Others point to a lack of true equality and consider it to have promoted weak governance and mismanagement in the Palestinian water sector (Selby, 2006). The perception that the treaty has largely been ineffective is bolstered in this study by weak overall treaty scores, which are below average for both regression models and the Literature Review.

A seemingly strong, above average *enforcement* mechanism within the agreement (a 0.5 compared to an average of 0.32 for all treaties) has design flaws that some studies conclude has allowed continued Israeli unequal control of water resources (Zeitoun 2008; Selby, 2006). The1995 Interim Agreement supposedly allows for more equitable sharing by establishing joint management of water resources via the Joint Water Commission. However, Palestinians allege that a clause in the 1995 agreement allows Israel to unilaterally veto any Palestinian water project which, combined with a lack of Palestinian funding, gives Israel control of the majority of deep wells and greater access to aquifers in the West Bank. An April 2009 World Bank report confirms that considerable disparity exists in water use from regional aquifers, stating that Israel overdraws up to 50 percent more than its quotas established by the Oslo II Agreement (World Bank, 2009). Despite efforts towards equitable use and a seeming strong ability to enforce the treaty, the large differences in power that exist between Israel and Palestine apparently have impacted its design and implementation.[57]

Identifying and solving the apparent residual inequities is hampered by a high level of uncertainty regarding Israeli and Palestinian water availability and use, most of which comes from groundwater. Such problems with groundwater management are not unique to the Jordan Basin. Globally, attempts to govern groundwater in a sustainable manner have achieved only limited success. The efficient use of groundwater has two key aspects: knowledge of aquifer parameters and the development of an effective management system (Foster, 1998). The 1995 treaty, unfortunately, does not address either of these elements, as evidenced by weaknesses in its *uncertainty*, *scale*, *flexibility*, and *enforcement* mechanisms. Based on the Literature Review scores, the treaty has only limited ability to address *uncertainty*, with a score of 0.2 compared to an average of 0.3 for all treaties. Concerns over uncertainty are not explicit in the treaty, and alternative scenarios, prediction models, and variability management are not included. Monitoring, the sole *uncertainty* attribute present in the treaty, is hampered by the lack of effective *enforcement* mechanisms. Water use and well-drilling in Israel is strictly monitored and enforced, but the Palestinian Water Authority in the West Bank is unable to impose the same level of efficiency. A significant number of West Bank Palestinians drill unlicensed wells or illegally connect to water pipelines (World Bank, 2008).

The issues with uncertainty could perhaps be overcome with increased flexibility within the treaty that allows for more efficient incorporation and application of data as it becomes available. While the treaty's *flexibility* score is average, its sole attribute is the JWC. The treaty does not have an amendment or adaptability mechanism to consider fluctuations in underlying drivers such as rapid urbanization, geopolitical factors, and poverty. This mechanism is particularly important since the basin's groundwater management is "sustainable only from a narrow technical perspective" that doesn't

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[57] According to the Delta Power derived from the three indices discussed in Section 4.2.3, Israel and the PA have an extremely large delta of 76 compared to 35 for all treaties.

include growth and neglects the environmental and third party impacts of overexploiting the groundwater system (Kallis, Kiparsky, & Milman, 2006; Selby, 2006). While the JWC is a strong *flexibility* mechanism and can address some of these issues, it is hampered by the lack of equitable *enforcement* and *uncertainty* mechanisms discussed previously.

The 1995 treaty does not have any attributes that address *scale* issues. Since groundwater is difficult to monitor and relatively easy to surreptitiously extract, optimal groundwater governance requires the cooperation and buy-in of all users. Management of groundwater especially occurs at all levels, from local to regional, and also involves all stakeholders. The treaty also has an average *integrativeness* score due to its linkages to the overall Oslo II Agreement, but it does not address the need to link several issues together such as surface water, ecology, agriculture, and climate change.

The 1994 Peace Agreement between Jordan and Israel appears to be a strong and robust treaty, with the exception of *scale*. Strong *flexibility, enforcement,* and *communications* treaty scores were evidenced in the successful handling of the drought conditions and subsequent complaints in 1999. The *enforcement* mechanism, with a score of 0.5 compared to 0.32 for all treaties, was utilized to attain a resolution after reaching the highest levels of governance.

According to some scholars, the overall strong 1994 treaty is limited by a joint Jordanian and Israeli choice to deemphasize the issue of provisions in the event of drought (Jagerskog, 2003). The treaty does not include rules for drought management or exceptions for water shortages, which would seemingly lead to conflict during periods where the treaty provisions are not met. In the case of the 1999 complaints, the complaints were over very specific allocation amounts and a resolution was reached after the *enforcement* mechanism engaged. Here, the complaint was not solved due to the strength of the *flexibility* mechanism, but the strong *flexibility* mechanism has been evidenced by a temporary agreement that was achieved in May 1997 to address water availability issues in Jordan during a short-term dry spell. Furthermore, ambiguity in the treaty may provide added *flexibility* in some cases. Despite a high *specificity* score that contains a temporal and allocation component with specific absolute quantities, there is room for interpretation. Precisely defining the timeframe, magnitude, and delivery location of the allocated water volumes can be difficult due to ambiguity in its wording (Fischhendler, 2008). In Table 35 below, Fischhendler's summary of the different interpretations of several of the 1994 agreement terms are shown.

Table 34 The role of ambiguity in differential water accounting for the water Israel concedes to Jordan under the 1994 Peace Treaty

Water Israel concedes to Jordan from different sources	The role of ambiguity in the differential accounting	Israeli accounting (in mcmy)*	Jordanian accounting (in mcmy)*
Yarmouk	Not stating the historical water use of Israel	0–20	55–95
	Not defining the legal status of the exchange water		
Sea of Galilee	Not defining the legal status of the exchange water	0	20–50
Storage on the Yarmouk	The storage capacity of the dam is not specified	0–30	30
Storage on the lower Jordan River	Not defining the meaning of 'average minimum'	0–20	20
	Not defining whose water use precedes the other's		
Lower Jordan River	The water available on the southern Jordan is not specified	0	40
	'No harm' is not defined		
Desalinization of brackish water	No ambiguity	10	10
Additional water to Jordan	Not specifying the cost-sharing of the additional water	Around 25	50
Total		35–105	225–295

*The range is due to different Israeli and Jordanian sources (Fischhendler, 2008; used with permission).

Analysis of All Jordan Basin Complaints

An analysis of 108 Jordan Basin complaints relative to all six treaties in this study (including those outside of the 1955, 1994, and 1995 treaties) was reviewed to determine the issues and causes of the complaint. As part of the review, each complaint was compared against the seven treaty mechanisms to determine which mechanism is of primary and secondary importance to managing the complaint (due to either the presence or absence of a mechanism in a treaty). For example, the following event from the TFDD that occurred in August 1997 had *integrativeness* labeled as the primary mechanism since land and construction disputes were tied to the complaint:

> "Israel confirmed Sunday it will build a reservoir dam on the al-Yarmouk River in territory claimed by Syria, in cooperation with Jordan, at the recommendation of Infrastructure Minister Sharon. Sharon spokesman Gissin told AFP that "Israel, Jordan, & foreign companies are doing the preliminary work at the site & then will begin construction." Syria has demanded the return of the Golan Heights as the price for peace with Israel" (TFDD, 2008).

When considering all Jordan basin complaints, *communications* was the mechanism most often relevant. Of the 108 total events for the six Jordan treaties, *communications* was a primary or secondary factor in 59 complaints. The 1955 Johnston Agreement (which although never implemented would have been in the best position to ameliorate most of these complaints) had no *communications* attributes that would have been of benefit, with a mechanism score of zero. *Flexibility* (25) and *enforcement* (21) as well as *integrativeness* and *specificity* (both with eighteen complaints) were also important to the overall complaints within the basin. The majority of the complaints considered were before the signing of the 1994 and 1995 treaties, which both have strong, relevant mechanisms, including above average *enforcement* and *flexibility* capabilities that would have been influential in managing several of the complaints. The 1994 treaty also has a strong *communications* mechanism, with requirements for prior notification, a joint management body in the JWC, and provisions for information exchange.

6.2.5.4 Outlook and Projected Impact on Water Resources from Climate Change

The analysis of the 1994 agreement indicates that a "multi-year deficit or drought" was responsible for climate-related non-compliance events. Within this study's PDSI record, the late 1990's drought was the most severe the region had experienced when considering the duration and level of the event. Projections for the Upper Jordan indicate that the climate-related challenges could become even more severe in the future. Most climate models agree on temperature increases and winter precipitation reduction (Samuels, 2010; Zentner, 2008). The combination causes higher evaporation rates throughout the year and less input to rivers and storages in the winter recharge season, resulting in flow reductions within the basin. While the absolute quantities are highly uncertain, the direction of change clearly shows decreased flows that will likely increase the vulnerability of the water allocation agreements.

Qualitative values capturing water variability for the portion of the Jordan in each country are summarized in Table 36. For both Israel (including the West Bank) and Jordan, which together utilize greater than 80 percent of the water in the basin, the extreme wet and dry scenario projections indicate an increase in variability in 2030. Jordan and Israel are projected to have an increase in variability in seven of the twelve scenarios through 2050, but the moderate scenario in 2030 projects low variability similar to the historical pattern.

Table 35 Modeled runoff variability using projected changes in climate change under certain scenarios for the riparians of the Jordan

		Future Variability Change Class					
Riparian	Present Variability Class	2030-Dry	2030-Middle	2030-Wet	2050-Dry	2050-Middle	2050-Wet
Israel	Low	High	Low	Moderate	Low	Moderate	Moderate
Jordan	Low	High	Low	Moderate	Low	Low	Moderate
Lebanon	Moderate	Moderate	Moderate	Moderate	Low	Low	Moderate
Syria	Low	High	Low	Moderate	Low	Low	Moderate

The 1994 agreement has several robust mechanisms for managing climate fluctuations. A review of all basin events prior to and after the 1994 signing indicate that the 1994 agreement, and the other agreements signed after 1944 to include the 1995 Oslo II, have had a positive impact on the ability to manage complaints. Of the 155 total events in the basin before the 1994 agreement was signed, 42 percent were negative or complaints. After the agreement was signed and until 2005, only 35 percent of the 76 events were negative in nature. While the treaty has a net positive influence, the terms of agreement can be ambiguous, perhaps representing an obstacle to the identification of the exact location, timing and magnitude of the agreed water allocation. This can make it more difficult to draw the line between compliance and noncompliance.

Perhaps more than any other case study, future stress to these treaties from climate change could be mitigated by increased use of technology. Israel continues to ramp up its alternative water resources, including recycling of wastewater for agricultural use, conservation, and especially desalination. Desalination will likely play an important role in increasing municipal water supplies for Israel, and by extension the PA. In 1999, of Israel's total water budget of about 2,000 MCM only 22.5 MCM came from desalination. Israel at the time had no active tenders to increase production. Recent increases to this capacity have raised production capacities to over 300 MCM and have concurrently decreased costs to about $0.47 /per cubic meter (Ankori, 2010; Global Water Intelligence, 2010; Water Technology.net, 2010). According to some reports, Israel's plans for desalination reportedly will provide up to 66 percent of the total drinking water requirements for the country (Hodge, 2010). Such increases in desalinated water use could decrease the reliance on treaty waters and help to even out natural fluctuations in availability.

The existing 1995 agreement has many positive attributes, including a working JWC that provides a mechanism for increased cooperation across many fronts. However, the treaty weaknesses, including *flexibility* and *enforcement*, limit the capacity to manage severe stress from climate change that is likely to complicate a political relationship that has historically been volatile. The intended temporary status of the 1995 agreement is illustrated by the Article 40 text, "Israel recognizes the Palestinian water Rights in the West Bank, to be negotiated in the permanent status negotiations." The utilization of joint water resources is one of the major issues, along with borders, the status of Jerusalem, Jewish settlements and Palestinian refugees, that will need to be negotiated before a long term agreement can be reached. The Mountain Aquifer is the primary water source for 2 million people and the disputed allocation of its resources makes it politically critical. An agreement between the two will need to both protect Israel’s access to aquifers and permit Palestine enough water resources to support an expanding population as well as agricultural and industrial development.

The 1994 agreements is strong in all categories, but also has design weaknesses that are likely to become more apparent as the region is increasingly stressed by changes in climate. The 1994 agreement does not contain provisions that specifically address management during periods of drought when delivery of the stated allocations is not feasible. Until now, other strong mechanisms (e.g. *enforcement*, *communications*) have eased tensions and overcome this seeming design oversight. The ambiguity in wording within the allocations may make enforcement more difficult and complicated, but it also may be a positive in some cases by increasing *flexibility* when short-term drought conditions are present. For extended periods of drought, strong *flexibility* and *uncertainty* mechanisms provide an enhanced ability to detect and implement any long-term required changes to the agreement.

Both the 1994 and 1995 agreements lack any *scale* mechanism and do not include all water and riparians in the basin. The complaints in this case study illustrate the connections between the treaties and how management of the water resources governed by the treaties blends and merges. Water resources supposedly separated by treaty agreements are not necessarily separated by hydrology and are consequently not managed in isolation. The intersection of the groundwater focus of the 1995 treaty and the surface water focus of the 1994 treaty could be especially difficult to disentangle since the hydrologic relationship remains not fully understood. Increased use exacerbated by changes in climate could bring the relationship between these two treaties into clearer focus and highlight their *scale* deficiencies.

6.3 Discussion

In the Chapter 5.6 discussion, the MLR and Literature Review analysis was used to examine the three hypotheses using the full dataset. In this section, the case study results expand on the previous results and examine their relationship to the hypotheses. This discussion is split into two chapters. The first part in Chapter 6.3.1 examines whether the case study results (that are specific to treaties with climate complaints) are consistent with the three hypotheses and the more general results. It also provides an opportunity to explore how well the treaty mechanisms explain real-world situations. The second part in Chapter 6.3.2 presents several concepts used to explain the results from both the mechanism analysis in Chapter 5.6 and the case study results.

6.3.1 Case Study and Hypotheses Discussion

Hypothesis 1: A state experiencing a period of increased hydrologic stress in the form of drought or additional variability will have an increased likelihood of complaints or state grievances involving a shared water resource, compared to a state that is not experiencing hydrologic stress.

The findings from the treaty and conflict Literature Review analysis for all treaties in Chapter 5.1 indicate that Hypothesis 1 generally does not hold true since drought does not occur any more frequently in basins that have reported complaints than it does in other basins. For the subset of treaties with climate-complaints there was a higher instance of complaints during periods of greater drought and hydrologic stress. The case studies were chosen from this subset to further examine the relationship between complaints and hydrologic fluctuations.

The case study results from this data subset confirm that climate complaints are often associated with changes in water availability expressed as drought or flooding. Climate complaints made up a small proportion of the total complaints (18/210, or about 9 percent) for all case study treaties. Of the 18 total climate complaints, 13 were filed during a period of relative and absolute drought. For the Helmand, Nile, and Tigris-Euphrates all climate complaints were filed during or just after years of unprecedented drought. For the Jordan, seven of 11 total climate complaints were recorded during unprecedented drought and one other complaint was during a year of relative drought. In the Indus, two of four complaints were filed on the heels of four straight years of severe drought that was worse than any recorded since 1945.

The case studies illustrate that for the subset of treaties with previous climate conflict, hydrologic stresses can be a driver for complaints to be made. However, for each basin there were mitigating factors or influences indicating that climate was not the only reason for the complaint to be made (Table 36). Several complaints do not cite an inability to meet allocation requirements, but seem to be the result of general stress (including climatic) to the system. In these cases, the treaty in general acts as an outlet for increased stress, with no particular emphasis on one part or requirement of the treaty. For example, all of the Indus climate complaints had a climate component, but none were specific to flow allocations and three of the four complaints referenced a general renegotiation of the treaty in response to water stress.

Table 36 Case study results regarding Hypothesis 1. Case study results were largely consistent with the hypothesis that drought can prompt complaints between nations.

Case Study Basin	Date	Hypothesis 1	Mitigating Factors
Helmand	9/7/1950	Consistent	Drought limited flows were also hampered by poor internal management capabilities in Afghanistan.
Indus	9/19/1960	Somewhat consistent	The four complaints were flood related or general complaints; not related to decreased flows. Only small percentage of total complaints are climate related.
Jordan	12/31/1955	Somewhat consistent	Pertained to flooding, not addressed in the unofficial Johnston treaty
Jordan	10/26/1994	Consistent	Majority of complaints during worst drought year on record.
Jordan	9/28/1995	Somewhat consistent	Complaint was during drought year, but primarily about planned diversions.
Nile	1/5/1953	Consistent	Severe drought conditions exacerbated by excessive releases by Uganda
Tigris-Euphrates	7/17/1987	Consistent	Climate complaint were associated with severe drought, but were tied to hydropower requirements.

Regarding Hypothesis 1, the case studies provide additional support that for treaties with a history of complaints, climatic stress can be a cause for a complaint to be made. Shifts in climate were shown to be source of stress, but a variety of influences muddies the relationship between severity of the climatic shifts and the frequency and stated reason for a complaint.

Hypothesis 2: Water sharing agreements that have mechanisms in place, namely specificity, uncertainty, enforcement, communications, flexibility, integrativeness, and scale, will have less conflict and fewer grievances, including those that are climate related. Each mechanism contributes equally to the treaty's utility in managing hydrologic stress, and the overall institutional resiliency of a treaty can be summarized by adding the number of mechanisms included in the treaty.

The findings from the treaty and conflict analysis for all treaties in Chapter 5.1 indicate that most robust treaties have a higher instance of both climate and general conflict. These results run counter to hypothesis 2 since it was expected that the weaker treaties with the fewest mechanisms would have the most complaints. The case studies are used to examine relationship between the strength of treaties and the presence of complaints. Overall strength of each treaty is discussed here; the importance of specific mechanisms is presented in the Hypothesis 3 discussion.

The treaty strength estimated by the Literature Review was shown to be similar to the treaty strength assessment from the more in-depth case study analysis, indicating that the Literature Review/mechanism methodology provides a good estimate of treaty capabilities. Strong treaties overall were able to minimize complaints and accomplish their ostensible goals (Table 38; goals determined by the author from the treaty text). Despite being weak, the 1953 Nile and 1950 Helmand treaties were able to accomplish their objective because of the limited nature of the goals. Weak treaties or the weaknesses in strong treaties in many cases contributed to the filing of a climate complaint. A detailed discussion of how the presence or absence of specific mechanisms influenced the filing of the complaint is presented in the Hypothesis 3 section below.

Of the seven treaties examined as case studies, four were weak (based on the total mechanism scores) when compared to all 146 treaties used in the research. The reason why many of the case study treaties were weak can be partially explained by their purpose or circumstances surrounding their implementation. The weak treaties were either: limited in scope (Helmand was intended to create a committee; Nile was intended to manage releases from specific locations rather than the entire basin); were not implemented (1955 Johnston Agreement); or were intended to be short-term arrangements that have persisted due to an inability to come to a new agreement (Tigris/Euphrates). Due to their limited purpose or intended time frame, the design was likely intentionally minimized and many mechanisms that are typically used to expand the strength of the treaty were not included. The treaties that were strong (1994 Jordan, 1960 Indus) had among the highest mechanism scores of all treaties in the study as their intended use was both broad in scope and for the long term.

Table 37 Estimated strength of each treaty according to the Literature Review Scores. With several caveats, case study results largely supported the hypothesis that stronger treaties have less conflict and achieve their goals.

Case Study Basin	Date	Estimated Strength Compared to All Treaties (Literature Review)	Water Related Goal	Treaty Achieved Water Related Goals?
Helmand	9/7/1950	Weak	Create Committee	Yes
Indus	9/19/1960	Strong	Allocation/cooperation	Yes
Jordan	12/31/1955	Weak	Allocation Consensus	No
Jordan	10/26/1994	Strong	Allocation/cooperation	Yes
Jordan	9/28/1995	Average	Allocation/cooperation	Unclear
Nile	1/5/1953	Weak	Lake Victoria Management	Yes
Tigris-Euphrates	7/17/1987	Weak	Allocation/cooperation	Unclear

The case study results are more in line with hypothesis 2 than the analysis that included all treaties. The majority of the case studies were weak treaties and experienced complaints, which would appear to support the hypothesis. However, while the case studies all have a history of climate complaints and were pulled from that subset of all treaties, the selected case studies appear to be the weakest of the climate conflict treaties and are not representative of the group as a whole. The Literature Review mechanism score for all climate complaint treaties was 2.5. The treaties selected as case studies together had an average score of 1.8. The case study selection presented a bias towards weaker treaties and cannot be used as a generalization towards support of Hypothesis 2.

Hypothesis 3: All mechanisms have added benefit, but some mechanisms are more important to providing increased institutional capacity to manage drivers of conflict such as hydrologic stress, as well as stress from differences in political power, national stability, and economics that, if left unmitigated, could otherwise lead to conflict.

The findings from the MLR models for all treaties in Chapter 5.3 indicate that each mechanism has its own magnitude and either a positive or negative influence on the frequency of complaints. MLR analysis illustrates that Hypothesis 3 is partially true since certain mechanisms, especially *communications* and *enforcement*, may enhance, rather than decrease the likelihood of a complaint being filed. The case study discussion below examines if the proposed MLR relationships are reflected in the practical application of the treaties. Mechanisms shown to be important to enhancing, mitigating, or responding to complaints are discussed, with an emphasis on climate-related stresses and complaints.

The case studies highlight weaknesses and strengths for each treaty and show that some mechanisms are more important for each complaint depending on the geophysical and sociopolitical circumstances. For the Indus, an otherwise strong *specificity* mechanism was a weakness due to the lack of specific drought considerations that are prevalent to and heavily impact the region. For the Nile, *scale* is a weakness since the complaint had origins from a lack of inclusion of all riparians not just in the 1953 treaty, but also within other treaties that are more important to shaping the water relations within the basin.

Treaty mechanism strength/weakness as estimated by the Literature Review analysis are similar to the case study results. A comparison between the mechanism analysis and the specific case studies is shown in Table 39. Of the 23 instances where mechanisms in the case studies exerted a clear influence on the presence or management of a complaint, 18 were estimated to be a strength/weakness by the Literature Review mechanism analysis.

Most mechanisms with an impact opposite to that predicted by the Literature Review were influenced by other mechanisms. Predicted mechanism strengths were often dependent upon other mechanisms for their application to be effective. For the Tigris/Euphrates, the *specificity* mechanism was a strength in that it clearly delineated the requirements of the signatories and allowed the issue to be recognized. However, without any other mechanisms in place to communicate and enforce the complaint, it may have been more of a liability than a management asset. The 1995 Jordan Interim Agreement had a strong *enforcement* mechanism and a JTC that enhanced communications. The practical application was sometimes not effective, limiting the *uncertainty* mechanism since water use was not able to be monitored. Additionally, weaknesses in one mechanism were sometimes strengthened and overcome by strengths in other mechanisms. For the 1953 Nile treaty, a weak *specificity* mechanism was overcome by a *communications* and *enforcement* mechanism with a protocol for engineers from both parties to be present on site. The engineers in turn established an ‘Agreed Curve’ with specific flow/release schedules that were not part of the initial agreement, yet provided effective management guidelines that increased both the *specificity* and *flexibility* capabilities.

Table 38 Strength of mechanism in the case studies compared to the Literature Review. Projected mechanism strengths from the Literature Review scores largely coincided with the positive or negative influence exerted within the case studies.

		Mechanisms As Positive/Negative Influence Regarding Complaints						
Case Study Basin	**Date Signed**	***Comms***	***Flexibility***	***Specificity***	***Integrativeness***	***Enforcement***	***Scale***	***Uncertainty***
Helmand	9/7/1950	Negative	Negative	Negative	NA	Negative	Negative	Negative
Indus	9/19/1960	Positive	NA	Negative	Positive	Positive	Negative	NA
Jordan	12/31/1955	Negative	Negative	NA	Negative	NA	NA	NA
Jordan	10/26/1994	Positive	Positive	NA	NA	Positive	NA	Negative
Jordan	9/28/1995	Positive	Negative	NA	NA	Positive/ Negative	Negative	Negative
Nile	1/5/1953	Positive	NA	Positive	Negative	Positive	Negative	NA
Tigris-Euphrates	7/17/1987	Negative	Negative	Positive/Negative	Negative	Negative	NA	Negative

The text indicates a positive/negative influence of each mechanism for managing stress as illustrated in the case study. Colors indicate projected mechanism design strength according to the Literature Review analysis: green indicates a projected relative strength, red indicates a projected relative weakness, and no color is close to the average compared to all treaties in the study. Treaties mechanisms are segregated into strength/weakness based on Literature Review percentiles against all treaties.

The case study results provided some confirmation of strength/weakness as estimated by the MLR. When compared across all case studies, some mechanisms (*specificity*, *uncertainty*) had ambiguous or contrary results regarding their positive or negative influence on the occurrence of complaints, but some mechanisms did provide clear trends. The MLR results indicating that an increase in *flexibility* and *enforcement* within a treaty result in fewer or better-managed complaints were confirmed in all case studies. MLR results for *communications* and *integrativeness* that indicate these mechanisms result in more conflict were not reflected in the cases studies. Both *communications* and *integrativeness* were associated with an improved capability to manage and deflate complaints. Of interest is that across all case studies, *scale* tended to be a reason for a complaint regardless of the mechanism strength. Part of this result has to do with the difficulties of implementing a treaty at all scales regardless of design. In the Helmand, the *scale* component design was considered strong, but the complaint largely originated due to a lack of management capacity at the local level. This may have been due to country instability in general, and may not have been ameliorated by an improved *scale* mechanism. The case study results seem to confirm the MLR results that *scale* weaknesses are related to complaints and that some mechanisms are associated with less management capability and consequently more complaints. The case study results indicate that hypothesis 3 is accurate in that an improved capability in all mechanisms exerts a positive influence on treaty capacity and resiliency, but that the result of the improved capability does not always result in less conflict. In the MLR analysis, the importance of each mechanism in general is estimated, but the hydrologic and political context within which the treaty operates is key to a final judgment on its merits to manage hydrologic stress.

6.3.2 Explanatory Concepts

Five explanatory concepts are presented below to frame and explain the results from both the case studies in Chapter 6.3.1 and the treaty analysis presented in Chapter 5.6. These explanatory concepts are used to show how the treaty both increases institutional resiliency in managing stress and shapes the importance of water in overall relations.

1. Political, economic, and social influences and factors that seem only indirectly related to water are a primary driver for determining the effectiveness of a treaty and the quantity and severity of water complaints.

The Literature Review count shows that the more robust treaties have more conflict. One explanation of stronger treaties resulting in more conflict is because outside factors, such as hydrologic and political stress, make these basins inherently more unstable and conflictive. More mechanisms in place may be an indicator of inherent distrust and an attempt by the treaty designers to preempt anticipated treaty violations. Assuming that stronger treaties lower the likelihood of complaints, broader issues could overwhelm even the stronger treaty's capabilities, resulting in complaints. In all of the case studies, a broader history and framework of relations shaped the complaints associated with the treaties. For the Indus and Jordan, many of the climate complaints seemed to be geared towards relations in general, with the hydrologic stress used as an excuse for negative interaction. Indus treaty mechanisms that are among the strongest of all treaties considered in this study are often rendered less effective due to distrust and poor overall relations (e.g. communications and data sharing). Internal security also impacts treaty effectiveness. For the Helmand complaint, poor internal stability in Afghanistan caused mismanagement that was interpreted by Iran as a deliberate attempt to deprive it of river flows.

Both the regression and count methods regarding power and drought analysis do not provide any indication of the outside influences captured in the case studies. Factors not captured by the drought/power variables must be in play if the outside factors are the primary drivers of conflict. As discussed in Chapter 2.1 by Buzan, these outside factors are likely to be the primary drivers for conflict and the hydrologic stresses only temporarily elevate water to the levels of national security level importance. Water politics are shaped by other issues that are not easily captured by blanket variables that can be equally applied to all treaties and nations.

2. Treaty design elements increase or decrease the influence and political impact of the treaty on overall stability of the signatories. In other words, the importance of the treaty to each country is in part shaped by the treaty itself. This in turn is a driver of whether or not a country is willing to utilize political collateral towards enforcing or utilizing the treaty.

Realist scholars point to water’s relatively low level of importance to national security (Ali, 2008). Yet, as is seen in several case studies, water sometimes extends beyond this low level to become part of the larger, national stability scheme. Within the case studies, the primary cause for the filing of most complaints, even those with a climate-related undercurrent, was a shift in the way a nation views water. Shifts occurred for a multitude of reasons including a change in weather patterns (hydrologic stress) that altered requirements, shifts in the overall political relations between the signatories, or changes in the utilization of the resource. Such shifts prompted political action exhibited as a complaint. All of these shifts are unique, but have an overarching theme: the shifts impacted the stability of one of the signatory nations in some way.

Water is only one stability component and its importance can fluctuate and influence a wide range of functions in the larger stability heirarchy. Two definitions of stability can be used to describe the point where stability for the nation as a whole is impacted by water. [58] First, *s*tability (with a little *s*) can be defined as the lower level impacts of generally humanitarian-type issues that impact the basic necessities and the quality of life. In this sense, water is used for diplomacy to build sustainable development, democracy, and equality. Such *s*tability is achieved through actions such as improved sanitation and water distribution, as exemplified by the Millenium Development Goals (MDGs).[59] A second definition of stability includes national security type issues and is described as *S*tability (with a big *S*), which relates to the overall stability of the state and the continuation of the existing government. Threats to the *S*tability of a government could include economic failure, domestic instability, and conflict with neighboring states. In most cases, water issues reside solidly in the *s*tability realm. While the MDGs are certainly worthwhile and exemplary, they tend to not reach the levels of importance to affect *S*tability.

It is when water impacts sectors of primary importance that consistently reside at the *S*tability level, such as land rights and economic growth, that water-driven relations become a factor in *S*tability. For the most part, nations do not view water itself as a

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[58] Dr. Jerome Priscolli at the USACE referenced the idea of dual definitions of *stability* during conversations with the author. The author has since taken liberties with the concept and Dr. Priscolli's definitions, which are not known to be documented in a formal publication, do not necessarily coincide with the author's. Personal communication with Dr. Priscolli is recommended for further information regarding his intended definitions.

[59] The MDGs are intended to be accomplished by 2015 and include the goals of halving the proportion of people who cannot reach or afford safe drinking water and halving the number who do not have basic sanitation. http://www.unesco.org/water/wwap/news/index.shtml#water_human_right Accessed 10 July 2010

resource worth political action, but instead measure its importance by how it relates to sectors that have high-level national security concerns. For example, countries such as Turkey, India, and Ethiopia are turning to hydropower to satisfy their energy security. Pakistan and Egypt consider water essential to their agricultural production which provides jobs for most of their populations, which in turn provides pacification for the population and stability for the government. The uses of water that many consider most vital—potable water for individual consumption, proper sanitation—are not what drive action for some, if not most, governments. Many nations are generally not interested in water's components that make up the UN's Human Development Index unless it impacts the stability of a populace and in turn the stability of the government. For example, Turkey's interest in the development of its water resources and efforts to improve quality likely stem from the practical relationship between water's impact on other sectors and GDP, which in turn has the largest impact on its stability.

In a very few cases the perceptions of water have reached levels where sufficient access to fulfill its primary function, drinking and sanitation, is called into question and it becomes valuable enough for itself to be a factor in *S*tability. The cases where *S*tability is impacted are where water conflict at the higher levels of government appears to be most prevalent, and it tends to occur in places that have established water-centric economies such as the Nile, Jordan, and Indus basins.

The most important mechanism for increasing the impact on *S*tability is *integrativeness*. Water issues arguably become more important, and possibly conflictive, when they are tied to other issues with a higher degree of impact on *S*tability. Countries may be more willing to go through the effort of enforcing a treaty with the filing of a complaint if it has more of an impact on its stability. This is captured in the MLR Model 2 results which show that *integrativeness* is one of two mechanisms that tend to be associated with increased amounts of complaints. Generally, water treaties and their mechanisms have a multitude of purposes that are primarily geared towards impacting what we have defined as being part of *s*tability, or the more conventional idea of water use. An increase in *integrativeness* expands the scope of the treaty to include issues outside of water. While it is often used as a method to increase the size of the 'pie' to encourage cooperation, it also raises the level of importance and impact on *S*tability, which also may partially explain the MLR results that indicate an increase in complaints with higher *integrativeness*.

3. Increased emphasis on water by nations where water has reached a higher level of consideration for *S*tability coincides with treaties that have both exhibited complaints in the past and are on average more robust (have more mechanisms) than treaties without complaints.

This study has focused on treaties with climate complaints, and those complaints seem to occur where water use/scarcity has raised the importance of water in the national calculus to become a part of the signatories' security and *S*tability calculations.[60] Especially for areas within the Middle East (Jordan, Nile, Tigris-Euphrates) where demand largely outstrips supply, the strategic implications have brought additional focus on water. In these countries, the securitization and importance of water is likely based on the domestic uses captured by *s*tability that in turn reaches the level of consideration for *S*tability. These countries have an elevated status of water primarily due to limited supplies that could threaten treaty-expanded associations as measured by increased *integrativeness*. For treaties with climate complaints, 55 percent have at least one element of *integrativeness* built into the treaty, with an average *integrativeness* score of 0.14. For treaties without climate complaints, only 45 percent contain the mechanism, with an average score of 0.09. The importance of the traditional uses of water (domestic consumption) combine with those captured by the *integrativeness* mechanism to form a total influence on *S*tability.

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[60] This is theorized and is not confirmed by any substantial analysis. Determining the exact importance placed on water is outside the scope of this study. The importance placed on water is subjective and likely cannot be captured by any existing index since several factors (water use, economics, politics, religion, etc) come into play.

The additional attention to water has resulted, for the most part, in more robust treaties with a wider array of mechanisms (unweighted Literature Review score of 0.33 for those with climate complaints compared to 0.23 for all treaties). Treaties with climate complaints have generally provided additional capacity towards achieving the definition of success used in this study (minimizing complaints stemming from hydrologic stress). Despite (or perhaps because of, see point number 5 below) the increased capacity, these nations have exhibited complaints regarding water, but tensions have not exceeded the institutional resiliency.

4. Mechanisms improve treaty effectiveness for managing stresses to the system, including hydrologic, political, and economic. However, the increased treaty capacity can result in more complaints.

All treaty mechanisms are shown in the case studies to generally exert a positive influence on a treaty's capability to mitigate and manage stresses to the system. Increased management capacity lends itself towards improved communications, clearer thresholds, and more effective enforcement. While this improves relations, it also helps to clearly define and facilitate the filing of complaints. Whether or not a mechanism results in more complaints is also dependent on the overall treaty design, the dynamic interaction between mechanisms, and the surrounding sociopolitical environment. In this way, quantifying the impact of a mechanism is difficult since the effectiveness of the mechanism can concurrently enhance overall capabilities and increase complaints, which is this study's indicator of a successful treaty.

For example, *specificity* has positive aspects in that it provides clear delineations for complaints and allows for nations to understand their responsibilities with regards to the treaty. However, with clear-cut expectations, it also makes it easier to discern when the treaty is not being fulfilled, leading to increased complaints. Additionally, if *flexibility* and *uncertainty* are not included in the treaty, then emerging conditions that were not considered when the treaty was written may overwhelm the specific stipulations that no longer reflect reality. *Communications* has been noted as a positive aspect since it ostensibly allows nations to express their concerns and work towards an equitable and mutually beneficial solution. However, those same attributes also allow for complaints to be more easily communicated. The expression of low-level complaints is one form of communication, and is not necessarily a negative part of a treaty, as discussed in point number 5 below.

As discussed in the case study and MLR analysis, treaties with stronger *enforcement* and *scale* mechanisms tend to increase management capacity. *Scale* provides a method for managing periods of stress by creating a network for reporting and implementation. *Scale* allows parties to express their needs and concerns, which can then be integrated into planning and implemented at all scales. While this helps to allay and manage complaints at all times, it perhaps becomes especially important during sudden high-impact, low-warning stresses such as from drought/flooding. The awareness and increased operability from full inclusion of all parties provides increased ability to communicate, plan, and react. The *enforcement* mechanism not only allows signatories to better manage conflictive issues that might arise, but the idea of effective *enforcement* also likely acts as an inhibitor and prevention for complaints.

5. Complaints are not necessarily an indicator of decreased institutional resiliency, weak, or ill-designed treaties, but in some cases illustrate that a treaty is functioning properly.

According to the Literature Review treaty scores, the stronger treaties typically have a higher frequency of complaints. This result can perhaps be explained by reexamining our original Hypothesis 1, which was based on the premise that conflict was an indicator of an inability to manage stress, or in other words an unsuccessful and consequently weak treaty. Upon review of the case studies and other data, complaints may not always indicate inability, but rather enhanced ability for stress management in some instances.

This potential explanation follows the line of Coser (1956) regarding the practical utility of conflict and the possibility that conflict (rather than a condemnation or negative indicator of a treaty) instead shows that a treaty is functioning as designed. Treaties can act to "release pent-up hostilities, create norms regulating conflict, and develop clear lines of authority" and are a means not of avoiding conflict, but a provide a way to "facilitate low-level conflict" (Allan, 2007). Through increased, structured interaction in the form of "low-level and more frequent conflict," the intended purpose of the treaty can be achieved "without threatening the overall stability of the relationships" (Allan, 2007). In this way, treaties positively impact stability and prevent the conflict from reaching higher levels of severity. "Far from being necessarily dysfunctional, a certain degree of conflict is an essential element in group formation and the persistence of group life" (Coser, 1956; p. 31).

Determining where Coser's 'certain degree of conflict' stops being positive and enters the realm of negative is difficult to discern. One way to potentially measure this is by determining an elevated increase in severity and the level of government associated with the complaint. However, the severity and level of government are also directly related to the level of national importance and the treaty's impact on *s*tability and *S*tability. The line where conflict becomes a potential hazard to both *s*tability and *S*tability is nebulous, as illustrated by Buzan's discussion on securitization:

> "The bottom line of security is survival, but it also reasonably includes a substantial range of concerns about the conditions of existence. Quite where this range of concerns ceases to merit the urgency of the 'security' label (which identifies threats as significant enough to warrant emergency action and exceptional measures including the use of force) and becomes part of everyday uncertainties of life is one of the difficulties of the concept" (Buzan, as quoted by Stone, 2009).

A blanket application of complaints as negative overlooks the potential nuances of conflict origin and utility. Treaties may facilitate interaction that is sometimes construed as low-level conflict, and discerning between positive conflict and conflict spurred by weaknesses in treaties may not be possible without in-depth knowledge of the treaty.

The core issue behind the use of complaints as the dependent variable is how that refines our definition of a successful treaty. Our dependent variable in this analysis used complaints as a measure of success: a lack of complaint during a period of drought indicates that a treaty successfully mitigates impacts from hydrologic stress. Using this measure of success, less conflict indicates a greater design capacity for managing fluctuations in climate.

After reviewing the case studies and exploring the practical utility of complaints, perhaps a better gauge of a successful treaty would be to estimate to what degree a treaty accomplishes its goals. For this goal-oriented definition, complaints are still a key indicator of a successful treaty since they are usually filed when goals are not being met. However, complaints are judged to be just one of many facets of success or failure of a treaty, along with other facets such as equitable water distribution, increased economic opportunities, or political cooperation. Each of these may be equally important as a treaty purpose. Discerning the intended purpose, however, is perhaps impossible without insight into both the historic and current goals of the signatories, which are constantly shifting with the domestic and international political, economic, and geophysical environment.

7 Conclusions

The drought results surprisingly and somewhat counter-intuitively indicated that drought (both frequency and severity) does not determine which treaties will have climate related complaints. Drought does not occur any more frequently in basins that have reported climate related conflict than it does in other basins: treaties with climate complaints are in absolute and relative drought less often, have a lower overall drought severity, and have less variability than treaties that have no conflict. Therefore, drought is not the primary cause or determiner of whether a treaty is going to have climate related conflict. However, for treaties with a history of complaints, drought seems to spur some conflict since there was a higher instance of complaints during periods of greater hydrologic stress. Drought did not appear to impact the severity of complaints, but does have an impact on whether or not a complaint is lodged. Implications of this analysis are that treaties with climate complaints are more susceptible and sensitive to changes in climate. In this way, the presence or absence of a climate complaint in any given year can be used as an indicator of stress to the treaties' capacity to manage hydrologic fluctuations.

Seven treaty mechanisms (*specificity*, *uncertainty*, *enforcement*, *communications*, *flexibility*, *integrativeness*, and *scale)* are shown to be important for shaping the institutional resiliency of a treaty. Contrary to expectations, according to the Literature Review scores the most robust treaties have a higher instance of both climate and general conflict. It is not precisely known why this is the case, but one explanation is that complaints are not necessarily an indicator of decreased institutional resiliency, weak, or ill-designed treaties, but in some cases illustrate that a treaty is functioning properly.[61] Coefficients obtained from regression analysis indicate that an increase in *flexibility*,

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[61] There are several other explanations not explored in depth in this analysis. A likely avenue for future consideration and research would investigate whether or not nations with a predisposition towards and a history of conflict would preemptively design their treaties with more robust mechanisms to manage, and prevent, conflict. This research would likely entail research into the creation process and negotiations of a broad range of treaties where conflict after signing was more likely than in other basins.

scale, and *enforcement* within a treaty are an indicator of less conflict or complaints and the negative coefficients for *communications*, *specificity*, and *integrativeness* tend to indicate more conflict.[62]

The mechanism analysis was useful for determining the range of tools used for increasing institutional resiliency, but the case studies illustrate that pinpointing the importance and impact of each mechanism, and the overall treaty design, on water relations is more difficult. Treaties and cooperative arrangements certainly have played important roles in de-escalating tensions when stresses have been applied to the system. However, there is not a linear causality between the inclusion of mechanisms and cooperation. Similarly, conflict de-escalation is not a direct cause and effect relationship between the capabilities of the water institutions and the amount of stress to the system. Instead, there is a complex relationship between change to the system and management efforts that involves a series of feedback loops and influence from non-water related sectors.

The combination of the five explanatory mechanisms in Chapter 6.3.1 together helps to understand the results of the analysis. Increased scope of a treaty and better-designed treaties may in fact increase the number of complaints. Each mechanism exerts an influence not just on the *management* aspect of relations, but also helps to shape the *context* of the problem. Some mechanisms may then be more important to ‘management’ (institutional resilience), while others are more important to ‘shaping’ the issue (political context). For example, a strong *integrativeness* mechanism that includes agriculture,

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[62] It is important to note that there is no evidence that the mechanisms with negative coefficients have a direct causal relationship with conflict and complaints. The results of the regression analysis using the seven mechanisms are intended to help evaluate mechanism differences between conflict and non-conflict treaties to better consider the interactions that some mechanisms (e.g. *communications* and *specificity*) may have with each other regarding complaint occurrence. The regression equations are not intended as precise indicators of where any treaty weakness originates or where conflict may occur.

industry, hydropower, or increased *communications* enlarges the scope of the treaty and its impact on Stability. This in turn partially determines how much emphasis is placed on the treaty by the signatories, especially during times of stress. Some mechanisms, such as *scale*, are especially important to increasing the management capacity (institutional resiliency). Increased *scale* provides a method for managing periods of stress by creating a network for reporting and implementation. *Scale* allows parties to express their needs and concerns, which can then be integrated into planning and implementation at all scales. While this helps to allay and manage complaints at all times, it perhaps becomes especially important during sudden high-impact, low-warning stresses such as from drought/flooding. The awareness and increased operability from full inclusion of all parties provides increased ability to communicate, plan, and react. Figure 30 illustrates how treaty design increases the scope (treaty expansion of influence) and management capabilities (treaty mechanisms for managing stress (Institutional Resiliency).

The dual impact of mechanisms on management capacity and also on shaping the political context also helps to explain the results of the two methods presented in this study for estimating the strengths of a treaty: the Literature Review count method (where the number of mechanisms are simply summed) and regression analysis. For management capabilities, it can be expected that all mechanisms exert a generally positive influence that expands the ability of the treaty to manage stress. It can then be concluded that the Literature Review count method provides a good summary of the total management capabilities of a treaty. In the regression analysis, each mechanism exerts an influence on the scope and utility of the treaty so that the impact on complaint mitigation does not equal the sum of its parts. Each mechanism can either increase or decrease the likelihood of a complaint through its influence on the treaty relevance to national stability and the mechanism's stress management capabilities. For this study's definition of success (decreased complaints), the regression method provides a means for estimating which mechanisms are more important for minimizing complaints when stressed hydrologically.

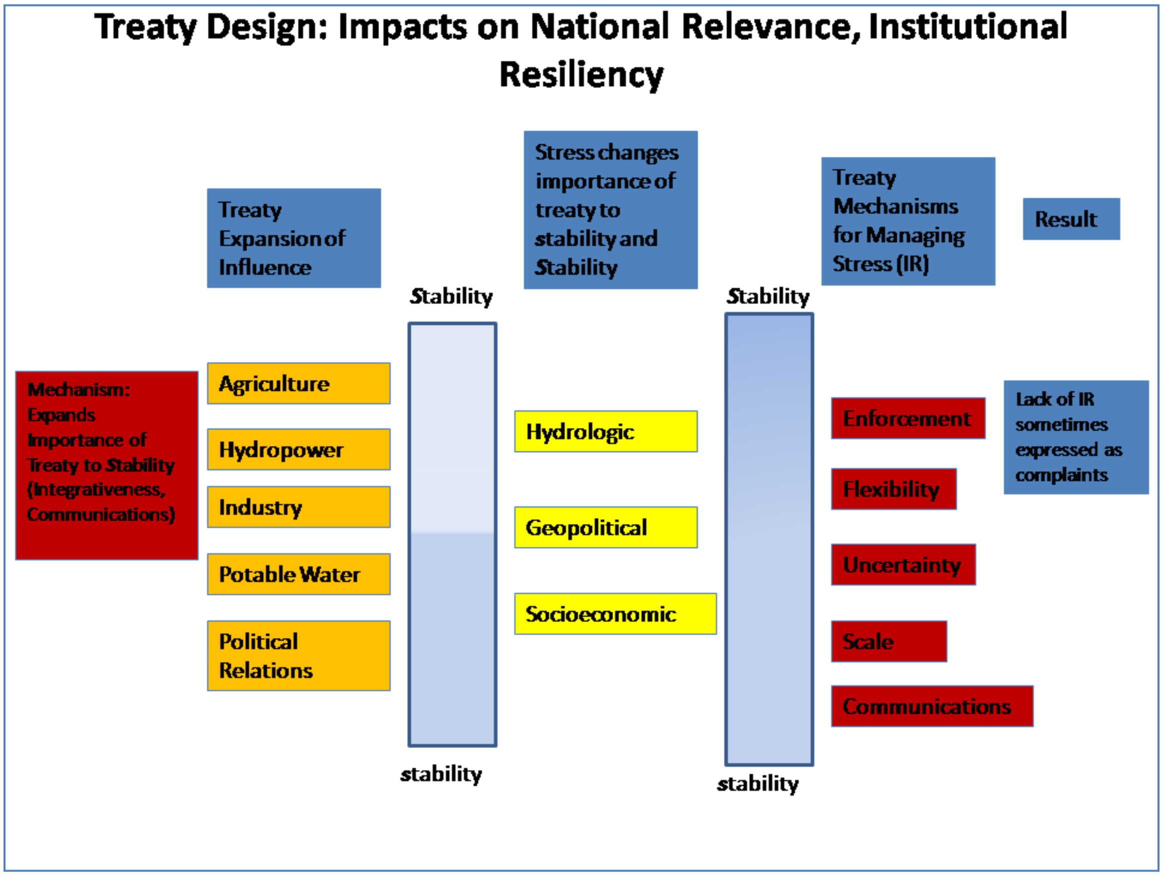

Figure 28 Design impact on the treaty scope and management capability. Design of a treaty not only shapes the stress-management capabilities, but also is a factor in determing the influence of the treaty in the overarching political and social sphere.

Treaties that are well designed with positive attributes in all major mechanisms remain susceptible to influence from the surrounding political and environmental situation. In some cases, conflict is an end in itself, and may not be oriented toward the specific treaty mechanisms or intended to produce water-related results. Treaty mitigation and management is possible when conflict is realistically tied to water and there are ways other than conflict to overcome and remedy the source of the complaint.

While predictions of climate will likely increase in accuracy and resolution, the impacts from climate change will continue to be extremely difficult to predict since impacts are dependent on a number of issues that extend beyond just climate. The purpose of this research was to determine the important factors in the design of a treaty so that institutional resiliency can be increased to better manage changes in climate. While general principles were presented, the application of these principles will vary depending on the basin since each will have unique challenges related to climate. Mechanisms that manage an important purpose in one basin may not be as relevant in another. While politics and environment may indeed vary, what is better understood through this research is that treaty design has a relevant and important role in shaping basin management so that nations may better achieve their goals in a changing climate.

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APPENDICES

Appendix A: Bibliography Analysis of Treaty Mechanisms

Uncer tainty	*Enforce ment*	*Specificit y*	*Flexi bility*	*Integrat iveness*	*Scale*	*Commun ications*	Relevant Text	Author	Year	Title
						X	The Indus Waters Treaty has served its purpose in deescalating tensions over riparian water and has provided a direct avenue for regular, if technical, dialogue between the countries.	(Ali)	2008	"Water politics in South Asia: Technocratic cooperation and lasting security in the Indus Basin and beyond." Journal of International Affairs 61
	X		X			X	The incentives for parties to decieve creates an incentive for others to monitor.	(Barrett)	2006	Environment and Statecraft: The Strategy of Environmental Treaty. New York, Oxford University Press.
				X			This evolution from a unilateral, zero sum assertion of rights to a positive sum cooperative resource maximization strategy can provide greater benefits, reduce grievences, and increase confidence among riparians.	(Bencala & Dabelko)	2008	"Water Wars: Obscuring Opportunities." Journal of International Affairs 61
X					X		First, cooperative arrangements are likely to be more successful when they involve strong and competent international river commissions, and if they systematically link such commissions and national level authorities, thereby ensuring financial and political support within riparian country bureaucracies. (E.g., Marty 2001) Joint data gathering and analysis can help in avoiding data disputes later on, which frequently are a major component of overall later conflict. Most studies note, however, that technological fixes have rarely if ever played a decisive role in solving international river problems. (E.g., Dinar et al. 2007)	(T. Bernauer)	2008	Transboundary Freshwater Resources as Sources of Conflict and Cooperation
							For an agreement on water sharing to be effective, it should be able to adapt to potential changes in site-specific circumstances that may develop within the time-period the agreement is in effect.	(T. Bernauer)	2001	Explaining success and failure in International River Management. Center for International Studies. Swiss Federal Institute of Technology, Zurich.
					X		…stakeholder involvement and performance improvements in the Brantas, Guadalquivir, and Murray-Darling cases have gone hand in hand.	(Blomquist, Dinar, & Kemper)	2005	Comparison of Intstitutional Arrangements for River Basin Management in Eight

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										Basins. Policy Research Working Paper 3636. W. Bank. Washington DC, World Bank
			X				Attending to the Levels of Action: Large surface waterprojects have introduced much needed flexibility because water is governed by a set of rights and rules that allow it be more readily released or transfreered than water governed by prior appropriation.	(Blomquist et al.)	2004	"Building the agenda for institutional research in water resource management." Journal of the American Water Resources Association 03147: 925-936.
						X	NBI: Diplomatic hydropolitical relations have improved, decision makers meet on a regular basis and capacity building has been developed.	(Cascao)	2008	"Ethiopia-Challenges to Egyptian hegemony in the Nile Basin." Water Policy 10
					X	X	Improvement of communication among those who determine water policy within and across watersheds. / Consideration of decision-making at a regional level encompassing multiple watersheds / Establishment of a regional commission to manage water jointly, and / Greater use of strategic scenarios as management and education tools / the ultimate success of all future scenarios, technical solutions and economic valuations of water rests on approaching water as a regional resource and on developing inter-state cooperation in all international river basins. Fresh water, whether from a river basin or an underground aquifer, has no nationality and does not recognize political boundaries. Therefore, a necessary condition to peaceful solutions of disputes over shared water resources is continued communication between the concerned states, strengthened by future incentives for cooperation.	(Charrier, Dinar, & Hiniker)	1998	Water, Conflict Resolution and Environmental Sustainability in the Middle East, 44 AridLands (1998)
X	X	X	X			X	The strenght of the resulting agreement is measured by a "strength index" which was developed to meaure the theoretical strength of a legally binding international agreement. A list of 12 categories was developed in consultation with academics and diplomats who have been involved in negotiating environmental treaties, in addition to a a review of relevant literature.	(P. Chasek)	1997	"A comparative analysis of multilateral environmental negotiations." Group Decision and Negotiation 6
X		X	X			X	See text	(Chavez)	2000	"ARTICLES FROM THE LA PAZ SYMPOSIUM

Uncer tainty	*Enforce ment*	*Specificit y*	*Flexi bility*	*Integrat iveness*	*Scale*	*Commun ications*	Relevant Text	Author	Year	Title
										ON TRANSBOUNDARY GROUNDWATER - Mining of Internationally Shared Aquifers The El Paso-Juarez Case." Natural resources journal 40(2): 237 (24 pages).
						X	It is therefore essential to build frameworks, within which states can interact, consult, and exchange information.	(Chazournes)	2001	The Role of Diplomatic Means
		X	X			X	Specific water allocation mechanism Specific water use rights reserved Information exchange Is there an explicit obligation to exchange information? Does the agreement provide for regular meetings of the parties? Consultation Is there a provision for Important forms of shared governance or joint management, such as the joint construction of hydroelectric facilities or the implementation of flood-control measures, are commonly articulated and codified in these less formal instruments rather than in treaties. regular consultation among the parties? Does the agreement create a permanent basin commission or similar governing body? Does the agreement create an obligation for peaceful resolution of disputes? Does it specify dispute resolution procedures?	(Conca)	2006	Global Regime Formation or Complex Institution Building? The Principled Content of International River Agreements
				X		X	Tigris-Euphrates: Information has been exchanged over more than forty years, and experts have established a water-related modus vivendi baed on three bilateral agreements reached in 1987, 1989, and 2001. …downstream Syria started to employ linkage strategies in its interactions with Turkey over water and security.	(Daoudy)	2008	"Hydro-hegemony and international water law: laying claims to water rights." Water Policy Supplement 2: 89-102.
	X						Develop transparent and shared monitoring system and databases for Afghanistans transboundary river basins.	(Deghan & Palmer-Moloney)	2009	Water security and scarcity: Potential destabalization in Western Afghanistan. USACE-ERDC. Washington DC, USACE: 1-10.

Uncertainty	*Enforcement*	*Specificity*	*Flexibility*	*Integrativeness*	*Scale*	*Communications*	Relevant Text	Author	Year	Title
	X				X	X	The ICPE provided a forum for identifying priority action from a “basin” perspective. Implementation of agreed measures took place at national or sub-national levels. The ICPE monitored implementation of measures by regularly publishing progress reports on the internet, which effectively served as an *enforcement* mechanism. Implementation of agreed measures took place at national or sub-national levels. The ICPE monitored implementation of measures by regularly publishing progress reports on the internet, which effectively served as an *enforcement* mechanism. the main factors were (1) a careful division of labor between the international and national levels in terms of priority setting, implementation and monitoring.	(Dombrowsky)	2008	Institutional design and regime effectiveness in transboundary river management-the Elbe water quality regime
	X		X			X	Effective Transboundary water sharing should be based on four guiding principles: coordination and cooperation, interdisciplinary analysis, watershed and river basin planning, and adaptive management.	(Draper)	2006	Sharing Water in Times of Scarcity. Reston, VA, American Society of Civil Engineers.
	X		X			X	One of the variables often stressed as a factor in the capacity to adapt to variability is the degree of flexibility incorporated in governance systems. Variability can also be managed through the establishment of formalized channels of communication.	(Drieschova et al.)	2008	"Governance Mechanisms to Address Flow Variability in Water Treaties." Global Environmental Change 18: 285-295.
			X				The provisions in the agreement should be sufficiently adaptable to allow them to evolve over time and to respond to changes in the climatic, hydrologic, economic, social, and even political conditions.	(Working group of the French Academie de l'Eau Eaux partagees)	2002	Working group of the French Academie de l'Eau, Proposals for a Strategic Guide to Assist in the Constitution of International Inter-State Commissions for Shared Water Resources, http://www.inbo-news.org/divers/thonon/AcademieRiobGuide_gb.PDF
		X	X		X	X	In the case of Greece and Bulgaria there is an urgent need for a thorough revision of the agreement...the issues lacking substantial support are water allocation, conflict resolution, monitoring, and information sharing. …countries sharing water resources should cooperate, aiming at integrated management based at the basin level…joint management in the case of a transboundary	(Eleftheriadou & Mylopoulos)	2008	"A methodological framework for supporting transboundary water agreements: the case of the Nestos/Mesta river basin." Water Policy 10: 239-257.

Uncertainty	*Enforcement*	*Specificity*	*Flexibility*	*Integrativeness*	*Scale*	*Communications*	Relevant Text	Author	Year	Title
							basin where all programmes should be coordinated for the whole area of a river basin even if the basins extend beyond the boundaries of the community.			
X		X	X				Rather, when a disagreement around ambiguity passes a threshold, it can escalate into a conflict in a very short time. However, there are also indications that ambiguity may have detrimental implications, especially during the implementation phase of agreements. Even the 1997 UN Convention on the Law of the Non-Navigational Uses of International Watercourses has been called into question due to its widespread use of vague and sometimes contradictory language. Yet, if ambiguity is still adopted, one of the tools that might be used to mitigate its adverse effects is the addition of mechanisms that can help to clarify the ambiguity or reduce the *uncertainty* associated with it. This may include conflict-resolution mechanisms or even just a joint committee that can set the floor for further negotiations.	(Itay Fischhendler)	2008	"When ambiguity in treaty design becomes destructive: A study of transboundary water." Global Environmental Politics 8
					X		…While both the agreement and the protocol include language about the protection of ecosystems, we argue that this is extremely unlikely to occur…considering the lack of representation by communities that will be affected by this control of the river.	(Fox)	1979	"The Problem of Scale in Community Resource Management" Environmental Management 16: 289-297.
		X		X		X	The most convincing method of overcoming asymetric gains is cited as integration among the states involved. The water discourse not only draws on the sharing of information about water sources as a means of cooperation.	(Furlong, Gleditsch, & Hegre)	2006	"Hidden theories, troubled waters: International relations, the 'territorial trap', and the Southern African Development Community's transboundary waters
		X		X		X	A 1998 agreement on the Syr Darya Basin, in which water management is exchanged for fossil fules, provies a post-Rio example of a basin states capitalizing on their shared resource interests. Water allocations, the most conflictive issue area between co-riparian states, are seldom clearly deliniated in water accords.	(M. A. Giordano & Wolf)	2003	"Sharing waters: Post-Rio international water management." Natural Resources Forum 27

Uncertainty	*Enforcement*	*Specificity*	*Flexibility*	*Integrativeness*	*Scale*	*Communications*	Relevant Text	Author	Year	Title
		X					Jordan: While the ambiguities that exist in the agreements are useful when trying to reach an agreement, they work as obstacles in the post-agreement phase when they are to be implemented. For example, the lackk of provision for drought in the Israeli-Jordanian agreements has served to create tension between the parties and has thus tested the robustness of the agreement.	(A. Jagerskog).	2003	Why States Cooperate Over Shared Water: the Water Negotiations in the Jordan River Basin. Department of Water and Environmental Studies, Linkoping Univer
					X		It is crucial to set up a platform in which all relevant stakeholders are represented.	(Jaspers)	2003	"Institutional arrangements for integrated river basin management." Water Policy 5: 77-90.
				X			Tigris/Euprhates: As a multiriparian initiative, ETIC has been unique in that it looks beyond water rights to themes related to environmental protection: development and gender equality, water management, and grassroots participation in a holistic, multi-stakeholder framework.	(Aysegul Kibaroglu)	2008	"The role of epistemic communities in offering new cooperation frameworks in the Tigris-Euphrates Rivers system. ." Journal of International Affairs, Spr
			X				A lack of flexibility is likely to lead to reduced regime effectiveness since the existing problem solving strategy may prove inadequate to cope with changing circumstances.	(Lindemann)	2005	Explaining success and failure in international river basin management-Lessons from Southern Africa. The 6th Open Meeting of the Human Dimensions of Glob
				X		X	While direct cost incentives have been lacking, there is evidence that asymmetric incentives for cooperation were balanced through indirect cost incentives. (issue-linkages). The process of knowledge creation and dissemination was anchored within the two water regimes themselves.	(Lindemann)	2008	Understanding water regime formation, Global Environmental Politics, Nov 2008, 8:4
		X	X				A regime cannot function properly unless it can provide detailed and exact guidelines for behavior. Flexible regimes are more successful. Lack of adaptive capacity is bound to impair regime performance.	(Marty)	1999	Managing international rivers : problems, politics and institutions. Bern, European Academic Publishers.
						X	Euphrates- without regular communication and institutionalized cooperation…win-win solutions will be difficult to find. Similar statements for Nile, Jordan, etc.	(McCaffrey)	2003	Water Disputes Defined: Characteristics and Trends for Resolving Them. Resolution of International

Uncer tainty	*Enforce ment*	*Specificit y*	*Flexi bility*	*Integrat iveness*	*Scale*	*Commun ications*	Relevant Text	Author	Year	Title
										Water Disputes. The International Bureau of the Permanent Court of Arbitration. The Hagues, The Netherlands, Kluwer Law International**:** 49-90.
			X		X		…suggests that the balance of evidence in this area shows that "neither purely local level management nor purely higher level management works well by itself:. He further makes the case that lower level management, and "community self organization (tend) toward sustainable practices.	(Nelson)	2007	"Adaptation to Environmental Change: Contributions of a Resilience Framework." Annu. Rev. Environ. Resour. 32: 395-419.
							The Model Agreements ASCE 2004 are based on four guiding principles that underlie the formulation and development of any compact.1. Negotiations must be conducted with a commitment to coordination and cooperation. 2. To overcome the inherent obstacles facing effective water sharing, an interdisciplinary approach to water allocation among parties must be used. 3. The agreement should provide for management on the basis of watersheds and/or river basins. 4. Adaptive management and flexible provisions should be included in the agreement. If nations are able to draft compacts that uphold these four principles, they have taken a significant step on the path of allocating the resource in a manner that reduces conflict and provides for the future of their citizens.	(Phelps & Wre)	2007	"Water and conflict: Historical perspective." Journal of Water Resources Planning and Management-Asce 133
		X					agreement has 'vague or ambiguous management objectives'...	(Rieckerma nn)	2006	"Assessing the performance of international water management at Lake Titicaca." Aquatic Sciences 68: 502-516.
				X			The underlying interest of many involved, often not recognized, is commonly not the water itself-but rather the benefits and opportunities they hope to obtain from access to that water (i.e. not cubic meters but dollars.) The positive sum nature of international cooperation in this context is more intuitive, because of the interaction of economic activities and the integrity of the ecosystem.	(Sadoff)	2002	"Beyond the River: the Benefits of Cooperation on International Rivers." Water Policy 4: 389-403.

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	X					X	Every agreement involving the establishment of allocations, normalization, transfer, or reallocation of water or water rights on a shared water resource should include factors such as financial or other forms of compensationn such as water exchange, or water import from external resources or desalination. Other factors should include: information sharing, joint commissions for inspection, monitoring and control of both quantity and quality on both sides of the border, and agreed upon methods of settling disputes including arbitration.	(Shuval)	1994	"Proposals for the integrated management of the shared transboundary water resources of the Jordan River Basin." water Science Technology 30
				X	X		Cooperation is most likely when countries can expect a multilevel game (repeated interaction on the same issu), can employ issue linkage, and the issue is salient in the domestic as well as the international arena.	(Song & Whittington)	2004	"Why have some countries on international rivers been successful negotiating treaties? A global perspective." Water Resources Research 40
	X		X			X	A problem facing many countries around the globe is the absence of a mechanism designed to facilitate negotiations to break stalemates or diffuse tensions between riparian states of an international watercourse. Thus the challenge…is not only to resolve water disputes between states, but also to facilitate negotation in order to resolve 'issues' before they become 'disputes' in the traditional and legal sense of that term.	(Subedi)	2003	Resolution of International Water Disputes: Challenges for the 21st Century. <u>Resolution of International Water Disputes</u>. The International Bureau of the Permanent Court of Arbitration. The Hague, The Netherlands, Kluwer Law International**:** 33-47.
				X		X	Conflict can be better avoided by talking and information sharing. The above described drawbacks can, in all likelihood, be remedied by an enlargement of the original scope fo the obligation not to cause harm.	(Tanzi)	2001	The United Nations Convention on the Law of International Watercourses. London, England, Kluwer Law International Press.
				X		X	It is imperative that the institution is effective, so rationality is assumed with respect to finances, information generation, data flow and availability. An effective strategy would need to embrace at least three elements of a broader national or regional policy if it is to effectively minimize the possibility of social instability.	(A. Turton & Ohlsson)	2000	"Water Scarcity and Social Stability: Towards a Deeper Understanding of the Key Concepts Needed to manage Water Scarcity in Developing Countries." SOAS Pu
				X			Nile: it is anticipated that these cooperative investmenets will yeild significant indirect benefits and leverage	(Whittingto n et al.)	2005	"Water resources management in the Nile

Uncer tainty	*Enforce ment*	*Specificit y*	*Flexi bility*	*Integrat iveness*	*Scale*	*Commun ications*	Relevant Text	Author	Year	Title
							opportuniteis "beyone the river" for greater regional integration and cooperation.			basin: the economic value of cooperation." Water Policy 7: 227-252.
		X					Defining concepts which are intentionally vague for both reasons of legal interpretation and for political expediance - 'reasonable', 'equitable', and 'significant' - guarantee continued ambiguity in the principles of customary law.	(A. Wolf)	1999	"Criteria for equitable allocations: the heart of itnernational water conflict." Natural Resources Forum 23: 3-30.
	X						the present system of international law seeks to establish and progressively raise the hurdles for acceptable State behaviour whilst maintaining the full consent and participation of all States	(Woodhous e)	2008	"Hydro-hegemony and international water law: grappling with the gaps of power and law." Water Policy 10
	X						A key finding is the identification of a newly emerging tool-the'compliance verification system' - as an important means of dispute avoidance in two regions: Europe and Southern Africa.	(Wouters)	2002	Universal and Regional Approaches to Resolving International Water Disputes: What Lessons Learned from State Practice? The Permanent Court of Arbitration Peace Palace Papers, pp Water Int'l, Vol 25 No2 p.202
	X		X			X	Concomitant with the lack of adjustment is a complete absence of coorination between the states in the development of the rivers.To maintain long-term cooperation, states must overcome their fear that others will cheat. An institution can accomplish this task by monitoring member states' behaviour, making commitments more credible, sanctioning cheaters, and managing disputes.	(N. Zawahri)	2006	"Stabalising Iraq's water supply: what the Euphrates and Tigris rivers can learn from the Indus." Third World Quarterly 27

Appendix B: Estimating Flow Probabilities to Meet Water Treaties Allocation Requirements

This appendix describes three methodologies to reconstruct past streamflow in basins where historical gaging data may be absent or too short to measure the compliance of specific water allocation requirements in the past. The description of the methods is followed by an assessment of their merits and weaknesses. The prerequisites needed to apply the described flow reconstruction and projection methods, as well as a final assessment, are also presented. This appendix is a summary of a World Bank report, "Estimating Flow Probabilities to Meet Water Treaties Allocation Requirements" submitted in November 2008 (Zentner et al., 2008). From the analysis in this appendix, a methodology (Methodology 3:*Utilizing Existing Global Datasets*) was selected for research use within this paper.

Why Flow Analysis is Necessary: From Streamflow Record to Probability of Water Allocation Failure

A historic flow record ideally consists of gaged stream level and/or flow, but it could also be reconstructed from climate or proxy variables using a model. This baseline can be used:

- To establish the degree to which treaty agreements have been met in the past;
- As a baseline against which future changes are assessed;
- To calibrate models that predict flows from climate data and can then be used to predict future flows from future climate-scenario data.

A hypothetical example is presented below to illustrate how flow-records can be analyzed and utilized. Figure 1 illustrates an example of a historic flow baseline. It shows a time series of streamflow in a river just above an international border. The river is located in a sub-humid/semi-arid region near the Mediterranean Sea. Normally rainfall occurs mostly in winter causing a peak in the river flow; however, variability from year to year is large.

Typical treaty flows in such environments and large rivers include the examples indicated in the figure: a minimum flow requirement and/or a volume to be delivered to the downstream country during a certain season or over the entire year.

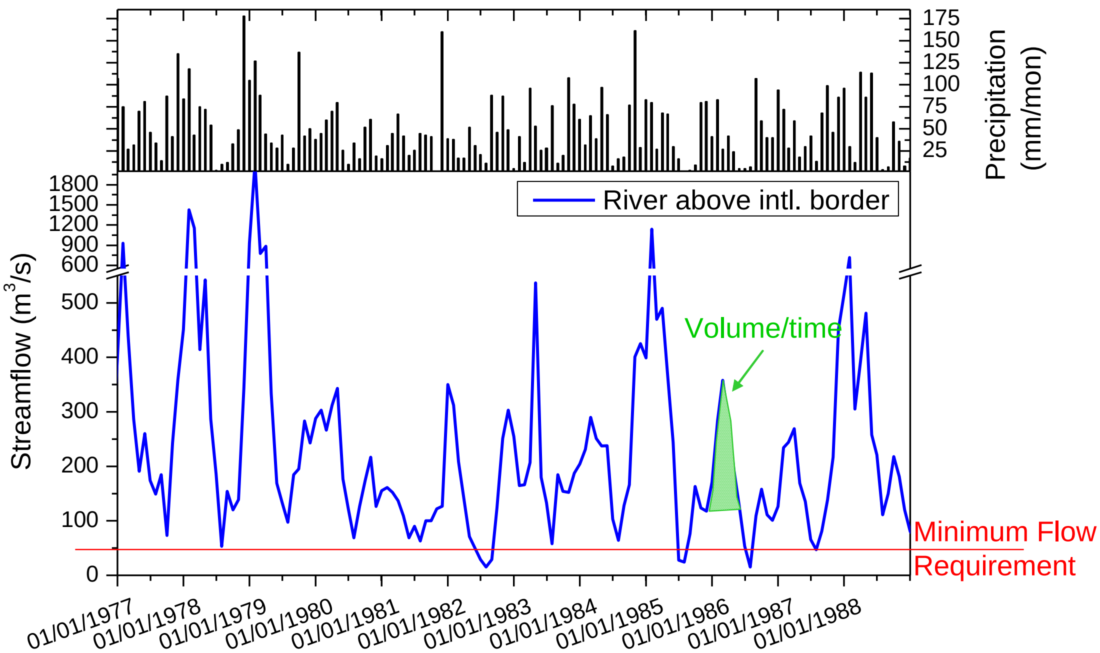

Figure 29 Illustration of potential treaty flows in an unidentified international basin.

The figure shows that the hypothetical minimum flow requirement of $50m^3/s$ was not met in 3 out of the 12 years shown. The total time this flow was not exceeded during the entire period of record available (from 1961 to 1991) can be easily extracted from the flow duration curve (or cumulative frequency distribution; Figure 2) and is 15 months or 4% of the time. If the treaty flow does not relate to the exceedance of a certain streamflow rate (such as a minimum flow requirement of $50m^3/s$), but to an annual or seasonal cumulative volume (such as “200 million cubic meters of water to be delivered from country A to country B every year between Oct and April”), The streamflow time series (usually given as daily or monthly mean flow in m^3/s) needs to be aggregated to this specific flow characteristic and the historic distribution--if this characteristic needs to be calculated and used.

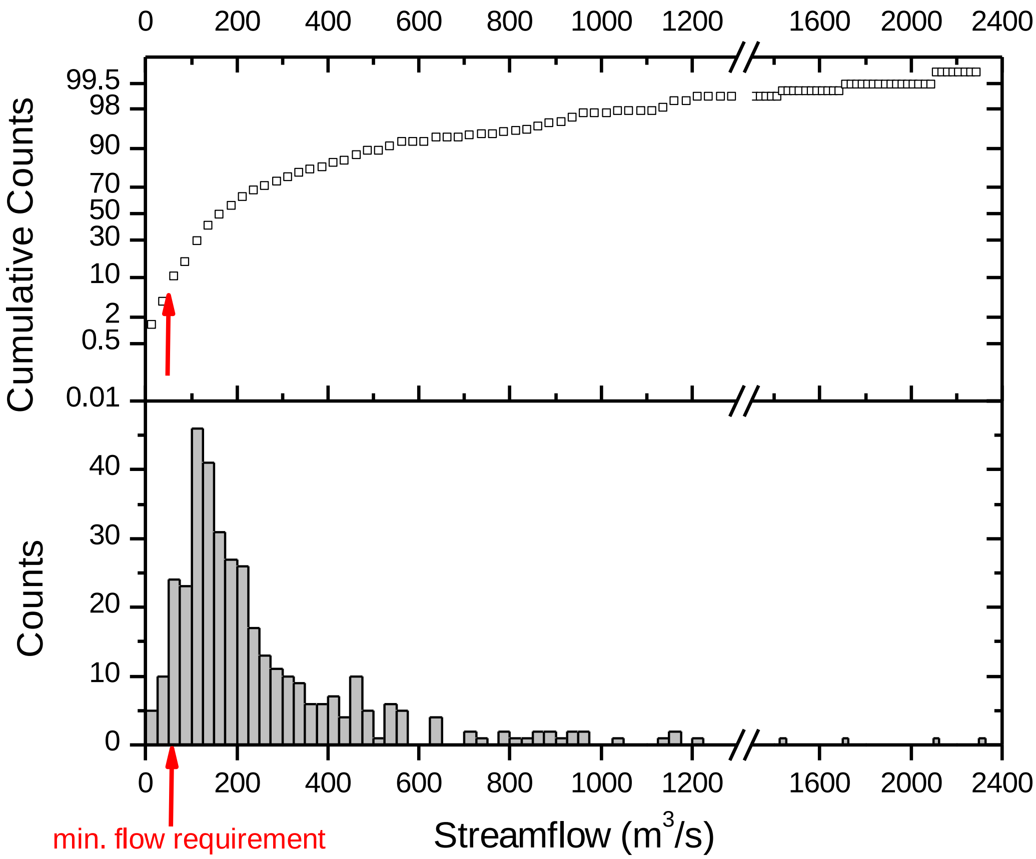

Figure 30 Histogram and cumulative distribution of monthly flows.

In order to be able to assess the specific flow characteristic relevant to the treaty, it is therefore necessary to know from treaties or from failures of agreements the:

1) Agreed flow characteristic (allocated water quantity, min. flow, etc.)
2) Agreed Location
3) Agreed time of allocation (e.g. “between Oct and March each year”)

If streamflow data is available or can be estimated from proxy data, it can be used to establish the probability distribution. If only anomalies of the variable or a proxy variable are available, then, for example, a date of occurrence of failure (minimum flow was not met/flow volume could not be delivered on time) could be used instead to find the anomaly value that corresponds to the real value of the agreed flow characteristic.

Overview of Flow Estimation Methods in Ungaged Rivers

For many areas, traditional ground-based gage measurements typically used to determine local hydrologic flux (such as manually measured water levels, mechanical flowmeters and weirs) may not be available or data dissemination may be problematic. In other cases, locations of interest may be located in remote areas that are difficult to access and data acquisition may be irregular. In areas where long records of flow are available at locations of interest for treaty compliance, the historical variability, and hence probability of surface water flow properties (such as minimum flow requirement or the cumulative water volume allocation) can be calculated directly from the record. For areas with records that are short, scattered, or of questionable accuracy, alternative flow estimation methods are necessary to create or expand flow history.

Much work has been done on estimating flows in areas where gaged data is limited or absent. The task, however, is difficult enough and past success has been limited enough to recently prompt the International Association of Hydrological Sciences to establish the Prediction in Ungaged Basins (PUB) initiative (http://pub.iwmi.org/). In hydrological research, historically, two fundamentally different approaches for prediction in ungaged basins (a task also called "regionalization") can be distinguished: the direct estimate of certain flow statistics, and the establishment of transferable models that allow the simulation of entire flow time series. A relatively young approach (to estimating flow where limited local gaging is available that does not fit in the regionalisation model categories) is the use of remote sensing data.

The regionalization of specific flow variables is firmly rooted in hydrological design and commonly applied to engineering problems such as flood peak estimates for flood protection or bridge design, or low flow estimates for minimum flow requirement compliance (e.g. Laaha & Blöschl, 2007). Most methods use a training data set of many gaged basins to relate the flow variable of interest to climate and basin properties (e.g. by regression) to build a statistical model which can then be applied to rivers where climate and basin property maps are available-- but flow variables such as peak, mean or low flow quantity need to be estimated. This approach is popular since predictors such as climatic variables, soil type, geology, topography, etc. are readily available or can be interpolated more easily across space. Initially, research also included direct interpolation of streamflow or investigating regional similarities according to climatic regime and basin properties through the grouping of basins. Sauquet (2006) presented an approach to calculate mean annual runoff based on geostatistical interpolation procedures, coupled with empirical relationships. A spatio-temporal linear dynamic model developed for patching short gaps in daily river runoff series presented by Amisigo and Giesen (2005) showed that their model was capable of providing good estimates of missing runoff values at a gaging station and at spatially correlated stations in the same sub-basin. However, the application of such empirical regionalisation approaches is based on the assumption of stationary hydrological conditions. Therefore their suitability for estimates of future flow variables in a changing climate is questionable and the approach is not considered further in this study.

The establishment of models that simulate an entire time series of streamflow in ungaged basins is used where predictions of multiple flow properties or measure of flow variability are required. Most commonly, conceptual hydrological (rainfall-runoff) models of varying levels of complexity are used. The underlying equations that transform rainfall into streamflow are physically based, but the complexity is generalized enough for the model parameters to require calibration in order to obtain a good simulation of observed flow. For application to ungaged basins, generally these model parameters are tuned to a training data set for which gaged streamflow is available, and are then either assumed to be valid in the ungaged basins or they are regionalized based on the establishment of systematic relations to basin characteristics such as topography, landuse, soils, etc. (similar to the regionalization method of flow properties described above). The use of regionalized hydrological models across large regions has become popular as climate data has become more readily available. Under the assumption that internal processes remain stationary, the effect of scenarios of a changed future climate (input change) can be simulated with such models.

With the advent of satellites, the availability of large amounts of remotely-sensed data allowed for greater possibilities in flow analysis of ungaged areas. Two different general approaches can be distinguished: a) the direct gaging of river stage from satellites, and b) the indirect aggregation of surface and soil wetness information. Direct gaging can only be done for large rivers with a known stage-discharge relationship. An example of the first approach is Zhang (2004), who used satellite data to measure surface water width and produce remote stage-discharge rating curves and calibrated the remote data using functions developed from observed discharge. The second, indirect approach is based on aggregate estimates of surface wetness/soil moisture derived from microwave remote sensing or on changes in mass derived from gravimetric sensors for the entire watershed area to derive an estimate of flow or of general land surface water storage changes (Troch et al., 2007). In an early study, information from remote sensing sources was used in an example by Schultz (1996) to compute runoff values indirectly with 3 models, with different temporal and spatial scales: a mathematical model which reconstructs monthly river runoff volumes on the basis of IR data; a model that computes flood hydrographs with the aid of a distributed system rainfall/runoff model; and a water balance model which computes all relevant variables of the water balance equation including runoff on a daily basis. Alsdorf et al. (2007) present a summary of remote sensing capabilities to determine the spatial and temporal variability of water stored on and near the surface of all continents (including surface water area, the elevation of the water surface (h), its slope, and temporal change). Wagner et al (2007) review the readiness of microwave remote sensing of soil moisture for hydrologic applications and suggested that most potential lies in the assimilation of operational hydrological models, such as the ones used for flood forecasting.

Description of Selected Modelling Approaches

The following sections (9.4, 9.5, and 9.6) consider the methodology of three different modelling approaches in more detail. They all have the aim of simulating past hydrological time series.

The first method described uses a remote sensing product of surface-wetness for all locations with sufficient flow and ancillary data (Basist et al., 2001) and is therefore an example for the approach b) described in the section above on remote sensing data. The second method consists of a simple water balance model with input from global climate data sets. Both methods need some gaged data for model calibration.

Finally, two existing global datasets that describe hydrological variation with time are tested: a drought index and flow data from the global hydrological model WaterGAP (Döll, Kaspar, & Lehner, 2003; Hamner, 2008). Both represent examples of models that work with parameters that were regionalized or transferred to the entire world.

Surface Wetness Product (Methodology 1)

Remote sensing data can be used to extend partial stream-flow records, to help overcome a lack of data availability, or to derive natural flow patterns from anthropogenically-modified river systems. The remotely sensed wetness product is derived from the Special Sensor microwave Imager (SSMI). The wetness product identifies liquid water from all sources (i.e. precipitation, snow melt, sub-surface). It is correlated with water in the top 10 cm of the soil, and therefore retains some memory of surplus/deficit of water over the recent period (Basist et al., 2001). The resolution of the satellite product is approximately 30 kilometers by 30 kilometers, therefore it is a good measure of stream flow for intermediate and large basins, but does not have the resolution required for smaller basins.

Parameters of the Basin

River basin boundaries are indentified as the region that drains into the basin of interest. Topography and other GIS tools are used to identify the specific domain. These areas are further analyzed to determine the specific contribution a pixel (1,000 square kilometers) to determine the correspondence between the satellite observations to the basin area. Then area weights are assigned to the various pixels to best represent the contribution of water from their area. It is important to know where the free flow of water is contained, since the flow downstream can be more of a construct from the release policy than the actual flowing into the containment area.

Calibration of the Models

The wetness data is then analyzed in terms of their monthly mean value. Initially the data set is set up as two vectors: the monthly river gage data, and the area weighted wetness anomalies, which represent the magnitude of water moving from the surface and/or sub surface. These values are post-processed to identify areas where the values are largely stationary water bodies (such as the Dead Sea and the Sea of Galilee) since these values do not contain a signal from soil moisture. We then test various lag-lead relationships, which account for time required after the surface gets wet for the water to work its way through the system and register at a downstream gage. In other words, our analysis allows for the creation of various lag relationships, which represent the rate wetness is transported through the natural stream system. The correlation between gage data and wetness values (using a stochastic relation between near-surface wetness and actual stream flow), provides the moments of the parametric model, and these identify the explanatory power of the model, and allow us to access the relationship.

Water Balance Model (Methodology 2)

In a simplified hydrological system (commonly the river basin) water from rainfall partitions into four general variables:

1. A loss due to evaporation and plant transpiration (and abstraction for irrigation etc);
2. Direct runoff that forms river flow with only a short delay (hours to days);
3. Filling of storage (soil, groundwater, surface reservoirs) that is discharged into the stream after a delay (months to years); when the storage is full, all rain will run off directly into the stream;
4. Seasonally delayed runoff due to precipitation that is stored upstream in the form of snow which is later melted (this does not occur in all basins).

Modelling streamflow therefore involves dealing with these different lags that are common to most hydrological systems, but that differ in magnitude and significance in basins. To take the lag times into account, streamflow is most commonly modelled with deterministic hydrological models that use ‘buckets’ (storages conceptualized as linear reservoirs), which delay runoff until they “overflow” when capacity is reached (Manabe, 1969).

For this study, it is proposed to use such a simple bucket based model to predict streamflow using time series of climate input (precipitation and temperature, the latter being used, for example, to estimate loss from evapotranspiration). The resulting water balance equation for a basin is given by:

$$S(t+1)=S(t)+P(t)-E(t)-Qse(t)-Qss(t) \qquad (1)$$

with storage S, precipitation P, Evapotranspiration E, direct runoff Qse (se for sat uration excess) and (delayed) subsurface runoff Qss. Equation (1) is used to simulate the temporal variation of water storage and the various outgoing fluxes at a monthly time step.

The model will generally be kept simple enough to be applied to multiple basins. However, where increased complexity is needed (e.g. considering snow or regions with very different vegetation), the modelling approach will follow the approaches of Atkinson et al. (2002) (Figure 3). They found that greater model complexity is needed with increasing temporal resolution and with increasing aridity.

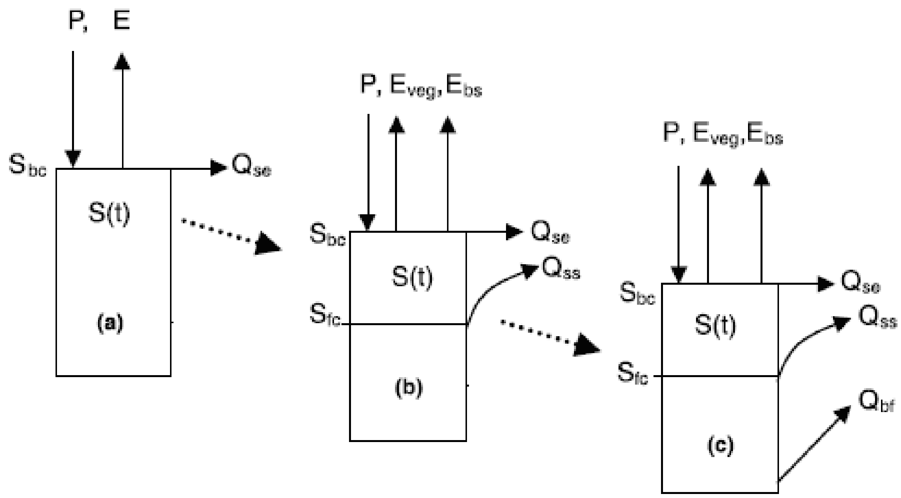

Figure 31 Bucket-based water balance models of increasing complexity (Atkinson et al., 2002)

The length of the time series (years of gaged streamflow data) that is necessary to calibrate the model parameters (outflow coefficients, loss parameter) depends on the year to year variability of the hydrological conditions: ten years is likely the minimum, but longer series may be required in semi-arid regions that have large differences from year to year. The parameters (two in the simplest version) will then be optimized for the best possible simulation of streamflow by varying both parameters within a physically plausible range and comparing an objective function for the multiple model runs. In such applications, usually the Nash-Suttcliffe efficiency (E) or its logarithm (if focus is on the fit of low flows) is used to compare simulated with observed streamflow for the calibration period.

The monthly precipitation and temperature input for the calibration period is derived from the nearest grid cell(s) of the CRU TS2.1 dataset (Mitchell, 2004). This dataset was derived by interpolation of station observations of temperature and precipitation around the world to a regular 0.5 degree global grid. Due to its global coverage, this data set is often used to establish environmental models for the purpose of studying climate change impacts.

Utilizing Existing Global Datasets (Methodology 3)

Data Sets

Various global data sets are available that are useful to derive hydrological conditions in a region of interest. All global datasets are derived from a model with the most simple one consisting of an interpolation model that, for example, estimates precipitation amounts (e.g. by day/month/year) for a regular grid from an irregular network of precipitation stations. Available data sets relevant to water shortages include a global compilation of the Palmer Drought Severity Index (PDSI) from 1870 to 2002 by Dai (Dai, 2004). Dai derived monthly precipitation and surface air temperature data for global land areas, except Antarctica and Greenland, on a 2.5° by 2.5° grid. The PDSI is a water balance measure that quantifies the cumulative departure (relative to local mean conditions) in atmospheric moisture supply and demand at the surface, using both precipitation and surface air temperature as input. Measures of the PDSI range from about 10 (dry) to 10 (wet), and can be used to make comparisons across regions and time. Hamner (2008) kindly provided individual watershed PDSI values for all transboundary watersheds. Using the Dai dataset as a source, Hamner was able to extract downscaled PDSI values with good resolution. GIS, gridded (raster) drought data, at the monthly and yearly level, were overlaid with river basins. Area-weighted average drought levels were then computed for each basin, for each time period, by extracting and summing the values of each basin polygon that had a drought value.

In addition, several global hydrological model applications exist. Some, in particular the land surface schemes coupled to GCMs, focus mainly on vertical exchanges of water between soil and atmosphere. One of the global hydrological models that puts considerable emphasis on the concentration of water into rivers and lateral routing along the river channels is the model WaterGAP model (*Water*—*G*lobal *A*ssessment and *P*rognosis) (Döll et al., 2003). Another model that is increasingly used at continental-to-global scales, but originally was designed for smaller scales, is the VIC model (Nijssen, O'Donnell, Lettenmaier, Lohmann, & Wood, 2001). Besides the larger grid sizes, a major difference of global hydrological models to management-scale hydrological models is that the global models cannot be calibrated easily for each individual basin. Smaller scale hydrological model applications also incorporate more locally and regionally specific land properties, and perhaps most importantly anthropogenic regulations from dams and abstractions. Such details are not available globally.

WaterGAP 2 output for 1961-2002 was kindly made available by CESR (Centre for Environmental Systems Research, Kassel) for selected gaging stations from the GRDC dataset (Alcamo & Döll, 2003; Döll et al., 2003). The WaterGAP model consists of two main components—a Global Water Use model and a Global Hydrology model. This project utilized the output of the model, which is "designed to simulate the characteristic macro scale behavior of the terrestrial water cycle, and to take advantage of all pertinent information that is globally available" (Alcamo & Döll, 2003). The model takes into account soil, vegetation, slope, and aquifer type in the calculation of the water budget, but also considers the reduction of river discharge by human water consumption (as computed by the Global Water Use model).

Examples

While the PDSI is not the same measure as stream flow, the average PDSI can be interpreted as a rough representation of water availability in an international basin over time. The PDSI is not an absolute measure of hydrologic and climatologic conditions, but is relative for a given area. The relative changes in water scarcity represented by the PDSI can be used to evaluate potential relationships between fluctuations in water scarcity and dispute. Figure 4 shows an example for the disputes around the Farrakka barrage operation in the Ganges basin at the border of India and Bangladesh. Most political events concerning the dispute were recorded about one or two years after the onset of the major drought event in the basin.

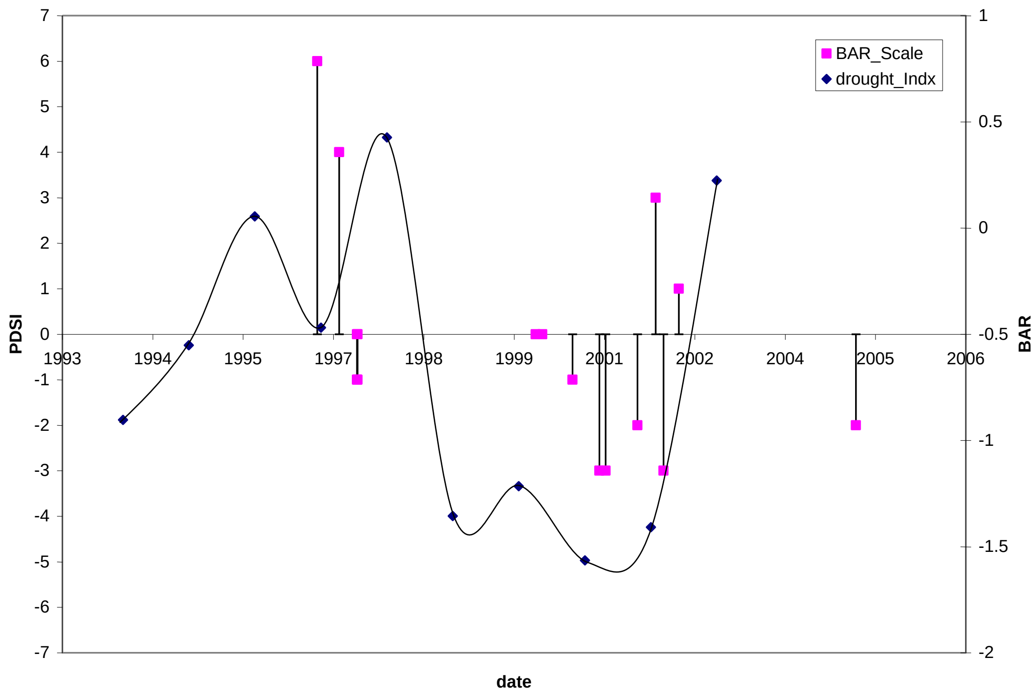

Figure 32 Palmer Drought Severity Index (PDSI) in the Ganges Basin and recorded political events on the BAR scale of conflict (negative) and cooperation (positive) (Yoffe, 2003).

The following two graphs in Figure 5 show the streamflow calculated by WaterGAP and the observations from the USGS gage of the Columbia River at The Dalles. The upper graph shows a 4-year period (1961-66) at a time when the Columbia was only slightly regulated. The lower graph shows a more recent period (1991-96) during which the hydrograph is strongly regulated by several large dams that have been built in the meantime. For a history of the alterations to the Columbia see for example Muckleston (2003).

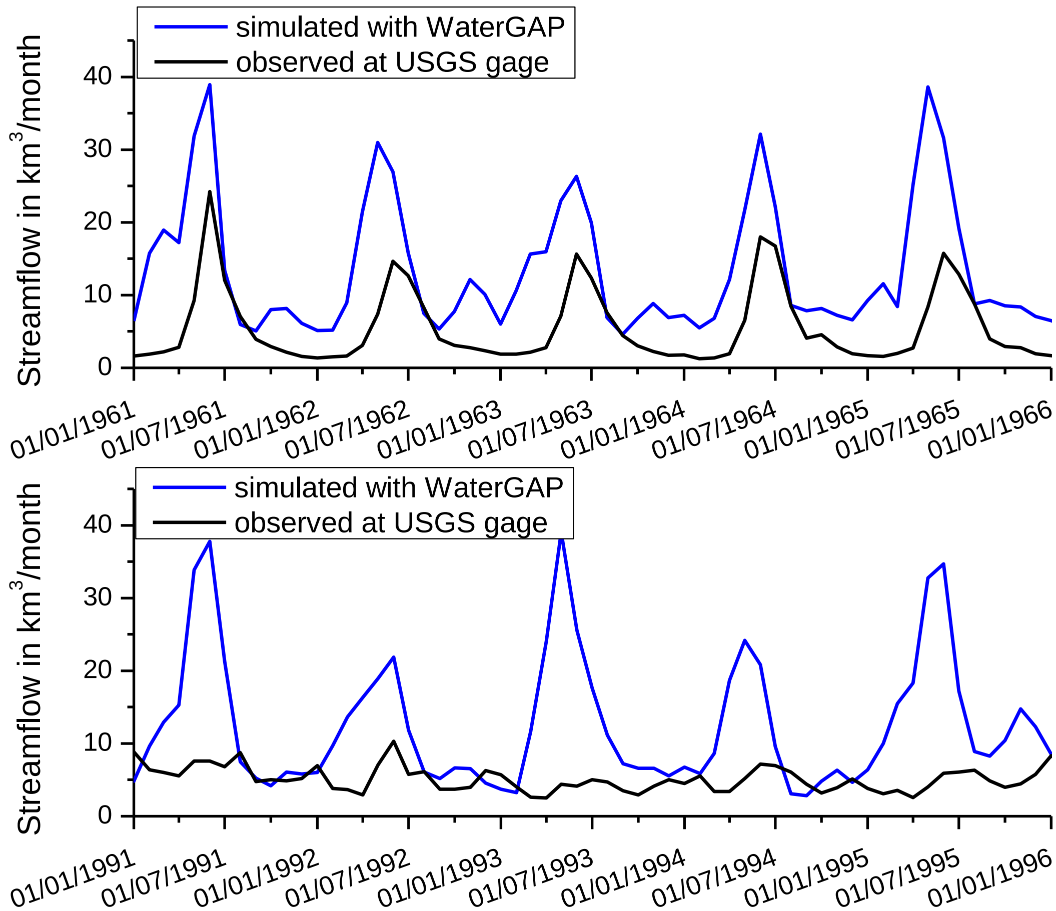

Figure 33 Observed and simulated (WaterGAP) discharge of the Columbia River at The Dalles (Oregon).

In the early period, the WaterGAP model simulates the general seasonality with the snow melt peak, but it considerably overestimates the amount. In addition, the model simulates a secondary peak in the fall, which in fact is not observed in reality. The reason may be that in reality, fall rainfall will first replenish the soil moisture deficit and recharge groundwater with little runoff to form streamflow. In addition, rain in November will fall as snow at higher elevation and this may not be well-simulated in WaterGAP. In the more recent period, the global hydrological model continues to simulate the "natural flow" despite anthropogenic changes to the system. Even with the inclusion of a water use module into the overall model, the simulation fails to consider the storage behind dams which alter the seasonal distribution of flow, nor does it correctly represent the increased overall reduction due to abstractions.

The Columbia River is one of the most heavily modified large rivers in the world. Without information on the details of the dam storage schedules, even a more complex hydrological model could not simulate the observed flow correctly. However, a smaller river used for hydropower generation may show relatively similar modifications and modelling challenges.

Assessment of the Three Selected Methods

Three methods to simulate or extend a streamflow time series from which to estimate treaty flow occurrence were selected that can be applied under different situations of data availability. They each have different advantages and disadvantages and not all can be used to predict future changes in every basin.

The largest potential of the SMMI-based flow estimation likely lies in the reconstruction of past flow series in regions/basins with a short-to-medium runoff concentration time. Applicability may vary among climatic zones and it has yet to be tested in some environments. For prediction of future changes, it would have to be assessed whether soil moisture of the uppermost soil layer (as predicted by climate models) was comparable to SMMI surface wetness in the past. This would be a prerequisite to using the defined link between surface wetness and streamflow and applying it to future GCM output of soil moisture. Currently, different GCMs simulate soil moisture very differently (Cornwell & Harvey, 2007).

An advantage of a calibrated water balance model is that because of the calibration, local details (including alterations from dams and abstractions) will implicitly be considered by the model, at least to a certain extent. However, at least a few years of gaged flow data is needed to calibrate the model. In addition, information on topography, vegetation, etc.

may be required to set up a model producing the required accuracy, which may then make this a time-consuming and costly exercise.

Existing datasets from regionalised models such as the reconstructed global PDSI or global hydrological model output from WaterGAP are generally convenient sources to be used for climate impact studies. Most global hydrological models have already been run into the future, driven by the IPCC scenarios. At least some estimates of future flow will usually be available along with a reference simulation of the past. Presently, a major caveat of the use of global model output in a study that aims particularly at hydropower-related treaties is that, as shown in the Columbia example, they cannot correctly simulate regulated streamflow. This may change in the future if information on reservoir management becomes globally available to be integrated in the model structure. An additional problem is that model output is often only available for a limited set of stations that have been used for validation in prior studies. Model output can be used to estimate the probability of treaty flows to be met if these happen to be defined at the same location. However, smaller subbasins, where the treaty flow may be defined, may have model outputs that are not reported or may be too small for the rather coarse resolution used in global modelling.

Water balance-related global datasets, such as the reconstructed Palmer Drought Severity Index grids, are readily available and may correlate well with the occurrence of a country' difficulties with treaty compliance in case of a drought. However, in order to estimate a streamflow value from the drought index that could be compared to a treaty flow, gaged data would again be necessary to derive a link between PDSI and flow. In addition, the PDSI is a climatological value and hence does not include information on water management and regulation. It is also difficult to validate locally, which would be a necessary step considering that the parameters that were originally derived for the US Midwest were now applied globally. To date there are no future PDSI projections available.

In summary, the main restriction with the first two methods is that they require a minimum of ten years of gaged streamflow data (and more in areas with high inter-annual variability) in order to fit the models that predict streamflow from remotely-sensed surface wetness or climate variables, respectively. The third method of using existing global hydrological model output doesn’t need local information, but provides generally less specific or less accurate results, possibly not in the right location. At present, only water balance or hydrological modeling that links climate variables to streamflow provides the possibility to consider the effect of future climate change as predicted by climate models.

Method for Modelling Future Flow Scenarios

The Fourth Assessment report of the IPCC (2007), which summarized the findings of scientific studies, concluded that runoff increases are likely in high latitudes and the wet tropics, and decreases can be expected in the mid-latitudes and some parts of the dry tropics. Changes in temperature and in the amount and timing of precipitation will affect river flows. While changes in precipitation directly affect surface runoff and delayed subsurface runoff, temperature changes will affect evapotranspiration, and in colder climates the proportion of precipitation falling as snow. Most studies that have investigated hydrological effects of climate change used a catchment hydrological model driven by GCM scenarios (Bates et al., 2008), similar to Methodology 2 in the previous section. Fewer studies have derived hydrological change either directly from grid-cell runoff computed within the GCM or from global hydrological models that were driven by GCM climate (mostly run off-line). At this time, these land surface modules of GCMs and the coupled global hydrological models have large prediction errors. In order to compare the output of river flow to observed/measured data, an additional bias correction needs to be applied. Therefore, such output is generally not yet considered suitable for water resources management questions, but is used mainly to identify large-scale or global patterns of relative changes.

Applications that relate directly to water management questions and the prediction of flow quantities hence tend to use a hydrological model which transforms climate input (mainly precipitation and temperature) into river flow (Figure 6). Such models usually take into account regional characteristics that influence the river basin's response to precipitation and have parameters that are calibrated to correctly reproduce historic flow records. The calibrated model can then be driven with scenarios of future precipitation and temperature input, and the hydrological response can be compared to the historic record.

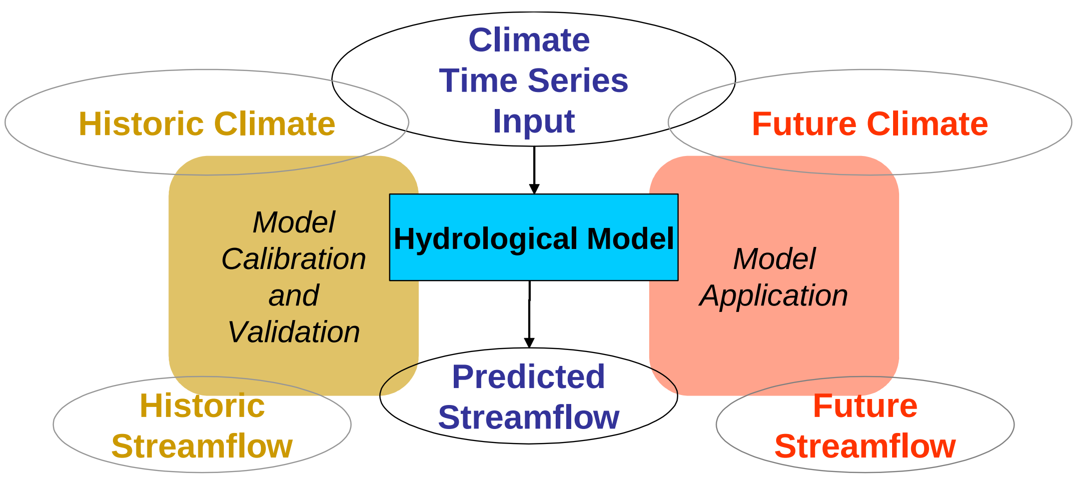

Figure 34 Application of hydrological model for prediction of future streamflow (schematic)

Xu (1999) reviewed studies and models used for this purpose and summarized model types that are suitable for input resolutions:

1) Empirical models (annual);

2) Water-balance models (monthly);

3) Conceptual lumped-parameter models (daily);

4) Process-based distributed-parameter models (hourly or finer).

The water-balance model for modelling of past flows thus will be suitable for the prediction of monthly streamflow changes.

Derivation of Climate Scenarios for River Basins

Hydrological models require time series of climate variables representative of the river basin in question. Precipitation and temperature vary highly in time and space, particularly in the complex terrain of mountain environments where water is abundant and thus where most hydropower generation takes place. Climate variables from a grid cell size of a GCM, however, provide a spatial average. Generally, the area of a GCM grid cell (300-400km grid spacing) is therefore large compared to the natural climate variability in a given basin. In fact, basins of interest for water management questions will often be smaller than one GCM grid cell. GCM output that has not been further manipulated is therefore not suitable for direct input into hydrological models. In general there are three options to derive climate series from GCM scenarios that represent the conditions in the basin: one is the ‘delta-change’ approach, and the other two are ‘statistical downscaling’ and ‘dynamical downscaling’.

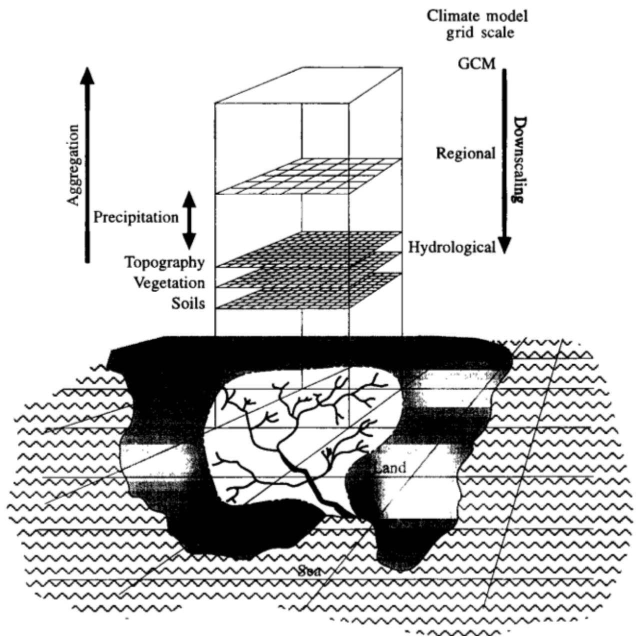

Figure 35 Three options to derive climate series from GCM scenarios (Wilby & Wigley, 1997).

<u>Delta-Change Approach</u>

First, GCM output of a historic period (matching a period for which locally observed data is available) is subtracted from output of a given future scenario to derive a change factor or ‘delta change’. This can be done for several climate variables and for one or more grid cells depending on the size of the basin and the region of interest. Figure 8 shows an example of monthly temperature changes for the GCM grid cell that covers the upper Yarmouk Basin in Jordan. The figure shows relative temperature changes from 3 different GCMs derived by subtracting the control-run base period (1961-90) from the runs of the SRES A1B scenario for the decades of the 2030s (blue colors) and the 2050s (red colors). Data for this example were extracted using the new Climate Mapper released recently by USAID, NASA and IAGT[63] and represent a selection from the IPCC’s Fourth Assessment

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[63] http://www.iagt.org/servir/servir_viz/climatemapper.asp Accessed 15 June 2009

Model Intercomparison Project (see also section 3.3). The Climate Mapper is currently available for the African Continent and the Middle East.

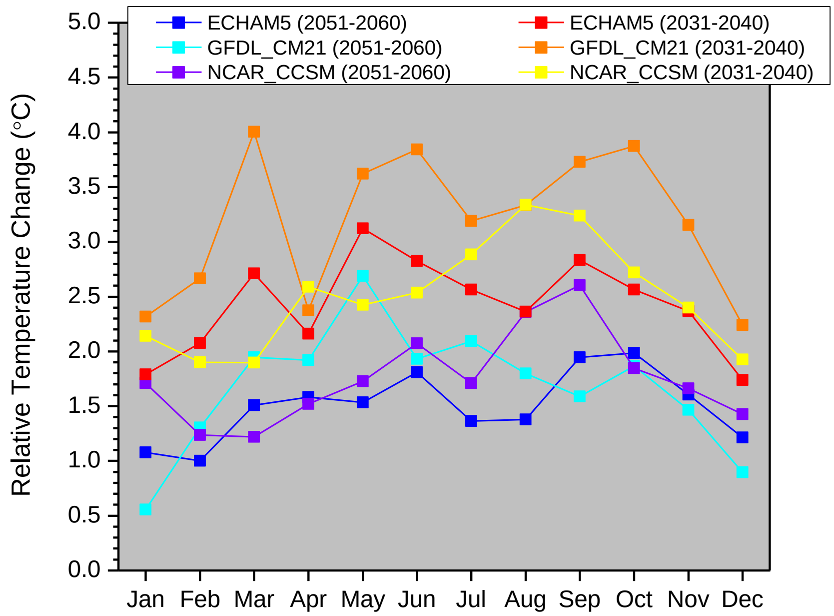

Figure 36 Mean monthly temperature changes for the 2030s and 2050s compared to the base period 1961-90 as modelled with three different GCMs.

Second, the relative changes that were derived from the comparison of past and future GCM output are then applied to the historic temperature time series in the basin; i.e. the historic record is simply modified by adding the relative change for a certain calendar month to the month of the historic series. The historic series are thus projected into the future (Figure 9). In the present example the 'historic data' came from the CRU data set, which consists of historic climate grids derived by interpolating station records to a grid of 0.5° latitude and longitude (Mitchell, 2004). CRU time series are hence not truly observed records, but where no local records are available they represent the closest estimation of actual conditions.

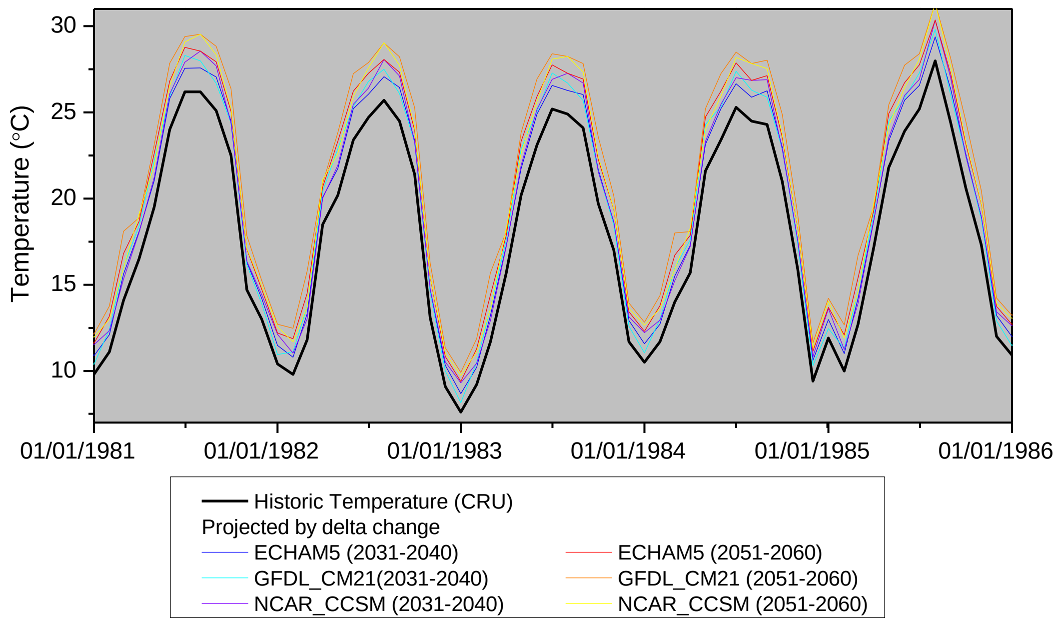

Figure 37 Projected monthly temperature time series using the delta-change from Figure 8 and CRU baseline.

The delta-change method is a classic and still widely used method. It assumes that relative variability will remain the same in the future, only at a higher/lower average level. Hence changes in the persistence and occurrence of cold/warm spells and wet/dry spells are not taken into account. For temperature, usually the difference is used; for precipitation, a relative percent change is applied.

<u>Statistical Downscaling</u>

A statistical downscaling model is derived by statistically relating a locally observed historic climate variable to larger scale grid cell averages of GCM output variables for the same historic time period. Most statistical downscaling models use multiple GCM variables (e.g. sea level pressure, water vapour, temperature at 2m, geopotential height) to predict one local climate variable such as temperature and precipitation (Figure 10). The most common models used are multiple linear regression and related models. If sufficient local information is unavailable, interpolated climate variables can be used (e.g. CRU, or regional interpolation from station network). The derived statistical model can then be applied to the large-scale GCM scenario output to obtain local scenarios.

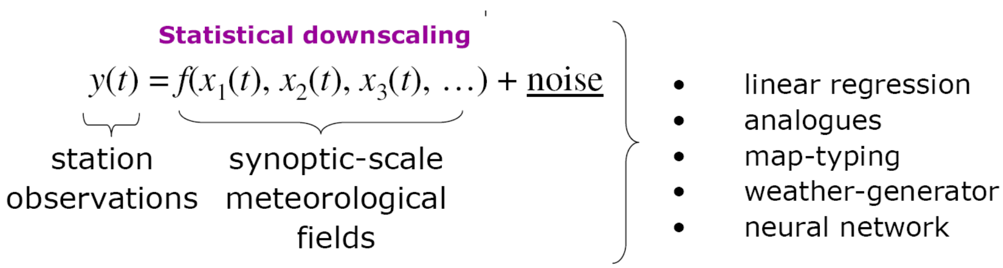

Figure 38 Statistical downscaling (Cannon, 2008)

Performance of statistical downscaling procedures varies among studies and sites/regions. Whether it provides more reliable predictions than the delta change method depends on whether it is possible to find a good statistical model. Various software applications exist to derive statistical downscaling models and thus it would be computationally feasible to derive statistical downscaling models for a few basins if the same approach is used everywhere (at the cost of finding better potentially better fits with individual solutions). A statistical model assumes stationarity in the link function, i.e. a certain combination of atmospheric variables will always cause the same local weather. If weather statistics such as the duration of wet and dry spells are linked to changes to atmospheric variables included in the model, and such changes are relevant to the impact under investigation, then the approach will be superior to the delta change method for the task of estimating basin scenarios.

Dynamical Downscaling

Dynamical downscaling is performed with a subgrid-scale Regional Climate Model (RCM) driven directly by the GCM. Only a few RCMs exist worldwide and their resolutions range from 10 to 50 km grid spacing. RCMs produce atmospheric variables at high temporal resolutions. Setting up and running a regional climate model for a specific area of interest is generally computationally expensive and could most likely only be done for one case study. In addition, the bias (difference) between modelled and observed precipitation still tends to be large and usually differs between different months and regions. Therefore, an additional bias correction needs to be applied to the RCM output to obtain suitable climate input for a hydrological model (Graham, Hagemann, S., & S. Beniston, 2007).

Data Availability and Feasibility of the Methods

While physical consistency increases from the delta change method to statistical and dynamical downscaling, computational cost increases. Obtaining finer scale climate scenario input from a RCM with bias correction is only possible if an RCM is run for the region of interest. As most RCMs specialize on the ‘home continent’, this approach is not an option for a global study. Delta change and statistical downscaling are more feasible methods for a global study.

For either approach, the same datasets and approach should probably be used for all basins to be modelled. This means that historical climate to fit the water balance model, as well as the delta change or downscaling, should come from global data set such as the CRU TS2.1, and the same GCM scenarios should be applied for future predictions.

Precipitation and temperature output from different Global Climate Models or from multiple runs of one model can show large differences. This causes large uncertainty when the climate model output is used in hydrological modelling and other freshwater studies. To take into account the differences between models, multi-model ensembles are often used to address the uncertainty of climate model choice. Therefore, it is recommended to use output from several scenarios that is available from the IPCC data distribution centers.

For modelled data, this analysis uses twenty-three A1B scenario GCM data from the GCM model output from the Intergovernmental Panel on Climate Change (IPCC) 4th

Assessment that is available at World Climate Research Programme's Working Group on Coupled Modelling Coupled Model Intercomparison Project Multi-Model Dataset Archive [64] at Program for Climate Model Diagnosis and Intercomparison (PCMDI)[65] (Meehl et al., 2007). To obtain the change factors for the described prediction methods, monthly mean surface temperature and monthly mean precipitation rates were extracted from the output of two experiments: the 20th century climate (20C3M) and the future SRES A1B scenario.

The A1 emission scenario is based on the following assumptions:

- World: market-oriented
- Economy: fastest per capita growth
- Population: 2050 peak, then decline
- Governance: strong regional interactions
- Income convergence
- Technology: three scenario groups:
- A1FI: fossil intensive
- A1T: non-fossil energy sources
- A1B: balanced across all sources

The relatively balanced A1B scenario is the future scenario that is simulated by most GCMs. Monthly output of temperature and precipitation is available for 24 models according to the PCMDI website:

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[64] http://www-pcmdi.llnl.gov/projects/cmip/index.php Accessed 19 May 2009
[65] http://www-pcmdi.llnl.gov Accessed 19 May 2009

- BCCR-BCM2.0, Norway GISS-ER, USA
- INGV-SXG, Italy
- INM-CM3.0, Russia
- IPSL-CM4, France
- MIROC3.2(hires), Japan
- MIROC3.2(medres), Japan
- MRI-CGCM2.3.2, Japan
- PCM, USA
- UKMO-HadCM3, UK
- UKMO-HadGEM1, UK
- CCSM3, USA
- CGCM3.1(T47), Canada
- CGCM3.1(T63), Canada
- CNRM-CM3, France
- CSIRO-Mk3.0, Australia
- CSIRO-Mk3.5, Australia
- ECHAM5/MPI-OM, Germany
- ECHO-G, Germany/Korea
- FGOALS-g1.0, China
- GFDL-CM2.0, USA
- GFDL-CM2.1, USA GISS-AOM, USA
- GISS-EH, USA

The GCMs work at various different spatial resolutions. A common procedure to prepare the data for local or regional usage is to first re-grid (interpolate) the GCM output to the same 0.5 degree grid used by the CRU TS2.1 reference data set. The CRU and GCM grids can be then intersected; in this project, for example, with the river basin delineations provided by TFDD for further analysis by basin.

Potential for application to global international basins

Predicting flows in a large number of basins with a wide range of climate, anthropogenic diversions of natural flows, and data availability is exceptionally difficult. Each basin is unique in its flow characteristics, and for high-resolution analysis would require the development of site-specific research plans and much resource-intensive data gathering. We assessed selected methods utilizing readily available, global, lower-resolution data for application across all basins regardless of site characteristics. The first set of methods described aim to provide a baseline dataset of historic flow conditions (reconstructed from either the SMMI, water balance, WaterGAP, or the PDSI datasets) for each watershed of interest. From this baseline, the vulnerability of water-allocation treaties in international river basins could then be derived.

In order to test the estimation of the vulnerability of failure of transboundary water allocations specified in treaties in the future, it is necessary to select cases for analysis. The estimation task requires that the cases to be selected meet certain requirements. In addition to the baseline requirement of a transboundary allocation agreement in the widest sense, the primary requirements mainly concern the availability of data that is needed in order to 1) define a critical threshold of a water allocation that might be vulnerable and; 2) estimate the probability of this threshold not being met.

The data prerequisites thus concern the availability of information regarding both treaties (e.g. quantity of allocation and where and when) and natural water availability in past and future. The ability to accurately analyze treaty compliance, and the methodologies used to do so, are hence highly dependent on the accuracy of the information available. For the streamflow, and hence the vulnerability analysis, an ideal case study would include:

1) A basin large enough to reflect temporal variability of regional anomalies in water availability derived from low resolution global data sets (SMMI, consolidated climate datasets, global models);
2) Substantial inter-annual variability of water availability;
3) Gaged streamflow above or near the allocation point, and above any dams that may alter natural/climatic water availability signal.

    a) Gaged streamflow data for at least 30 years if used to directly estimate probabilities of treaty compliance;
    b) Gaged streamflow data for at least 10 years within the period 1988 –present if used to predict streamflow as a function of remotely sensed surface wetness (SMMI);

c) Gaged streamflow data for at least 10 years if used to calibrate a simple water balance model that predicts streamflow from global precipitation and temperature data.

Of the several approaches presented in this analysis to predict future scenarios of climate change impact on streamflows relevant to treaty agreements, the delta-change method of projecting a past series of temperature and precipitation into the future seems most useful. Climate models are unable to predict local climatic conditions accurately and are most reliable in terms of relative change. The method of using a local water-balance model that utilizes the readily available global climate variables to predict streamflow can be most directly applied to produce future flow scenarios anywhere where some gaged streamflow records are available. Global hydrological models are in principal similarly qualified and can even predict streamflow changes where no gauged records exist, yet to date they do not consider the river-specific details that can substantially modify a flow regime, and are hence less likely to represent local conditions correctly.

Flow Analysis Methods: Conclusion

This analysis gives an overview of potential methodologies to estimate historical and future flows under certain climate-change conditions, which can in turn be used to evaluate the vulnerability of institutional arrangements and water-sharing treaty implementation. With the understanding that predicting potentially very small impacts of climate-change on flow is very difficult (and perhaps impossible in some cases where local anthropogenic interventions are extensive), using a compilation of multiple lower-resolution techniques allows for at least some predictive capability in order to compare past and future flows across multiple basins. While recognizing that residual uncertainty will always exist, this analysis of the evaluation of the hydrologic record and predicted changes under climate change can be used as a guide to best manage transboundary water resources in the future.

Appendix C: Treaty Summary

Basin	TFDD ID	Signatory	Date signed	Years Enforced	No. of parties (Bilateral/Multilateral-1/2)	Treaty Description
Amazon	289	Bolivia, Brazil	2/8/1984	24	1	Agreement concerning the Cachuela Esperanza hydroelectric plant, supplementary to the agreement on economic and technical co-operation between the government of the Federative Republic of Brazil and the government of the Republic of Bolivia
Amazon	180	Bolivia, Brazil	8/2/1988	20	1	Exchange of notes constituting an agreement for the construction of a hydroelectric plant in Cachuela Esperanza, supplementary to the agreement on economic and technical cooperation
Amur, Har Us Nur, Pu Lun T'o	187	Mongolia, China	4/29/1994	14	1	Agreement between the government of the People's Republic of China and the government of Mongolia on the protection and utilization of transboundary waters. The two sides “will decide through consultation the annual consumption of the transboundary waters. “Other Government Agency” is perhaps misleading for conflict resolution. The treaty says that disputes will be resolved through “friendly consultation.”
Amur, Har Us Nur, Pu Lun T'o	187	Mongolia, China	4/29/1994	14	1	Agreement between the government of the People's Republic of China and the government of Mongolia on the protection and utilization of transboundary waters. The two sides “will decide through consultation the annual consumption of the transboundary waters. “Other Government Agency” is perhaps misleading for conflict resolution. The treaty says that disputes will be resolved through “friendly consultation.”
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An Nahr Al Kabir	403	Syria, Lebanon	4/20/2002	6	1	An agreement between the Syrian Arab Republic and the Lebanese Republic for the sharing of the Great Southern River Basin water and building of joint dam on the maincourse of the river
Aral Sea	194	Kazakhstan, Uzbekistan, Tajikistan	3/17/1998	10	2	Agreement between the government of the Republic of Kazakhstan, the government of the Kyrgyz Republic and the government of the Republic of Uzbekistan on the use of water and energy resources of the Sry Darya Basin

Basin	TFDD ID	Signatory	Date signed	Years Enforced	No. of parties (Bilateral/Multilateral-1/2)	Treaty Description
Aral Sea	195	Kazakhstan, Kyrgyz Republic, Uzbekistan	3/17/1998	10	2	Agreement between the governments of the Republic of Kazakhstan, the Kyrgyz Republic, and the Republic of Uzbekistan on joint and complex use water and energy resources of the Naryn Syr Darya cascade reservoirs
Aral Sea	197	Uzbekistan, Tajikistan, Kazakhstan	5/7/1999	9	2	Protocol on inserting amendments and addenda in the agreement between the governments of the Republic of Kazakhstan, the Kyrgyz Republic, and the Republic of Uzbekistan on the use of water and energy resources of the Syr Darya Basin
Asi/Orontes	273	Syria, Lebanon	9/20/1994	14	1	Bilateral agreement, Act No. 15 concerning the division of the water of Al-Asi River (Orontes) between the Syrian Arab Republic and the Lebanon
Atrak	100	IRN, USR	8/11/1957	51	1	Agreement between Iran and the Soviet Union for the joint utilisation of the frontier parts of the rivers Aras and Atrak for irrigation and power generation
Colorado	55	United States of America, Mexico	11/14/1944	58	1	Treaty between the United States of America and Mexico relating to the waters of the Colorado and Tijuana Rivers, and of the Rio Grande (Rio Bravo) from Fort Quitman, Texas, to the Gulf of Mexico, signed at Washington on 3 February 1944
Colorado	135	United States of America, Mexico	8/24/1966	42	1	Exchange of notes constituting an agreement concerning the loan of waters of the Colorado River for irrigation of lands in the Mexicali Valley
Colorado	253	United States of America, Mexico	7/16/1994	14	1	Minute no. 291 of the International Boundary and Water Commission, U.S.A. and Mexico, concerning improvements to the conveying capacity of the international boundary segment of the Colorado River
Colorado	153	United States of America, Mexico	4/30/1973	35	1	Agreement extending minute no. 241 of the International Boundary and Water Commission, United States and Mexico, on July 14, 1972.

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Colorado	150	United States of America, Mexico	7/14/1972	36	1	Agreement effected by minute no. 241 of the International Boundary and Water Commission, United States and Mexico, adopted at El Paso.
Columbia	116	Canada, United States of America	1/17/1961	47	1	Treaty relating to cooperative development of the water resources of the Columbia River Basin (with annexes)
Columbia	116	Canada, United States of America	1/17/1961	47	1	Treaty relating to cooperative development of the water resources of the Columbia River Basin (with annexes)
Columbia	125	United States of America, Canada	1/22/1964	44	1	Exchange of notes constituting an agreement between Canada and the United States of America concerning the treaty relating to cooperative development of the water resources of the Columbia River Basin
Columbia	131	United States of America, Canada	9/16/1964	44	1	Exchange of notes constituting an agreement between Canada and the United States of America authorizing the Canadian entitlement purchase agreement provided for under the treaty relating to cooperative development of the water resources of the Columbia River.
Columbia	246	United States of America, Canada	4/1/1968	40	1	Exchange of notes concerning a special operating programme for the Duncan and Arrow storages on the Columbia River System
Columbia	246	United States of America, Canada	4/1/1968	40	1	Exchange of notes concerning a special operating programme for the Duncan and Arrow storages on the Columbia River System

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Columbia	126	Canada, United States of America	1/22/1964	44	1	Exchange of notes constituting an agreement between Canada and the United States of America regarding sale of Canada's entitlement to downstream benefits under the treaty relating to co-operative development of the water resources of the Columbia River Basin.
Danube	77	Austria, Bavaria, Germany	2/13/1952	56	1	Agreement between the government of the Republic of Austria and the government of the Federal Republic of Germany and of the free state of Bavaria concerning the Donaukraftwerk-Jochenstein-Aktiengesellschaft (Danube Power-Plant and Jochenstein)
Danube	86	Austria, Yugoslavia	5/25/1954	54	1	Convention between the government of the Federal People's Republic of Yugoslavia and the Federal Government of the Austrian Republic concerning water economy questions relating to the Drava, signed at Geneva
Danube	86	Austria, Yugoslavia	5/25/1954	54	1	Convention between the government of the Federal People's Republic of Yugoslavia and the Federal Government of the Austrian Republic concerning water economy questions relating to the Drava, signed at Geneva
Danube	80	Romania, USSR	12/25/1952	56	1	Convention between the government of the Union of Soviet Socialist Republics and the government of the Romanian People's Republics concerning measures to prevent floods and to regulate the water regime.
Danube	278	European Economic Community, Germany, Austria	12/1/1987	21	2	Agreement between the Federal Republic of Germany and the European Economic Community, on the one hand, and the Republic of Austria, on the other, on cooperation on managemnet of water resources in the Danube Basin, Regensburg
Danube	68	Hungary, USSR	2/24/1950	58	1	Treaty between the government of the Union of Soviet Socialist Republics and the government of the Hungarian People's Republic concerning the regime of the Soviet-Hungarian state frontier.
Danube	84	Czechoslovakia, Hungary	4/16/1954	54	1	Agreement between Czechoslovakia and Hungary concerning the settlement of technical and economic questions relating to frontier water.
Danube	433	UNEP	5/22/2003	5	2	Framework Convention on the Protection and Sustainable Development of the Carpathians

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Danube	73	AUT, BAV	10/16/1950	58	1	Agreement between the Austrian Federal government and the Bavarian State government concerning the diversion of water in the Rissbach, Durrach and Walchen districts
Dnieper, Don	332	Ukraine, Russia	10/19/1992	16	1	Agreement between the government of the Russian Federation and the government of Ukraine concerning the joint use and protection of transboundary waters
Dnieper, Don	332	Ukraine, Russia	10/19/1992	16	1	Agreement between the government of the Russian Federation and the government of Ukraine concerning the joint use and protection of transboundary waters
Douro/Duero	129	Spain, Portugal	7/16/1964	44	1	Convention between Spain and Portugal for regulating the hydroelectric development of the international reaches of the Duero river and of its tributaries
Fenney, Ganges-Brahmaputra-Meghna, Karnaphuli	269	India, Bangladesh	1/18/1986	22	1	Summary record of discussions of the first meeting of the Joint Committee of Experts held in Dhaka between 16-18 January, 1986
Ganges-Brahmaputra-Meghna	172	India, Bangladesh	12/12/1996	12	1	Treaty between the government of the Republic of India and the government of the People's Republic of Bangladesh on sharing of the Ganga/Ganges waters at Farakka
Ganges-Brahmaputra-Meghna	172	India, Bangladesh	12/12/1996	12	1	Treaty between the government of the Republic of India and the government of the People's Republic of Bangladesh on sharing of the Ganga/Ganges waters at Farakka
Ganges-Brahmaputra-Meghna	192	Nepal, India	2/12/1996	12	1	Treaty between His Majesty's government of Nepal and the government of India concerning the integrated development of the Mahakali River including Sarada Barrage, Tanakpur Barrage, and Pancheshwar Project
Ganges-Brahmaputra-Meghna	136	Nepal, India	12/19/1966	42	1	Amended agreement between His Majesty's government of Nepal and the government of India concerning the Kosi Project
Ganges-Brahmaputra-Meghna	158	India, Bangladesh	11/5/1977	31	1	Agreement between the government of the People's Republic of Bangladesh and the government of the Republic of India on sharing of the Ganges waters at Farakka and on augmenting its flows

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Ganges-Brahmaputra-Meghna	267	Bangladesh, India	10/7/1982	26	1	Indo-Bangladesh memorandum of understanding on the sharing of Ganga waters at Farakka
Ganges-Brahmaputra-Meghna	85	Nepal, India	4/25/1954	54	1	Agreement between the government of India and the government of Nepal on the Kosi project
Ganges-Brahmaputra-Meghna	111	Nepal, India	12/4/1959	49	1	Agreement between His Majesty's government of Nepal and the government of India on the Gandak Irrigation and Power Project
Ganges-Brahmaputra-Meghna	151	India, Bangladesh	11/24/1972	36	1	Statute of the Indo-Bangladesh Joint Rivers Commission
Ganges-Brahmaputra-Meghna	268	Bangladesh, India	7/20/1983	25	1	Agreement on ad hoc sharing of the Teesta waters between India and Bangladesh reached during the 25th meeting of the Indo-Bangladesh Joint Rivers Commission held in July 1983, at Dhaka
Ganges-Brahmaputra-Meghna	163	India, Bangladesh	7/20/1983	25	1	Meeting of the Joint Rivers Commission
Ganges-Brahmaputra-Meghna	159	India, Nepal	4/7/1978	30	1	Agreement between Nepal and India on the renovation and extension of Chandra Canal, Pumped Canal, and distribution of the Western Kosi Canal
Ganges-Brahmaputra-Meghna	411	India, Bangladesh	4/18/1975	33	1	Provisional conclusion of the treaty of 18 April 1975 on the division of the waters of the Ganges
Garonne	107	France, Spain	7/12/1958	50	1	Agreement between the government of the French Republic and the Spanish government relating to Lake Lanoux
Garonne	390	Spain, France	7/29/1963	45	1	Convention between the government of the French Republic and Spanish government relative to the management of the upper course of the Garonne
Gash	75	Sudan, Eritrea	4/18/1951	57	1	Letters between the irrigation adviser and director of irrigation, Sudan government, and the controller of agriculture, Eritrea

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Guadiana, Minho/Miño	141	Portugal, Spain	5/29/1968	40	1	Agreement regulating the use and development of the water resources of the international reaches of the rivers Miño, Limia, Tajo, Guadiana, and Chanza and of their tributaries (with additional protocol), signed at Madrid
Helmand	72	Iran, Afghanistan	9/7/1950	58	1	Terms of reference of the Helmand River Delta Commission and an interpretive statement relative thereto, agreed by conferees of Afghanistan and Iran
Incomati	184	South Africa, Swaziland	3/13/1992	16	1	Treaty on the development and utilisation of the water resources of the Komati River Basin between the government of the Kingdom of Swaziland and the government of the Republic of South Africa
Incomati	185	South Africa, Swaziland	3/13/1992	16	1	Treaty on the establishment and functioning of the joint water commission between the government of the Republic of South Africa and the government of the Kingdom of Swaziland
Incomati	185	South Africa, Swaziland	3/13/1992	16	1	Treaty on the establishment and functioning of the joint water commission between the government of the Republic of South Africa and the government of the Kingdom of Swaziland
Incomati	174	Mozambique, Swaziland, South Africa	2/17/1983	25	2	Agreement between the government of the Republic of South Africa, the government of the Kingdom of Swaziland and the government of the People's Republic of Mozambique relative to the establishment of a tripartite permanent technical committee
Incomati	174	Mozambique, Swaziland, South Africa	2/17/1983	25	2	Agreement between the government of the Republic of South Africa, the government of the Kingdom of Swaziland and the government of the People's Republic of Mozambique relative to the establishment of a tripartite permanent technical committee
Incomati	174	Mozambique, Swaziland, South Africa	2/17/1983	25	2	Agreement between the government of the Republic of South Africa, the government of the Kingdom of Swaziland and the government of the People's Republic of Mozambique relative to the establishment of a tripartite permanent technical committee

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Incomati	206	South Africa, KaNgwane	10/7/1992	16	1	Agreement on the development and utilisation of the resources of the Komati River Basin between the government of the Republic of South Africa and the government of KaNgwane
Incomati	234	Mozambique, Swaziland, South Africa	2/15/1991	17	2	Tripartite permanent technical committee ministerial meeting of ministers responsible for water affairs.
Indus	114	India, Pakistan, International Bank for Reconstruction and Development	9/19/1960	48	1	Indus waters treaty 1960 between the government of India, the government of Pakistan and the International Bank for Reconstruction and Development
Isonzo	394	Italy, Yugoslavia	7/18/1957	51	1	Agreement between the government of the Italian Republic and the government of the Federal People's Republic of Yugoslavia concerning the water supply of the town of Gorizia in accordance with paragraph 5 of Annex 5 of the treaty of peace with Italy.
Isonzo	394	Italy, Yugoslavia	7/18/1957	51	1	Agreement between the government of the Italian Republic and the government of the Federal People's Republic of Yugoslavia concerning the water supply of the town of Gorizia in accordance with paragraph 5 of Annex 5 of the treaty of peace with Italy.
Johore	414	Malaysia, Singapore	9/29/1962	46	1	Johore River water agreement
Johore	413	Malaysia, Singapore	11/24/1990	18	1	Agreement between the Government of the State of Johor and the Public Utilities Board of the Republic of Singapore
Johore	435	Malaysia, Singapore	8/15/2000	8	1	Agreed items between Malaysia Prime Minister Dr Mahathir Mohamed and Senior Minister Lee Kaun Yew at their 4-eye meeting at Putrajaya
Johore	434	Malaysia, Singapore	10/14/2002	6	1	Exchange of Notes (August 24,2000- October 14, 2002) between Singapore and Malaysia

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Jordan	168	Jordan, Israel	10/26/1994	14	1	Treaty of peace between the state of Israel and the Hashemite Kingdom of Jordan, done at Arava/Araba crossing point
Jordan	82	Jordan, Syria	6/4/1953	55	1	Agreement between the Republic of Syria and the Hashemite Kingdom of Jordan concerning the utilization of the Yarmuk waters.
Jordan	171	Israel, PLO	9/28/1995	13	1	Israeli-Palestinian interim agreement on the West Bank and the Gaza Strip, with Annexes I to VII
Jordan	92	Syria, Lebanon, Jordan, Israel	12/31/1955	53	2	Johnston Negotiations
Jordan	449	Syria, Jordan	9/3/1987	21	1	Agreement concerning the utilization of the Yarmuk waters (with Annex). Signed at Amman on 3 September 1987
Jordan	449	Syria, Jordan	9/3/1987	21	1	Agreement concerning the utilization of the Yarmuk waters (with Annex). Signed at Amman on 3 September 1987
Kuiseb	383	Namibia, South Africa	3/1/1994	14	1	Agreement between the government of the Republic of South Africa and the government of the Republic of Namibia on water related matters pertaining to the incorporation of Walvis Bay in the territory of the Republic of Namibia
Kunene	143	South Africa, Portugal	1/21/1969	39	1	Agreement between the government of the Republic of South Africa and the government of Portugal in regard to the first phase of development of the water resource of the Cunene River Basin
La Plata	288	Brazil, Uruguay	5/6/1997	11	1	Complementary settlement to the agreement of cooperation between the government of the Eastern Republic of Uruguay and the government of the Federal Republic of Brazil for the use of natural resources and the development of the Cuareim river basin
La Plata	152	Brazil, Paraguay	4/26/1973	35	1	Treaty between the Federative Republic of Brazil and the Republic of Paraguay concerning the hydroelectric utilization of the water resources of the Parana River owned in condominium by the two countries, from and including the Salto Grande de Sete Quedas
La Plata	103	Paraguay, Argentina	1/23/1958	50	1	Agreement between the Argentine Republic and the Republic of Paraguay concerning a study of the utilization of the water power of the Apipe Falls

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La Plata	162	Argentina, Brazil, Paraguay	10/19/1979	29	2	Agreement on Paraná River projects
La Plata	448	Brazil, Uruguay, Paraguay, Argentina, Bolivia	8/14/1970	38	2	Treaty of the River Plate Basin
Lake Titicaca-Poopo System	98	Bolivia, Peru	2/19/1957	51	1	Agreement between Bolivia and Peru concerning a preliminary economic study of the joint utilization of the waters of Lake Titicaca.
Maritsa	142	Bulgaria, Turkey	10/23/1968	40	1	Agreement between the People's Republic of Bulgaria and the Republic of Turkey concerning cooperation in the use of waters of rivers flowing through the territory of both countries
Maritsa, Nestos, Struma	276	Greece, Bulgaria	4/22/1994	14	1	Agreed minutes of the first meeting of the Greek-Bulgarian joint programming and follow-up Committee
Mekong	170	Thailand, Laos, People's Democratic Republic of	4/5/1995	13	2	Agreement on the cooperation for the sustainable development of the Mekong River Basin
Mekong	133	Thailand, Laos	8/12/1965	43	1	Convention between Laos and Thailand for the supply of power
Mekong	436	Mekong River Commission	6/21/1999	9	2	Decision No. 144/1999/QD-TTg, Ratifying the plan on the control and use of flood water in Mekong River Delta Area for the period from now to the year 2010
Mekong	437	Mekong River Commission	9/20/2000	8	2	Directive No. 17/2000/Ct-TTg of September 20,2000 on coping with flooding in the Mekong River Delta
Minho/Miño, Guadiana	157	Portugal, Spain	2/12/1976	32	1	Second additional to the agreement of 29 May 1968 between Spain and Portugal regulating the use and development of the water resources of the international reaches of the rivers Miño, Limia, Tajo, Guadiana and Chanza and of

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						their tributaries
Minho/Miño, Guadiana	157	Portugal, Spain	2/12/1976	32	1	Second additional to the agreement of 29 May 1968 between Spain and Portugal regulating the use and development of the water resources of the international reaches of the rivers Miño, Limia, Tajo, Guadiana and Chanza and of their tributaries
Minho/Miño, Guadiana	157	Portugal, Spain	2/12/1976	32	1	Second additional to the agreement of 29 May 1968 between Spain and Portugal regulating the use and development of the water resources of the international reaches of the rivers Miño, Limia, Tajo, Guadiana and Chanza and of their tributaries
Minho/Miño, Guadiana	157	Portugal, Spain	2/12/1976	32	1	Second additional to the agreement of 29 May 1968 between Spain and Portugal regulating the use and development of the water resources of the international reaches of the rivers Miño, Limia, Tajo, Guadiana and Chanza and of their tributaries
Mississippi	181	United States of America, Canada	10/24/1989	19	1	Agreement between the government of Canada and the government of the United States of America for water supply and flood control in the Souris River Basin
Naatamo	76	Norway, Finland	4/25/1951	57	1	Agreement between Finland and Norway on the transfer from the course of the Näätämo (Neiden) River to the course of the Gandvik River of water from the Garsjoen, Kjerringvatn and Forstevannene Lakes
Nelson-Saskatchewan	248	United States of America, Canada	8/30/1988	20	1	Exchange of notes between the government of Canada and the government of the United States of America constituting an agreement concerning the construction of a joint ring levee
Nestos	277	Greece, Germany	12/22/1995	13	1	Agreement between the Government of Hellenic Republic and the Government of the Republic of Bulgaria for the use of the Nestos River waters
Niger	182	Niger, Nigeria	7/18/1990	18	1	Agreement between the Federal Republic of Nigeria and the Republic of Niger concerning the equitable sharing in the development, conservation and use of their common water resources

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Nile	110	ARE, SDN	11/8/1959	49	1	Agreement between the government of the United Arab Republic and the government of Sudan
Nile	359	Ethiopia, Egypt	7/1/1993	15	1	Framework for general co-operation between the Arab Republic of Egypt and Ethiopia
Nile	79	Egypt	1/5/1953	55	1	Exchange of notes constituting an agreement between the government of the United Kingdom of Great Britain and Northern Ireland and the government of Egypt regarding the construction of the Owen Falls Dam in Uganda
Oder/Odra	104	Czechoslovakia, Poland	3/21/1958	50	1	Agreement between the government of the Czechoslovak Republic and the government of the Polish People's Republic concerning the use of water resources in frontier waters
Okavango	190	Namibia, Botswana, Angola	9/16/1994	14	2	Agreement between the governments of the Republic of Angola, the Republic of Botswana, and the Republic of Namibia on the establishment of a permanent Okavango River Basin Water Commission (OKACOM)
Orange	164	Lesotho, South Africa	10/24/1986	22	1	Treaty on the Lesotho Highlands Water Project between the government of the Republic of South Africa and the government of the Kingdom of Lesotho
Orange	202	South Africa, Lesotho	1/1/1999	9	1	Protocol VI to the treaty on the Lesotho Highlands Water Project: supplementary arrangements regarding the system of governance for the project
Orange	202	South Africa, Lesotho	1/1/1999	9	1	Protocol VI to the treaty on the Lesotho Highlands Water Project: supplementary arrangements regarding the system of governance for the project
Orange	186	South Africa, Namibia	9/14/1992	16	1	Agreement between the government of the Republic of Namibia and the government of the Republic of South Africa on the establishment of a permanent water commission
Pasvik	297	Finland, Norway	2/24/1956	52	2	Protocol concerning amendments to the Regulations of 24 April 1947 for the regulation of Lake Inari in connexion with the use of the Niskakoski Dam and the Protocol of 29 April 1954 concerning amendments to paragraph 2 of the said Regulations, signed at O

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Pasvik	108	Norway, Finland	4/29/1959	49	2	Agreement between the government of the Union of Soviet Socialist Republics, the government of Norway and the government of Finland concerning the regulation of Lake Inari by means of the Kaitakoski hydro-electric power station and dam and additional prot
Pasvik	102	Norway	12/18/1957	51	1	Agreement between Norway and the Union of Soviet Socialist Republics on the utilization of water power on the Pasvik (Paatso) River
Po	395	Italy, Switzerland	5/27/1957	51	1	Convention between the Swiss Confederation and the Italian Republic on the subject of utilization of the hydraulic force of the Spol and additional protocol
Po	395	Switzerland, Italy	5/27/1957	51	1	Convention between the Swiss Confederation and the Italian Republic on the subject of utilization of the hydraulic force of the Spol and additional protocol
Rhine	360	Germany, European Econimic Community, Czech Republic	10/1/1987	21	2	Agreement between the government of the French Republic, the government of the Federal Republic of Germany, and the government of the Grand Duchy of Luxembourg on flood warning for the catchment basin of the Moselle
Rhine	361	France, Luxembourg	6/23/1986	22	1	Exchange of notes constituting an agreement concerning the execution of improvement works on the River Gander at Mondorff (France) and at Mondorf-les-Bains (Luxembourg), Paris, 3 and 23 June 1986
Rhine	134	Switzerland, Austria	4/30/1966	42	2	Agreement withdrawal of water from Lake Constance
Rhine	106	Luxembourg	7/10/1958	50	1	State treaty between Luxembourg and West Germany concerning the construction of hydroelectric power-installations on the Our (with annexes)
Rio Bravo/Rio Grande	55	United States of America, Mexico	11/14/1944	58	1	Treaty between the United States of America and Mexico relating to the waters of the Colorado and Tijuana Rivers, and of the Rio Grande (Rio Bravo) from Fort Quitman, Texas, to the Gulf of Mexico, signed at Washington on 3 February 1944, and suplementary

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Rio Bravo/Rio Grande	417	United States of America, Mexico	9/10/1970	38	1	Improvement of the international flood control works of the lower Rio Grande
Roia	138	France, Italy	9/28/1967	41	1	Franco-Italian convention concerning the supply of water to the town of Menton
Roia	138	France, Italy	9/28/1967	41	1	Franco-Italian convention concerning the supply of water to the town of Menton
Scudai, Tebrau	408	Malaysia, Singapore	9/1/1961	47	1	Tebrau and Scudai Rivers water agreement
Senegal	147	Senegal, Mauritania, Mali, Guinea	1/30/1970	38	2	Convention of Dakar
Skagit	175	United States of America, Canada	4/2/1984	24	1	Treaty between the United States of America and Canada relating to the Skagit River and Ross Lake, and the Seven Mile Reservoir on the Pend D'Oreille River
St. Lawrence	69	United States of America, Canada	2/27/1950	58	1	Treaty between the United States of America and Canada relating to the uses of the waters of the Niagara River
St. Lawrence	83	United States of America, Canada	11/12/1953	55	1	Exchange of notes constituting an agreement between the United States and Canada relating to the establishment of the St. Lawrence River joint board of engineers
St. Lawrence	145	Canada, United States of America	3/21/1969	39	1	Exchange of notes constituting an agreement between the United States of America and Canada for the temporary diversion for power purposes of the water normally flowing over the American Falls at Niagara

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St. Lawrence	245	United States of America, Canada	2/27/1950	58	1	Treaty between Canada and the United States of America concerning the diversion of the Niagara River, with agreement between Canada and Ontario and protocol of exchange
St. Lawrence	245	United States of America, Canada	2/27/1950	58	1	Treaty between Canada and the United States of America concerning the diversion of the Niagara River, with agreement between Canada and Ontario and protocol of exchange
Struma	397	Greece, Yugoslavia	3/31/1956	52	1	Proces-verbal of the delegations of the Federal People's Republic of Yugoslavia and of the Kingdom of Greece, meeting of 23 to 30 March 1956 for the question of Lake Doiran's water level
Tigris-Euphrates-Shatt al Arab	156	Iraq, Iran	12/26/1975	33	1	Agreement between Iran and Iraq concerning the use of frontier watercourses, and protocol
Tigris-Euphrates-Shatt al Arab	257	Syria, Iraq	4/17/1989	19	1	Law No.14 of 1990, ratifying the Joint Minutes concerning the provisional division of the waters of the Euphrates River
Tigris-Euphrates-Shatt al Arab	156	Iraq, Iran	12/26/1975	33	1	Agreement between Iran and Iraq concerning the use of frontier watercourses, and protocol
Tigris-Euphrates-Shatt al Arab	451	Iran, Turkey	11/18/1955	53	1	Treaty between Turkey and Iran on the Sarisu and Karasu River
Tigris-Euphrates-Shatt al Arab	999	Syria, Turkey	7/17/1987	21	1	Protocol on matters pertaining to economic cooperation. Signed at Damascus
Tigris-Euphrates-Shatt al Arab	127	Kuwait, Iraq	2/11/1964	44	1	Agreement between Iraq and Kuwait concerning the supply of Kuwait with fresh water
Torne/Tornealven	366	Finland, Sweden	12/15/1971	37	1	Agreement between Finland and Sweden concerning frontier waters
Torne/Tornealven	366	Finland, Sweden	12/15/1971	37	1	Agreement between Finland and Sweden concerning frontier waters
Vistula/Wista	130	USSR, Poland	7/17/1964	44	1	Agreement between the government of the Polish People's Republic and the government of the Union of Soviet Socialist Republics concerning the use of water resources in frontier waters

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Vuoksa	149	Finland	7/12/1972	36	1	Agreement between the government of the Republic of Finland and the government of the Union of Soviet Socialist Republics concerning the production of electric power in the part of the Vuoksi River bounded by the Imatra and Svetogorsk hydroelectric statio
Vuoksa	455	Finland, USSR	10/26/1989	19	1	Agreement concerning the regulations governing Lake Saimaa and the Vuoksi River (with annexes). Signed at Helsinki
Zambezi	176	Portugal, South Africa	5/2/1984	24	2	Agreement between the governments of the Republic of Portugal, the People's Republic of Mozambique and the Republic of South Africa relative to the Cahora Bassa Project
Zambezi	177	Botswana, Zimbabwe, Tanzania, Zambia	5/28/1987	21	2	Agreement on the action plan for the environmentally sound management of the common Zambesi River System
Zambezi	178	Zambia, Zimbabwe	7/28/1987	21	1	Agreement between the Republic of Zimbabwe and the Republic of Zambia concerning the utilization of the Zambesi River
Zambezi	81	Portugal, Great Britain	1/21/1953	55	1	Exchange of notes constituting an agreement between Her Majesty's government in the United Kingdom of Great Britain and Northern Ireland and the Portuguese government providing for the Portuguese participation in the Shiré Valley Project
Zambezi	81	Portugal, Great Britain	1/21/1953	55	1	Exchange of notes constituting an agreement between Her Majesty's government in the United Kingdom of Great Britain and Northern Ireland and the Portuguese government providing for the Portuguese participation in the Shiré Valley Project

Appendix D: Treaty Mechanism Components Summary*

Not all mechanisms are included in this appendix due to space limitations.

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)---(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Amazon	289	Hydro-power/Hydro-electricity	0	0	0	None	0	0	0	0
Amazon	180	Hydro-power/Hydro-electricity	0	1	0	Capital	0	0	0	1
Amur, Har Us Nur, Pu Lun T'o	187	Water Quantity	7	0	0	None	1	0	Other Government Agency	1
Amur, Har Us Nur, Pu Lun T'o	187	Water Quantity	7	0	0	None	1	0	Other Government Agency	1
Amur, Har Us Nur, Pu Lun T'o	187	Water Quantity	7	0	0	None	1	0	Other Government Agency	1
An Nahr Al Kabir	403	Water Quantity	4	0	0		1	0	0	0
Aral Sea	194	Hydro-power/Hydro-electricity	0	1, 4	0	Capital, Other	0	0	Negotiations and consultations, arbitration court established by parties for each specific case (Article IX)	0

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)--(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Aral Sea	195	Water Quantity	1	0	0	None	0	0	0	0
Aral Sea	197	Water Quantity	0	0	0	Energy in exchange for reservoir water storage for irrigation.	0	0	Negotiations and consultations, arbitration court established by parties for each specific case (Article IX)	0
Asi/Orontes	273	Water Quantity	2	0	0	None	1	0	0	0
Atrak	100	Water Quantity	4	0	0	Land	0	0	0	0
Colorado	55	Water Quantity	1	0	0	None	1	0	0	1
Colorado	135	Water Quantity	3	0	0	Capital	0	0	0	0
Colorado	253	Flood Control/Relief	0	0	1	None	0	0	0	1
Colorado	153	Water Quantity	1	0	0	None	1	0	Council	0
Colorado	150	Water Quantity	1	0	0	None	1	0	Council	0
Columbia	116	Hydro-power/Hydro-electricity	0	4	0	Capital	1	0	Council	1
Columbia	116	Flood control/relief	0	0	1	Capital	1	0	Council	1
Columbia	125	Flood Control/Relief	0	0	1	None	1	0	0	1
Columbia	131	Hydro-power/Hydro-electricity	0	4	0	Capital	0	0	Other Government Agency	1
Columbia	246	Flood control/relief	0	0	1	None	1	0	0	0

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)--(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Columbia	246	Hydro-power/Hydro-electricity	0	1	0	None	1	0	0	0
Columbia	126	Hydro-power/Hydro-electricity	0	0	0	Capital	0	0	0	1
Danube	77	Hydro-power/Hydro-electricity	0	4	0	Capital	0	Council	arbitral tribunal	1
Danube	86	Water Quantity	2	0	0	Capital	1	0	Court of Arbitration	1
Danube	86	Water Quantity	7	0	0	Capital	1	0	Court of Arbitration	1
Danube	80	Flood Control/Relief	0	0	1	None	1	Council	0	1
Danube	278	Flood control/relief	0	0	0	financing	0	0	Diplomatic means, arbitral tribunal	1
Danube	68	Flood Control/Relief	0	0	1	None	1	0	0	0
Danube	84	Water Quantity	4	0	0		1			
Danube	433	Flood Control/Relief	0	0	1	None	1	0	negotiations or any other means in accordance with international law	0
Danube	73	Water Quantity	6	0	0	None	0	0	0	0
Dnieper, Don	332	Flood control/relief	0	0	in Russian	None	0	0	0	0
Dnieper, Don	332	Flood control/relief	0	0	in Russian	None	0	0	0	0
Douro/Duero	129	Water Quantity	7	0	0	None	1	Council	Council	1

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)---(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Fenney, Ganges-Brahmaputra-Meghna, Karnaphuli	269	Water Quantity	0	0	0	None	0	0	0	1
Ganges-Brahmaputra-Meghna	172	Water Quantity	1	0	0	None	1	0	Indo-Bangladesh Joint Rivers Commission	1
Ganges-Brahmaputra-Meghna	172	Water Quantity	4	0	0	None	1	0	Indo-Bangladesh Joint Rivers Commission	1
Ganges-Brahmaputra-Meghna	192	Water Quantity	1	0	0	Land	1	0	Council	1
Ganges-Brahmaputra-Meghna	136	Hydro-power/Hydro-electricity	0	4	0	Land	1	0	Other Government Agency	1
Ganges-Brahmaputra-Meghna	158	Water Quantity	4	0	0	None	1	0	Other Government Agency	1
Ganges-Brahmaputra-Meghna	267	Water Quantity	2	0	0	None	1	0	0	0
Ganges-Brahmaputra-Meghna	85	Hydro-power/Hydro-electricity	0	4	0	Capital	1	0	UN /Third party	0
Ganges-Brahmaputra-Meghna	111	Water Quantity	1	0	0	Other	1	0	UN /Third party	0

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)--(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Ganges-Brahmaputra-Meghna	151	Water Quantity	0	0	0	None	0	0	0	1
Ganges-Brahmaputra-Meghna	268	Water Quantity	4	0	0	None	1	0	0	1
Ganges-Brahmaputra-Meghna	163	Water Quantity	4	0	0	None	1	0	0	0
Ganges-Brahmaputra-Meghna	159	Water Quantity	1	0	0	Capital	1	0	0	0
Ganges-Brahmaputra-Meghna	411	Water Quantity	1	in French	in French	None	0	0	0	in French
Garonne	107	Hydro-power/Hydro-electricity	1	0	0	None	1	0	UN /Third party	1
Garonne	390	Water Quantity	1	0	0	None	0	0	0	in French
Gash	75	Water Quantity	1	0	0	None	0	0	0	0
Guadiana, Minho/Miño	141	Water Quantity	6	0	0	None	0	0	Direct negotiations, arbitral tribunal, mediator from Polytechnic Institute in Zurich, International Court of Justice	1
Helmand	72	Water Quantity	0	0	0	None	1	0	0	1

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)--(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Incomati	184	Water Quantity	2	0	0	Capital	1	0	UN /Third party	1
Incomati	185	Water Quantity	0	0	0	None	1	0	Negotiations between parties; then arbitral tribunal; the UN Secretary General appoints an arbitrator	1
Incomati	185	Water Quantity	0	0	0	None	1	0	Negotiations between parties; then arbitral tribunal; the UN Secretary General appoints an arbitrator	1
Incomati	174	Water Quantity	0	0	0	None	0	0	0	1
Incomati	174	Water Quantity	0	0	0	None	0	0	0	1
Incomati	174	Water Quantity	0	0	0	None	0	0	0	1
Incomati	206	Water Quantity	2	0	0	Land	0	0	negotiation, arbitration tribunal	1
Incomati	234	Water Quantity	3	0	0	None	0	0	0	1
Indus	114	Water Quantity	6	0	0	Capital	1	Council	Council, then a Neutral third party	1
Isonzo	394	Water Quantity	1	0	0	None	1	0	0	1
Isonzo	394	Water Quantity	4	0	0	None	1	0	0	1

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)---(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Johore	414	Water Quantity	1	0	0	Land	0	0	Single arbitrator, or two arbitrators when no single intermediary is agreed upon.	0
Johore	413	Water Quantity	1	0	0	None	0	0	Three party arbitration, one chosen by each party and a third agreed upon. In the case of no agreement, the third arbitrator will be appointed by the Director of the Regional Centre of Arbitration at Kuala Lumpur. The appointed arbitrator cannot be a nati	0
Johore	435	Water Quantity	1	0	0	None	0	0	0	0
Johore	434	Water Quantity	1	0	0	None	0	0	0	0
Jordan	168	Water Quantity	1	0	0	Other	1	0	Council	1
Jordan	82	Water Quantity	6	0	0	Other	1	0	0	1
Jordan	171	Water Quantity	1	0	0	Capital	1	Council	UN /Third	1

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)--(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
									party	
Jordan	92	Water Quantity	4	0	0	Capital	0	Economic	UN /Third party	1
Jordan	449	Water Quantity	1	0	0	Capital	0	0	Joint Syria-Jordan Commission- a legal corporate body with 3 members from each state	1
Jordan	449	Water Quantity	6	0	0	Capital	0	0	Joint Syria-Jordan Commission- a legal corporate body with 3 members from each state	1
Kuiseb	383	Water Quantity	6	0	0	None	0	0	0	0
Kunene	143	Water Quantity	4	0	0	Capital	0	0	0	0
La Plata	288	Water Quantity	9	in Spanish	in Spanish	None	1	0	0	in Spanish
La Plata	152	Hydro-power/Hydro-electricity	0	4	0	Capital	0	Council	0	1
La Plata	103	Hydro-power/Hydro-electricity	0	0	0	None	0	0	0	0
La Plata	162	Water Quantity	1	0	0	None	1	0	0	1
La Plata	448	Water Quantity	0	0	0	None	0	0	0	1

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)--(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Lake Titicaca-Poopo System	98	Hydro-power/Hydro-electricity	0	0	0	None	0	0	0	1
Maritsa	142	Water Quantity	0	0	0	None	1	council	Commissio	1
Maritsa, Nestos, Struma	276	Water Quantity	0	0	0	None	0	0	0	0
Mekong	170	Water Quantity	7	0	0	None	1	0	There are three stages of conflict resolution. First, the commission itself. Then the dispute is referred to the governments of the Commission. Lastly, and only unanimously, all governments can request mediation.	1
Mekong	133	Hydro-power/Hydro-electricity	0	0	0	Capital	0	0	0	1
Mekong	436	Flood Control/Relief	0	0	1	None	1	council	0	1
Mekong	437	Flood Control/Relief	0	0	1	None	0	0	0	1

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)--(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Minho/Miño, Guadiana	157	Infrastructure/Development	0	0	0	None	0	0	0	1
Minho/Miño, Guadiana	157	Infrastructure/Development	0	0	0	None	0	0	0	1
Minho/Miño, Guadiana	157	Hydro-power/Hydro-electricity	0	0	0	None	0	0	0	1
Minho/Miño, Guadiana	157	Hydro-power/Hydro-electricity	0	0	0	None	0	0	0	1
Mississippi	181	Water Quantity	1	0	0	None	1	0	Council	1
Naatamo	76	Water Quantity	6	0	0	Capital	0	0	0	1
Nelson-Saskatchewan	248	Flood Control/Relief	0	0	1	None	0	0	Negotiations or "other forms of dispute resolution"	0
Nestos	277	Water Quantity	4	0	0	None	1	0	Commissio	1
Niger	182	Water Quantity	0	0	0	None	1	0	Council	1
Nile	110	Water Quantity	1	0	0	Capital	1	0	Council	0
Nile	359	Water Quantity	0	0	0	None	0	0	0	0
Nile	79	Hydro-power/Hydro-electricity	0	0	0	Capital	0	0	0	0
Oder/Odra	104	Water Quantity	7	0	0	None	1	Council	0	0
Okavango	190	Water Quantity	0	0	0	None	1	0	0	1
Orange	164	Water Quantity	1	0	0	Capital	1	Council	Council	1

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)---(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Orange	202	Hydro-power/Hydro-electricity	0	0	0	None	1	0	Council	1
Orange	202	Water Quantity	0	0	0	None	1	0	Council	1
Orange	186	Water Quantity	0	0	0	None	0	0	if failure to come to consensus, further negotiations are required	1
Pasvik	297	Water Quantity	2	0	0	None	1	0	0	0
Pasvik	108	Water Quantity	2	0	0	Capital	0	0	Council	0
Pasvik	102	Water Quantity	6	0	0	Capital	0	0	0	0
Po	395	Water Quantity	1	0	in French	None	1	0	Negotiations, arbitral tribunal	in French
Po	395	Water Quantity	1	0	in French	None	1	0	Negotiations, arbitral tribunal	in French
Rhine	360	Flood Control/Relief	0	0	1	capital	1	0	0	1
Rhine	361	Flood Control/Relief	0	0	1	None	0	0	0	0
Rhine	134	Water Quantity	5	0	0	None	1	0	Council, diplomatic channels	0
Rhine	106	Hydro-power/Hydro-electricity	0	0	0	None	1	0	0	0
Rio Bravo/Rio Grande	55	Water Quantity	1	0	0	None	1	0	0	1

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)--(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Rio Bravo/Rio Grande	417	Flood Control/Relief	0	0	1	None	0	0	0	1
Roia	138	Water Quantity	1	0	0	Capital	1	Council	UN /Third party	0
Roia	138	Water Quantity	4	0	0	Capital	1	Council	UN /Third party	0
Scudai, Tebrau	408	Water Quantity	6	0	0	Land	1		Single arbitrator when agreed upon, otherwise each of the two parties can use their selected arbitrator	0
Senegal	147	Hydro-power/Hydro-electricity	1	0	0	None		Council		
Skagit	175	Hydro-power/Hydro-electricity	0	0	0	None	1	Economic	Council	1
St. Lawrence	69	Water Quantity	1	0	0	None	1	0	Council	1
St. Lawrence	83	Hydro-power/Hydro-electricity	0	0	0	None	0	0	0	1
St. Lawrence	145	Water Quantity	1	0	0	Other	1	0	0	1
St. Lawrence	245	Water Quantity	4	0	0	None	0	0	0	1
St. Lawrence	245	Water Quantity	7	0	0	None	0	0	0	1
Struma	397	Water Quantity	0	0	0	None	0	0	0	0

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)--(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Tigris-Euphrates-Shatt al Arab	156	Water Quantity	4	0	0	None	0	0	Refers to Article 6 of Treaty Concerning State Frontier, signed 6/13/1975.	1
Tigris-Euphrates-Shatt al Arab	257	Water Quantity	4	0	0	None	0	0	0	1
Tigris-Euphrates-Shatt al Arab	156	Water Quantity	4	0	0	None	0	0	Refers to Article 6 of Treaty Concerning State Frontier, signed 6/13/1975.	1
Tigris-Euphrates-Shatt al Arab	451	Water Quantity	1	0	0	border	1	0	0	1
Tigris-Euphrates-Shatt al Arab	999	Water Quantity	3	0	0	oil and gas, trade, transportation	0	0	0	1
Tigris-Euphrates-Shatt al Arab	127	Water Quantity	1	0	0	None	0	0	0	0
Torne/Tornealven	366	Water Quantity	4	0	0	None	0	0	0	1
Torne/Tornealven	366	Water Quantity	7	0	0	None	0	0	0	1
Vistula/Wista	130	Flood Control/Relief	0	0	0	None	1	0	0	0

Basin	TFDD ID	Issue Type	Water Allocation Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHANISM (no/yes)--(0/1)	Non-water linkages	MONITORING (no/yes)---(0/1)	ENFORCEMENT MECHANISM	CONFLICT RESOLUTION MECHANSIM	COMMISSION /COUNCIL---(no/yes)--(0/1)
Vuoksa	149	Hydro-power/Hydro-electricity	0	0	0	Other	1	Council	Other Government Agency	0
Vuoksa	455	Water Quantity	2	0	0	None	1	0	Committee, then diplomatic channels	1
Zambezi	176	Hydro-power/Hydro-electricity	0	0	1	Capital	1	parties guarantee and ensure that each company will comply with provisions of treaty	0	1
Zambezi	177	Water Quantity	0	0	0	None	1	0	0	1
Zambezi	178	Water Quantity	4	0	0	None	1	0	UN /Third party	1
Zambezi	81	Hydro-power/Hydro-electricity	0	4	0	Capital	0	0	0	0
Zambezi	81	Flood control/relief	0	0	1	Capital	0	0	0	0

*Water and Hydropower Allocation Methods:

Basin	TFD D ID	Issue Type	Water Alloca-tion Method (0-9)*	Hydro-power Allocation Method (0-9)*	SPECIFIC FLOOD-CONTROL MECHAN-ISM (no/yes)--(0/1)	Non-water linkages	MONITOR-ING (no/yes)---(0/1)	ENFORCE-MENT ME-CHANISM	CONFLICT RESOLU-TION ME-CHANSIM	COMMIS-SION /COUNCIL---(no/yes)--(0/1)

0-none; 1-fixed quantities; 2-fixed quantities which vary according to water availability; 3-fixed quantities recouped in the following period; 4-percentage; 5-prior approval; 6-allocation of entire rivers; 7-consulation ;8-fixed quantities and percentages; 9-prioritization of uses

Appendix E: Treaty Drought, Independent Variable, and Delta Power Summary

Basin	TFDD ID	Independent Variable (Climate complaints only) (#Complaints in Basin*Average Bar Basin)/Years Enforced	Independent Variable (Climate Complaints Only) (# Complaints Treaty*AvgBar)/Years Enforced	Independent Variable (All Basin Complaints) (# Complaints Basin*AvgBarBasin)/Years Enforced	Independent Variable (All Treaty Complaints) (# Complaints Treaty*Avg Bar)/Years Enforced	Average Drought Index (1950-2003, 2 year average)	Average Drough h Index Since Treaty Signed , 2 year average	Percent of Time Since Treaty Signed in Relative Drought	**Standard Deviation Since Treaty Was Signed**	HDI Delta Between Riparians	FSI Delta Between Riparians	GDP Delta Between Riparians	Average of 3 Indices Delta Between Riparians
Amazon	289	0.0	0.0	-0.1	0.0	-0.21	-0.63	19%	0.9	38.0	60.0	94.0	64.0
Amazon	180	0.0	0.0	-0.1	0.0	-0.21	-0.53	15%	0.9	38.0	60.0	94.0	64.0
Amur, Har Us Nur, Pu Lun T'o	187	0.0	0.0	0.0	0.0	-0.50	-2.12	30%	1.8	23.0	62.0	141.0	75.3
Amur, Har Us Nur, Pu Lun T'o	187	0.0	0.0	0.0	0.0	-0.50	-2.12	30%	1.8	23.0	62.0	141.0	75.3
Amur, Har Us Nur, Pu Lun T'o	187	0.0	0.0	0.0	0.0	-0.50	-2.12	30%	1.8	23.0	62.0	141.0	75.3
An Nahr Al Kabir	403	0.0	0.0	0.0	0.0	-0.50	-2.61	50%	1.6	24.0	16.0	7.0	15.7
Aral Sea	194	0.0	0.0	-0.4	0.0	-0.24	-1.88	50%	2.4	21.7	40.1	43.8	35.2
Aral Sea	195	0.0	0.0	-0.4	-0.3	-0.24	-1.88	50%	2.4	21.7	40.1	43.8	35.2

Basin	TFDD ID	Independent Variable (Climate complaints only) (#Complaints in Basin*Average Bar Basin)/Years Enforced	Independent Variable (Climate Complaints Only) (# Complaints Treaty*AvgBar)/Years Enforced	Independent Variable (All Basin Complaints) (# Complaints Basin*AvgBarBasin)/Years Enforced	Independent Variable (All Treaty Complaints) (# Complaints Treaty*Avg Bar)/Years Enforced	Average Drought Index (1950-2003, 2 year average)	Average Drought Index Since Treaty Signed, 2 year average	Percent of Time Since Treaty Signed in Relative Drought	**Standard Deviation Since Treaty Was Signed**	HDI Delta Between Riparians	FSI Delta Between Riparians	GDP Delta Between Riparians	Average of 3 Indices Delta Between Riparians
Aral Sea	197	0.0	0.0	-0.4	-0.1	-0.24	-2.16	60%	2.4	20.3	33.9	43.1	32.4
Asi/Orontes	273	0.0	0.0	0.0	0.0	-0.16	-1.14	30%	1.7	24.0	16.0	7.0	15.7
Atrak	100	0.0	0.0	0.0	0.0	-1.05	-1.22	43%	2.7	17.0	23.0	17.0	19.0
Colorado	55	0.0	-0.5	-0.1	-0.6	0.38	0.40	33%	2.1	40.0	56.0	10.0	35.3
Colorado	135	0.0	0.0	-0.2	0.0	0.38	0.87	31%	2.2	40.0	56.0	10.0	35.3
Colorado	253	-0.1	0.0	-0.5	0.0	0.38	0.09	18%	2.4	40.0	56.0	10.0	35.3
Colorado	153	-0.1	0.0	-0.2	0.0	0.38	0.91	34%	2.4	40.0	56.0	10.0	35.3
Colorado	150	-0.1	0.0	-0.2	0.0	0.38	0.87	36%	2.4	40.0	56.0	10.0	35.3
Columbia	116	0.0	0.0	-0.1	-0.1	0.07	0.09	33%	2.0	9.0	6.0	7.0	7.3
Columbia	116	0.0	0.0	-0.1	-0.1	0.07	0.09	33%	2.0	9.0	6.0	7.0	7.3
Columbia	125	0.0	0.0	-0.1	0.0	0.07	0.17	35%	2.0	9.0	6.0	7.0	7.3
Columbia	131	0.0	0.0	-0.1	0.0	0.07	0.17	35%	2.0	9.0	6.0	7.0	7.3
Columbia	246	0.0	0.0	-0.1	0.0	0.07	0.19	36%	2.1	9.0	6.0	7.0	7.3
Columbia	246	0.0	0.0	-0.1	0.0	0.07	0.19	36%	2.1	9.0	6.0	7.0	7.3
Columbia	126	0.0	0.0	-0.1	0.0	0.07	0.17	35%	2.0	9.0	6.0	7.0	7.3
Danube	77	0.0	0.0	-0.5	0.0	-0.66	-0.59	29%	1.7	8.0	13.0	19.0	13.3
Danube	86	0.0	0.0	-0.5	0.0	-0.66	-0.57	30%	1.7				
Danube	86	0.0	0.0	-0.5	0.0	-0.66	-0.57	30%	1.7				
Danube	80	0.0	0.0	-0.5	0.0	-0.66	-0.59	29%	1.7	8.0	53.0	34.0	31.7

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Danube	278	0.0	0.0	-1.3	0.0	-0.66	-1.83	29%	1.6	8.0	13.0	19.0	13.3
Danube	68	0.0	0.0	-0.5	0.0	-0.66	-0.63	30%	1.7	28.0	65.0	30.0	41.0
Danube	84	0.0	0.0	-0.5	0.0	-0.66	-0.57	30%	1.7	1.0	2.0	14.0	5.7
Danube	433	0.0	0.0	-5.4	0.0	-0.66	-3.72	0%	1.6	18.1	27.6	16.0	20.6
Danube	73	0.0	0.0	-0.5	0.0	-0.66	-0.63	30%	1.7				
Dnieper, Don	332	0.0	0.0	0.0	0.0	0.02	-0.26	17%	1.5	14.0	33.0	37.0	28.0
Dnieper, Don	332	0.0	0.0	0.0	0.0	0.02	-0.26	17%	1.5	14.0	33.0	37.0	28.0
Douro/Duero	129	0.0	0.0	-0.1	-0.1	-1.05	-1.18	30%	2.0	19.0	12.0	23.0	18.0
Fenney, Ganges-Brahmaputra-Meghna, Karnaphuli	269	-0.1	0.0	-0.1	0.0	-0.32	-0.78	28%	1.5	12.0	84.0	41.0	45.7
Ganges-Brahmaputra-Meghna	172	-2.2	-1.2	-5.5	-3.1	-0.27	-0.47	0%	0.7	12.0	84.0	41.0	45.7
Ganges-Brahmaputra-Meghna	172	-2.2	-1.2	-5.5	-3.1	-0.27	-0.48	0%	0.7	12.0	84.0	41.0	45.7
Ganges-Brahmaputra-Meghna	192	-2.2	-0.1	-5.5	-0.8	-0.27	-0.48	0%	0.7	10.0	67.0	98.0	58.3
Ganges-Brahmaputra-Meghna	136	-0.6	0.0	-1.6	0.0	-0.27	-0.35	10%	0.8	10.0	67.0	98.0	58.3

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Ganges-Brahmaputra-Meghna	158	-0.8	0.0	-2.1	-0.2	-0.27	-0.33	10%	0.7	12.0	84.0	41.0	45.7
Ganges-Brahmaputra-Meghna	267	-1.0	-0.2	-2.5	-0.2	-0.27	-0.54	0%	0.8	12.0	84.0	41.0	45.7
Ganges-Brahmaputra-Meghna	85	-0.5	0.0	-1.2	0.0	-0.27	-0.26	12%	0.8	10.0	67.0	98.0	58.3
Ganges-Brahmaputra-Meghna	111	-0.5	0.0	-1.3	0.0	-0.27	-0.31	4%	0.8	10.0	67.0	98.0	58.3
Ganges-Brahmaputra-Meghna	151	-0.7	0.0	-1.8	0.0	-0.27	-0.29	12%	0.7	12.0	84.0	41.0	45.7
Ganges-Brahmaputra-Meghna	268	-1.0	-0.2	-2.6	-0.2	-0.27	-0.54	0%	0.8	12.0	84.0	41.0	45.7
Ganges-Brahmaputra-Meghna	163	-1.0	0.0	-2.6	0.0	-0.27	-0.39	0%	0.7	12.0	84.0	41.0	45.7
Ganges-Brahmaputra-Meghna	159	-0.9	0.0	-2.2	0.0	-0.27	-0.36	0%	0.7	10.0	67.0	98.0	58.3
Ganges-Brahmaputra-Meghna	411	-0.8	0.0	-2.0	0.0	-0.27	-0.54	0%	0.8	12.0	84.0	41.0	45.7
Garonne	107	0.0	0.0	0.0	0.0	-1.11	-1.00	24%	2.8	7.0	8.0	3.0	6.0

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Garonne	390	0.0	0.0	0.0	0.0	-1.11	-1.17	24%	2.9	7.0	8.0	3.0	6.0
Gash	75	0.0	0.0	0.0	0.0	-0.66	-0.64	23%	1.6	15.0	41.0	84.0	46.7
Guadiana, Minho/Miño	141	0.0	-0.1	-0.1	-0.2	-1.14	-1.44	33%	2.5	19.0	12.0	23.0	18.0
Helmand	72	0.0	0.0	-0.1	-0.1	-0.50	-0.47	19%	2.2	93.0	42.0	85.0	73.3
Incomati	184	0.0	0.0	-0.1	-0.1	-1.05	-2.65	46%	3.2	13.0	52.0	114.0	59.7
Incomati	185	0.0	0.0	-0.1	0.0	-1.05	-2.78	42%	3.3	13.0	52.0	114.0	59.7
Incomati	185	0.0	0.0	-0.1	0.0	-1.05	-2.78	42%	3.3	13.0	52.0	114.0	59.7
Incomati	174	0.0	0.0	0.0	0.0	-1.05	-2.25	33%	2.8	22.1	27.1	59.6	36.2
Incomati	174	0.0	0.0	0.0	0.0	-1.05	-2.25	33%	2.8	22.1	27.1	59.6	36.2
Incomati	174	0.0	0.0	0.0	0.0	-1.05	-2.25	33%	2.8	22.1	27.1	59.6	36.2
Incomati	206	0.0	0.0	-0.1	0.0	-1.05	-2.78	42%	3.3	13.0	52.0	114.0	59.7
Incomati	234	0.0	0.0	-0.1	0.0	-1.05	-2.78	42%	3.3	22.1	27.1	59.6	36.2
Indus	114	-0.1	-0.1	-4.4	-4.1	-0.38	-0.51	20%	1.2	7.0	87.0	32.0	42.0
Isonzo	394	0.0	0.0	0.0	0.0	-0.69	-0.68	13%	1.2				
Isonzo	394	0.0	0.0	0.0	0.0	-0.69	-0.68	13%	1.2				
Johore	414	0.0	0.0	0.0	0.0	-0.32	-1.21	29%	2.2	43.0	41.0	4.0	29.3
Johore	413	0.0	0.0	0.0	0.0	-0.32	-0.58	21%	2.0	43.0	41.0	4.0	29.3
Johore	435	0.0	0.0	0.0	0.0	-0.32	-0.97	0%	1.4	43.0	41.0	4.0	29.3
Johore	434	0.0	0.0	0.0	0.0	-0.32	-0.56	0%	1.0	43.0	41.0	4.0	29.3

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Jordan	168	-1.6	-1.3	-5.7	-2.5	-0.28	-1.08	24%	2.7	35.5	27.1	23.7	28.8
Jordan	82	-0.4	0.0	-1.5	0.0	-0.28	-0.28	25%	2.2	11.0	46.0	26.0	27.7
Jordan	171	-1.8	-0.3	-6.2	-0.5	-0.28	-1.08	24%	2.7	83.0	118.0	27.0	76.0
Jordan	92	-0.4	0.0	-1.5	-0.6	-0.28	-0.36	22%	2.2	33.9	18.4	18.1	23.5
Jordan	449	-1.1	0.0	-3.8	-0.2	-0.28	-2.32	40%	2.1	11.0	46.0	26.0	27.7
Jordan	449	-1.1	0.0	-3.8	0.0	-0.28	-2.57	44%	2.2	11.0	46.0	26.0	27.7
Kuiseb	383	0.0	0.0	0.0	0.0	-1.79	-3.07	20%	1.8	1.0	100.0	91.0	64.0
Kunene	143	0.0	0.0	-0.1	-0.1	-0.83	-1.25	49%	1.5	95.0	37.0	4.0	45.3
La Plata	288	0.0	0.0	-1.7	0.0	0.06	0.26	0%	1.1	25.0	34.0	74.0	44.3
La Plata	152	0.0	0.0	-0.5	-0.1	0.06	0.22	15%	1.0	26.0	13.0	102.0	47.0
La Plata	103	0.0	0.0	-0.4	0.0	0.06	0.10	17%	1.2	26.0	13.0	102.0	47.0
La Plata	162	0.0	0.0	-0.6	-0.1	0.06	0.32	16%	1.1	26.0	24.8	53.5	34.8
La Plata	448	0.0	0.0	-0.5	-0.4	0.06	-0.13	0%	0.7	29.1	39.2	44.9	37.7
Lake Titicaca-Poopo System	98	0.0	0.0	0.0	0.0	-0.23	-0.36	30%	2.1	35.0	25.0	51.0	37.0
Maritsa	142	0.0	0.0	0.0	-0.1	-1.40	-1.82	39%	2.9	18.0	38.0	56.0	37.3
Maritsa, Nestos, Struma	276	0.0	0.0	0.0	0.0	-1.40	-3.84	40%	3.3	36.0	16.0	46.0	32.7
Mekong	170	0.0	0.0	0.0	0.0	-0.23	0.00	22%	1.4	22.7	27.4	49.9	33.4
Mekong	133	0.0	0.0	0.0	0.0	-0.23	-0.34	15%	1.1	46.0	48.0	106.0	66.7
Mekong	436	0.0	0.0	0.0	0.0	-0.23	0.59	20%	1.3	22.7	27.4	49.9	33.4

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Mekong	437	0.0	0.0	0.0	0.0	-0.23	0.96	25%	0.4	22.7	27.4	49.9	33.4
Minho/Miño, Guadiana	157	0.0	0.0	-0.1	-0.1	-0.44	-0.54	25%	1.8	19.0	12.0	23.0	18.0
Minho/Miño, Guadiana	157	0.0	0.0	-0.1	-0.1	-0.44	-0.54	25%	1.8	19.0	12.0	23.0	18.0
Minho/Miño, Guadiana	157	0.0	0.0	-0.1	-0.1	-0.44	-0.54	25%	1.8	19.0	12.0	23.0	18.0
Minho/Miño, Guadiana	157	0.0	0.0	-0.1	-0.1	-0.44	-0.54	25%	1.8	19.0	12.0	23.0	18.0
Mississippi	181	0.0	0.0	0.0	0.0	0.06	0.09	13%	1.1	9.0	6.0	7.0	7.3
Naatamo	76	0.0	0.0	0.0	0.0	1.36	1.43	49%	3.1	11.0	1.0	6.0	6.0
Nelson-Saskatchewan	248	-0.5	-0.5	-0.7	-0.7	-0.99	-3.02	0%	0.7	9.0	6.0	7.0	7.3
Nestos	277	-0.1	-0.1	-0.1	-0.1	-1.35	-3.54	22%	2.9	36.0	16.0	46.0	32.7
Niger	182	0.0	0.0	0.0	0.0	-1.39	-2.47	7%	0.9	24.0	3.0	92.0	39.7
Nile	110	0.0	0.0	-0.6	-0.2	-1.30	-1.64	20%	1.6	27.0	38.0	21.0	28.7
Nile	359	-0.1	0.0	-1.8	0.0	-1.30	-2.15	9%	0.8	48.0	24.0	47.0	39.7
Nile	79	0.0	0.0	-0.5	0.0	-1.30	-1.37	24%	1.7	102.0	117.0	46.0	88.3
Oder/Odra	104	0.0	0.0	0.0	0.0	-0.39	-0.39	22%	1.9	5.0	4.0	17.0	8.7
Okavango	190	0.0	0.0	0.0	0.0	-0.97	-1.82	20%	1.5	9.6	48.1	26.4	28.1
Orange	164	0.0	0.0	-0.1	-0.1	-0.70	-1.24	22%	1.4	27.0	61.0	123.0	70.3
Orange	202	0.0	0.0	-0.2	0.0	-0.70	-0.94	20%	1.3	27.0	61.0	123.0	70.3

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Orange	202	0.0	0.0	-0.2	0.0	-0.70	-0.94	20%	1.3	27.0	61.0	123.0	70.3
Orange	186	0.0	0.0	-0.1	0.0	-0.70	-1.38	25%	1.5	1.0	100.0	91.0	64.0
Pasvik	297	0.0	0.0	0.0	0.0	1.19	1.60	44%	3.1	37.6	58.6	8.1	34.8
Pasvik	108	0.0	0.0	0.0	0.0	1.19	1.53	47%	3.0	37.6	58.6	8.1	34.8
Pasvik	102	0.0	0.0	0.0	0.0	1.19	1.51	46%	3.0	70.0	102.0	10.0	60.7
Po	395	0.0	0.0	0.0	0.0	-0.43	-0.41	9%	1.2	9.0	19.0	12.0	13.3
Po	395	0.0	0.0	0.0	0.0	-0.43	-0.41	9%	1.2	9.0	19.0	12.0	13.3
Rhine	360	0.0	0.0	0.0	0.0	-0.21	-0.60	22%	1.7	7.4	5.1	33.2	15.2
Rhine	361	0.0	0.0	0.0	0.0	-0.21	-0.65	18%	1.7	3.0	7.0	56.0	22.0
Rhine	134	0.0	0.0	0.0	0.0	-0.21	-0.21	26%	1.8	7.8	9.6	8.5	8.7
Rhine	106	0.0	0.0	0.0	0.0	-0.21	-0.26	24%	1.8	11.0	10.0	59.0	26.7
Rio Bravo/Rio Grande	55	-0.4	-0.5	-0.5	-0.6	0.14	0.20	27%	2.0	40.0	56.0	10.0	35.3
Rio Bravo/Rio Grande	417	-0.7	0.0	-0.8	0.0	0.14	0.70	22%	2.0	40.0	56.0	10.0	35.3
Roia	138	0.0	0.0	0.0	0.0	-0.96	-1.24	19%	2.5	10.0	4.0	1.0	5.0
Roia	138	0.0	0.0	0.0	0.0	-0.96	-1.24	19%	2.5	10.0	4.0	1.0	5.0
Scudai, Tebrau	408	0.0	0.0	0.0	0.0	-0.32	-0.56	21%	2.0	43.0	41.0	4.0	29.3
Senegal	147	0.0	0.0	0.0	0.0	-2.04	-3.78	26%	1.4	10.0	42.0	18.1	23.4
Skagit	175	0.0	0.0	0.0	0.0	0.18	0.07	25%	1.8	9.0	6.0	7.0	7.3

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St. Lawrence	69	0.0	0.0	0.0	0.0	-0.37	-0.35	13%	1.3	9.0	6.0	7.0	7.3
St. Lawrence	83	0.0	0.0	0.0	0.0	-0.37	-0.35	13%	1.3	9.0	6.0	7.0	7.3
St. Lawrence	145	0.0	0.0	0.0	0.0	-0.37	-0.35	13%	1.3	9.0	6.0	7.0	7.3
St. Lawrence	245	0.0	0.0	0.0	0.0	-0.37	-0.41	14%	1.3	9.0	6.0	7.0	7.3
St. Lawrence	245	0.0	0.0	0.0	0.0	-0.37	-0.34	14%	1.4	9.0	6.0	7.0	7.3
Struma	397	0.0	0.0	0.0	0.0	-1.56	-1.54	35%	3.0				
Tigris-Euphrates-Shatt al Arab	156	0.0	0.0	-2.1	0.0	-0.57	-0.83	17%	2.1	88.0	44.0	31.0	54.3
Tigris-Euphrates-Shatt al Arab	257	0.0	0.0	-3.7	-0.1	-0.57	-0.83	21%	2.1	107.0	29.0	70.0	68.7
Tigris-Euphrates-Shatt al Arab	156	0.0	0.0	-2.1	0.0	-0.57	-0.68	18%	2.0	88.0	44.0	31.0	54.3
Tigris-Euphrates-Shatt al Arab	451	0.0	0.0	-1.3	0.0	-0.57	-1.38	29%	2.5	9.0	41.0	14.0	21.3
Tigris-Euphrates-Shatt al Arab	999	0.0	0.0	-3.3	-3.0	-0.57	-1.67	33%	2.4	28.0	56.0	53.0	45.7
Tigris-Euphrates-Shatt al Arab	127	0.0	0.0	-1.6	0.0	-0.57	-0.66	18%	1.9	31.0	118.0	52.0	67.0
Torne/Tornealven	366	0.0	0.0	0.0	0.0	0.51	0.94	21%	2.0	5.0	1.0	10.0	5.3

Basin	TFDD ID	Independent Variable (Climate complaints only) (#Complaints in Basin*Average Bar Basin)/Years Enforced	Independent Variable (Climate Complaints Only) (# Complaints Treaty*AvgBar)/Years Enforced	Independent Variable (All Basin Complaints) (# Complaints Basin*AvgBarBasin)/Years Enforced	Independent Variable (All Treaty Complaints) (# Complaints Treaty*Avg Bar)/Years Enforced	Average Drought Index (1950-2003, 2 year average)	Average Drought Index Since Treaty Signed, 2 year average	Percent of Time Since Treaty Signed in Relative Drought	**Standard Deviation Since Treaty Was Signed**	HDI Delta Between Riparians	FSI Delta Between Riparians	GDP Delta Between Riparians	Average of 3 Indices Delta Between Riparians
Torne/Tornealven	366	0.0	0.0	0.0	0.0	0.51	0.94	21%	2.0	5.0	1.0	10.0	5.3
Vistula/Wista	130	0.0	0.0	0.0	0.0	-0.80	-0.79	33%	2.2	30.0	70.0	9.0	36.3
Vuoksa	149	0.0	0.0	0.0	0.0	0.10	0.30	25%	2.9	59.0	101.0	16.0	58.7
Vuoksa	455	0.0	0.0	0.0	0.0	0.10	-0.59	20%	3.2	59.0	101.0	16.0	58.7
Zambezi	176	0.0	0.0	-0.1	0.0	-1.32	-3.12	30%	2.1	70.6	38.0	49.1	52.6
Zambezi	177	0.0	0.0	-0.1	0.0	-1.32	-3.17	29%	2.1	20.6	41.6	14.1	25.4
Zambezi	178	0.0	0.0	-0.1	-0.1	-1.32	-3.17	29%	2.1	164.0	59.0	16.0	79.7
Zambezi	81	0.0	0.0	0.0	0.0	-1.32	-1.32	31%	2.4	13.0	2.0	28.0	14.3
Zambezi	81	0.0	0.0	0.0	0.0	-1.32	-1.32	31%	2.4	13.0	2.0	28.0	14.3

Appendix F: Treaty Complaint Summary

Basin	TFDD ID	Treaty BAR All Complaints	Treaty BAR Non-Climate Driven Complaints	Treaty BAR Climate Driven Complaints	Treaty Number Complaints	Treaty Number Climate Complaints	Basin BAR All Complaints	Basin BAR Non-Climate Complaints	Basin BAR Climate Complaints	Basin Number complaints	Basin Number Climate Complaints	Basin Percent Climate Complaints
Amazon	289						-2	-2		1	0	0%
Amazon	180						-2	-2		1	0	0%
Amur, Har Us Nur, Pu Lun T'o	187											
Amur, Har Us Nur, Pu Lun T'o	187											
Amur, Har Us Nur, Pu Lun T'o	187											
An Nahr Al Kabir	403											
Aral Sea	194						-2	-2		2	0	0%
Aral Sea	195	-3	-3		1	0	-2	-2		2	0	0%
Aral Sea	197	-1	-1		1	0	-2	-2		2	0	0%
Asi/Orontes	273											
Atrak	100											
Colorado	55	-2.1	-2.7	-2.0	17	14	-1.8	-2.5	-1	4	2	50%
Colorado	135						-1.8	-2.5	-1	4	2	50%
Colorado	253						-1.8	-2.5	-1	4	2	50%
Colorado	153						-1.8	-2.5	-1	4	2	50%
Colorado	150						-1.8	-2.5	-1	4	2	50%
Columbia	116	-1.5	-2.0	-1.0	2	1	-1.5	-2	-1	2	1	50%
Columbia	116	-1.5	-2.0	-1.0	2	1	-1.5	-2	-1	2	1	50%
Columbia	125						-1.5	-2	-1	2	1	50%
Columbia	131						-1.5	-2	-1	2	1	50%
Columbia	246						-1.5	-2	-1	2	1	50%

Basin	TFDD ID	Treaty BAR All Complaints	Treaty BAR Non-Climate Driven Complaints	Treaty BAR Climate Driven Complaints	Treaty Number Complaints	Treaty Number Climate Complaints	Basin BAR All Complaints	Basin BAR Non-Climate Complaints	Basin BAR Climate Complaints	Basin Number complaints	Basin Number Climate Complaints	Basin Percent Climate Complaints
Columbia	246						-1.5	-2	-1	2	1	50%
Columbia	126						-1.5	-2	-1	2	1	50%
Danube	77						-1.5	-1.5		18	0	0%
Danube	86						-1.5	-1.5		18	0	0%
Danube	86						-1.5	-1.5		18	0	0%
Danube	80						-1.5	-1.5		18	0	0%
Danube	278						-1.5	-1.5		18	0	0%
Danube	68						-1.5	-1.5		18	0	0%
Danube	84						-1.5	-1.5		18	0	0%
Danube	433						-1.5	-1.5		18	0	0%
Danube	73						-1.5	-1.5		18	0	0%
Dnieper, Don	332											
Dnieper, Don	332											
Douro/Duero	129	-1.0	-1.0		3	0	-1.3	-1.0	-2.0	4	1	25%
Fenney, Ganges-Brahmaputra-Meghna, Karnaphuli	269						-1.0		-1.0	2	2	100%
Ganges-Brahmaputra-Meghna	172	-1.5	-1.4	-1.8	25	8	-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	172	-1.5	-1.4	-1.8	25	8	-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	192	-1.7	-1.4	-1.0	6	1	-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	136						-1.5	-1.3	-1.6	44	16	36%

Basin	TFDD ID	Treaty BAR All Complaints	Treaty BAR Non-Climate Driven Complaints	Treaty BAR Climate Driven Complaints	Treaty Number Complaints	Treaty Number Climate Complaints	Basin BAR All Complaints	Basin BAR Non-Climate Complaints	Basin BAR Climate Complaints	Basin Number complaints	Basin Number Climate Complaints	Basin Percent Climate Complaints
Ganges-Brahmaputra-Meghna	158	-1.5	-1.7	-1.0	4	1	-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	267	-1.0		-1.0	6	6	-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	85						-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	111						-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	151						-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	268	-2.0	-2.0	-2.0	3	2	-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	163						-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	159						-1.5	-1.3	-1.6	44	16	36%
Ganges-Brahmaputra-Meghna	411						-1.5	-1.3	-1.6	44	16	36%
Garonne	107											
Garonne	390											
Gash	75											
Guadiana, Minho/Miño	141	-1.0	-1.0	-1.0	6	3	-0.8	1.0	0.0	4	1	25%
Helmand	72	-1.4	-1.5	-1.0	5	1	-1.4	-1.5	-1.0	5	1	20%
Incomati	184	-1.0	-1.0		1	0	-1.0	-1.0		1	0	0%

Basin	TFDD ID	Treaty BAR All Complaints	Treaty BAR Non-Climate Driven Complaints	Treaty BAR Climate Driven Complaints	Treaty Number Complaints	Treaty Number Climate Complaints	Basin BAR All Complaints	Basin BAR Non-Climate Complaints	Basin BAR Climate Complaints	Basin Number complaints	Basin Number Climate Complaints	Basin Percent Climate Complaints
Incomati	185						-1.0	-1.0		1	0	0%
Incomati	185						-1.0	-1.0		1	0	0%
Incomati	174						-1.0	-1.0		1	0	0%
Incomati	174						-1.0	-1.0		1	0	0%
Incomati	174						-1.0	-1.0		1	0	0%
Incomati	206						-1.0	-1.0		1	0	0%
Incomati	234						-1.0	-1.0		1	0	0%
Indus	114	-1.8	-1.8	-1.3	112	4	-1.8	-1.8	-1.3	118	4	3%
Isonzo	394											
Isonzo	394											
Johore	414											
Johore	413											
Johore	435											
Johore	434											
Jordan	168	-1.5	-1.2	-1.8	24	10	-1.6	-1.5	-1.8	51	13	25%
Jordan	82	-2.0	-2.0		1	0	-1.6	-1.5	-1.8	51	13	25%
Jordan	171	-1.8	-1.5	-2.0	4	2	-1.6	-1.5	-1.8	51	13	25%
Jordan	92	-1.7	-1.8	-1.0	19	1	-1.6	-1.5	-1.8	51	13	25%
Jordan	449	-1.3	-1.3		4	0	-1.6	-1.5	-1.8	51	13	25%
Jordan	449						-1.6	-1.5	-1.8	51	13	25%
Kuiseb	383											
Kunene	143	-2.0	-2.0		2	0	-2.0	-2.0		1	0	0%
La Plata	288						-1.2	-1.2		15	0	0%
La Plata	152	-1.5	-1.5		2	0	-1.2	-1.2		15	0	0%
La Plata	103						-1.2	-1.2		15	0	0%

Basin	TFDD ID	**Treaty BAR All Complaints**	**Treaty BAR Non-Climate Driven Complaints**	**Treaty BAR Climate Driven Complaints**	**Treaty Number Complaints**	**Treaty Number Climate Complaints**	Basin BAR All Complaints	Basin BAR Non-Climate Complaints	Basin BAR Climate Complaints	Basin Number complaints	Basin Number Climate Complaints	Basin Percent Climate Complaints
La Plata	162	-1.0	-1.0		2	0	-1.2	-1.2		15	0	0%
La Plata	448	-1.3	-1.3		11	0	-1.2	-1.2		15	0	0%
Lake Titicaca-Poopo System	98											
Maritsa	142	-2.0	-2.0		1	0						
Maritsa, Nestos, Struma	276											
Mekong	170											
Mekong	133											
Mekong	436											
Mekong	437											
Minho/Miño, Guadiana	157	-1.0	-1.0		3	0	-1.0	-1.0		3	0	0%
Minho/Miño, Guadiana	157	-1.0	-1.0		3	0	-1.0	-1.0		3	0	0%
Minho/Miño, Guadiana	157	-1.0	-1.0		3	0	-1.0	-1.0		3	0	0%
Minho/Miño, Guadiana	157	-1.0	-1.0		3	0	-1.0	-1.0		3	0	0%
Mississippi	181											
Naatamo	76											
Nelson-Saskatchewan	248	-2.2	-3.0	-2.0	6	5	-2.2	-3.0	-2.0	6	5	83%
Nestos	277	-1.0		-1.0	1	1	-1.0		-1.0	1	1	100%
Niger	182											
Nile	110	-1.6	-1.6		5	0	-1.9	-2.0	-1.0	14	1	7%
Nile	359						-1.9	-2.0	-1.0	14	1	7%
Nile	79	-1.0		-1.0	1	1	-1.9	-2.0	-1.0	14	1	7%
Oder/Odra	104	-2.0	-2.0		1	0						

Basin	TFDD ID	Treaty BAR All Complaints	Treaty BAR Non-Climate Driven Complaints	Treaty BAR Climate Driven Complaints	Treaty Number Complaints	Treaty Number Climate Complaints	Basin BAR All Complaints	Basin BAR Non-Climate Complaints	Basin BAR Climate Complaints	Basin Number complaints	Basin Number Climate Complaints	Basin Percent Climate Complaints
Okavango	190											
Orange	164	-2.0	-2.0		1	0	-2.0	-2.0		1	0	0%
Orange	202						-2.0	-2.0		1	0	0%
Orange	202						-2.0	-2.0		1	0	0%
Orange	186						-2.0	-2.0		1	0	0%
Pasvik	297											
Pasvik	108											
Pasvik	102											
Po	395											
Po	395											
Rhine	360											
Rhine	361											
Rhine	134											
Rhine	106											
Rio Bravo/Rio Grande	55	-2.1	-2.7	-2.0	17	14	-2.2	-3.0	-2.2	13	12	92%
Rio Bravo/Rio Grande	417						-2.2	-3.0	-2.2	13	12	92%
Roia	138											
Roia	138											
Scudai, Tebrau	408											
Senegal	147											
Skagit	175											
St. Lawrence	69											
St. Lawrence	83											
St. Lawrence	145											

Basin	TFDD ID	Treaty BAR All Complaints	Treaty BAR Non-Climate Driven Complaints	Treaty BAR Climate Driven Complaints	Treaty Number Complaints	Treaty Number Climate Complaints	Basin BAR All Complaints	Basin BAR Non-Climate Complaints	Basin BAR Climate Complaints	Basin Number complaints	Basin Number Climate Complaints	Basin Percent Climate Complaints
St. Lawrence	245											
St. Lawrence	245											
Struma	397											
Tigris-Euphrates-Shatt al Arab	156						-1.4	-1.4	0.0	51	1	2%
Tigris-Euphrates-Shatt al Arab	257	-0.5	-0.5		4	0	-1.4	-1.4	0.0	51	1	2%
Tigris-Euphrates-Shatt al Arab	156						-1.4	-1.4	0.0	51	1	2%
Tigris-Euphrates-Shatt al Arab	451						-1.4	-1.4	0.0	51	1	2%
Tigris-Euphrates-Shatt al Arab	999	-1.4	-1.5	0.0	45	1	-1.4	-1.4	0.0	51	1	2%
Tigris-Euphrates-Shatt al Arab	127	-2.0	-2.0		1	0	-1.4	-1.4	0.0	51	1	2%
Torne/Tornealven	366											
Torne/Tornealven	366											
Vistula/Wista	130											
Vuoksa	149											
Vuoksa	455											
Zambezi	176						-2.0	-2.0		1	0	0%
Zambezi	177						-2.0	-2.0		1	0	0%
Zambezi	178	-2.0	-2.0		1	0	-2.0	-2.0		1	0	0%
Zambezi	81						-2.0	-2.0		1	0	0%

Basin	TFD D ID	**Treaty BAR All Com- plaints**	**Treaty BAR Non- Climate Driven Com- plaints**	**Treaty BAR Cli- mate Dri- ven Com- plaints**	**Treaty Number Com- plaints**	**Treaty Number Climate Com- plaints**	Basin BAR All Com- plaints	Basin BAR Non- Climate Com- plaints	Basin BAR Climate Com- plaints	Basin Number com- plaints	Basin Number Climate Com- plaints	Basin Percent Climate Com- plaints
Zambezi	81						-2.0	-2.0		1	0	0%

Appendix G: Treaty Mechanism Scores (Literature Review and MLR)

Basin	TFDD ID	Literature Review Un-weighted Treaty Strength	Literature Review Weighted Treaty Strength	Literature Review Fully Weighted Treaty Strength	Model 1 Average Un-weighted Strength	Model 1 Average Weighted Strength	Model 1 Average Fully Weighted Strength	Model 2 Average Un-weighted Strength	Model 2 Average Un-weighted Strength	Model 2 Average Fully Weighted
Amazon	289	1.20	1.04	0.17	0.11	-0.09	-0.16	0.22	-0.46	1.91
Amazon	180	0.98	1.29	0.19	-0.01	-0.05	0.04	0.01	-0.26	-0.41
Amur, Har Us Nur, Pu Lun T'o	187	2.97	2.99	0.49	-0.13	-0.25	-1.08	-0.34	-0.93	1.23
Amur, Har Us Nur, Pu Lun T'o	187	2.97	2.99	0.49	-0.13	-0.25	-1.08	-0.34	-0.93	1.23
Amur, Har Us Nur, Pu Lun T'o	187	2.97	2.99	0.49	-0.13	-0.25	-1.08	-0.34	-0.93	1.23
An Nahr Al Kabir	403	2.27	2.20	0.33	-0.05	-0.13	-1.00	-0.25	-0.54	-0.41
Aral Sea	194	2.22	2.60	0.36	-0.02	-0.01	-1.80	-0.36	-0.12	-4.20
Aral Sea	195	1.18	1.53	0.21	-0.10	0.03	-0.13	-0.36	-0.07	-2.74
Aral Sea	197	0.78	0.89	0.15	-0.01	0.04	0.82	-0.15	-0.20	1.42
Asi/Orontes	273	1.18	1.22	0.20	-0.08	-0.03	0.43	-0.20	-0.18	0.18
Atrak	100	1.03	1.49	0.28	-0.09	-0.11	1.47	-0.09	-0.65	4.89
Colorado	55	3.62	3.74	0.56	-0.25	-0.31	-1.65	-0.71	-0.80	-2.75
Colorado	135	2.22	2.23	0.33	-0.21	0.04	-0.76	-0.67	0.02	-3.06
Colorado	253	2.13	2.15	0.32	-0.12	-0.04	-1.48	-0.30	-0.24	-3.10
Colorado	153	1.07	1.06	0.18	-0.03	0.10	0.06	-0.20	-0.01	0.00
Colorado	150	0.62	0.90	0.15	0.00	0.03	0.70	0.01	-0.20	1.42
Columbia	116	3.82	4.18	0.60	-0.19	-0.40	-2.18	-0.35	-1.01	-4.39

Basin	TFDD ID	Literature Review Un-weighted Treaty Strength	Literature Review Weighted Treaty Strength	Literature Review Fully Weighted Treaty Strength	Model 1 Average Un-weighted Strength	Model 1 Average Weighted Strength	Model 1 Average Fully Weighted Strength	Model 2 Average Un-weighted Strength	Model 2 Average Un-weighted Strength	Model 2 Average Fully Weighted
Columbia	116	3.82	4.05	0.58	-0.19	-0.40	-2.18	-0.35	-1.01	-4.39
Columbia	125	2.70	2.81	0.37	-0.14	-0.17	-2.77	-0.30	-0.35	-7.13
Columbia	131	1.97	2.70	0.35	-0.01	-0.15	-1.78	-0.15	-0.38	-4.98
Columbia	246	1.63	1.89	0.26	-0.06	-0.03	-1.24	-0.20	-0.12	-4.02
Columbia	246	1.63	2.02	0.28	-0.06	-0.03	-1.24	-0.20	-0.12	-4.02
Columbia	126	1.28	1.66	0.23	0.12	-0.12	0.03	0.27	-0.61	0.27
Danube	77	3.13	3.07	0.42	-0.05	-0.19	-2.33	-0.40	-0.49	-4.07
Danube	86	2.88	3.08	0.48	-0.21	-0.18	-1.11	-0.55	-0.68	-0.92
Danube	86	2.88	3.08	0.48	-0.21	-0.18	-1.11	-0.55	-0.68	-0.92
Danube	80	2.52	2.87	0.47	-0.08	-0.25	-0.50	0.01	-1.03	1.78
Danube	278	2.32	2.54	0.42	-0.01	-0.30	-0.33	0.22	-1.23	3.19
Danube	68	2.27	2.56	0.39	-0.12	-0.26	0.18	-0.40	-0.77	1.04
Danube	84	0.82	0.87	0.16	-0.07	-0.06	0.54	-0.20	-0.22	1.60
Danube	433	0.82	0.75	0.15	-0.07	-0.06	0.54	-0.20	-0.22	1.60
Danube	73	0.57	0.66	0.08	0.03	0.17	-0.18	-0.11	0.33	-2.74
Dnieper, Don	332	0.20	0.19	0.02	0.04	0.14	-0.07	-0.10	0.28	-1.32
Dnieper, Don	332	0.20	0.19	0.02	0.04	0.14	-0.07	-0.10	0.28	-1.32
Douro/Duero	129	2.32	2.07	0.30	0.08	0.04	-1.44	-0.30	-0.04	-1.69
Fenney, Ganges-Brahmaputra-Meghna, Karnaphuli	269	0.25	0.40	0.10	0.01	-0.04	1.05	0.01	-0.36	3.74
Ganges-	172	3.62	3.34	0.53	-0.30	-0.24	-1.30	-0.51	-0.92	-0.87

Basin	TFDD ID	Literature Review Un-weighted Treaty Strength	Literature Review Weighted Treaty Strength	Literature Review Fully Weighted Treaty Strength	Model 1 Average Un-weighted Strength	Model 1 Average Weighted Strength	Model 1 Average Fully Weighted Strength	Model 2 Average Un-weighted Strength	Model 2 Average Un-weighted Strength	Model 2 Average Fully Weighted
Brahmaputra-Meghna										
Ganges-Brahmaputra-Meghna	172	3.62	3.34	0.53	-0.30	-0.24	-1.30	-0.51	-0.92	-0.87
Ganges-Brahmaputra-Meghna	192	3.20	3.32	0.45	-0.09	-0.20	-2.48	-0.25	-0.51	-6.21
Ganges-Brahmaputra-Meghna	136	3.05	3.25	0.52	-0.22	-0.17	-0.68	-0.71	-0.68	0.18
Ganges-Brahmaputra-Meghna	158	2.83	2.77	0.40	-0.05	-0.15	-1.96	-0.10	-0.45	-4.02
Ganges-Brahmaputra-Meghna	267	2.75	2.43	0.38	-0.28	-0.06	-1.20	-0.61	-0.26	-2.33
Ganges-Brahmaputra-Meghna	85	2.43	2.83	0.42	-0.06	-0.11	-1.04	-0.40	-0.54	-0.96
Ganges-Brahmaputra-Meghna	111	1.52	2.17	0.27	-0.03	-0.11	-0.98	-0.15	-0.32	-3.89

Basin	TFDD ID	Literature Review Un-weighted Trea-ty Strength	Literature Review Weighted Treaty Strength	Literature Review Fully Weighted Treaty Strength	Model 1 Aver-age Un-weighted Strength	Model 1 Average Weighted Strength	Model 1 Average Fully Weighted Strength	Model 2 Aver-age Un-weighted Strength	Model 2 Aver-age Un-weighted Strength	Model 2 Average Fully Weighted
Ganges-Brahmaputra-Meghna	151	1.48	1.41	0.22	-0.07	-0.05	-0.52	-0.09	-0.37	-0.59
Ganges-Brahmaputra-Meghna	268	1.48	1.41	0.24	-0.12	0.06	0.10	-0.30	-0.12	0.73
Ganges-Brahmaputra-Meghna	163	1.18	1.22	0.20	-0.08	-0.03	0.43	-0.20	-0.18	0.18
Ganges-Brahmaputra-Meghna	159	1.15	1.30	0.22	-0.07	-0.07	0.46	-0.35	-0.22	1.41
Ganges-Brahmaputra-Meghna	411	0.57	0.66	0.08	0.03	0.17	-0.18	-0.11	0.33	-2.74
Garonne	107	2.18	2.00	0.32	-0.10	-0.05	-0.63	-0.30	-0.18	-0.37
Garonne	390	2.18	2.58	0.34	0.11	-0.02	-2.06	0.06	-0.25	-4.62
Gash	75	0.37	0.60	0.07	0.10	0.12	-0.02	0.11	0.13	-1.32
Guadiana, Min-ho/Miño	141	2.32	2.20	0.35	-0.04	-0.11	-0.54	-0.25	-0.37	0.86
Helmand	72	0.78	0.85	0.15	0.06	-0.13	0.76	0.22	-0.57	3.01
Incomati	184	3.17	3.39	0.44	0.11	-0.29	-2.63	0.52	-1.01	-5.90

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Incomati	185	2.93	2.91	0.48	0.02	-0.24	-0.92	0.22	-1.19	1.78
Incomati	185	2.93	2.91	0.48	0.02	-0.24	-0.92	0.22	-1.19	1.78
Incomati	174	2.38	2.00	0.31	-0.08	-0.12	-2.22	-0.30	-0.33	-2.42
Incomati	174	2.38	2.00	0.31	-0.08	-0.12	-2.22	-0.30	-0.33	-2.42
Incomati	174	2.38	2.00	0.31	-0.08	-0.12	-2.22	-0.30	-0.33	-2.42
Incomati	206	0.95	1.43	0.23	0.00	-0.01	0.87	-0.15	-0.32	2.15
Incomati	234	0.82	1.06	0.18	-0.07	0.05	0.78	-0.20	-0.12	0.92
Indus	114	4.28	4.69	0.67	-0.15	-0.43	-1.87	-0.60	-1.21	-3.16
Isonzo	394	2.38	2.54	0.34	-0.10	-0.19	-1.57	-0.25	-0.49	-3.70
Isonzo	394	2.38	2.54	0.34	-0.10	-0.19	-1.57	-0.25	-0.49	-3.70
Johore	414	1.68	1.94	0.30	-0.07	-0.05	0.16	-0.36	-0.18	-0.18
Johore	413	1.35	1.41	0.24	-0.11	-0.04	-0.01	-0.41	-0.02	-0.18
Johore	435	0.37	0.50	0.07	0.05	0.12	-0.27	-0.10	0.28	-1.51
Johore	434	0.20	0.31	0.04	0.04	0.14	-0.07	-0.10	0.28	-1.32
Jordan	168	3.08	3.13	0.51	-0.30	-0.21	-0.89	-0.91	-0.59	-0.37
Jordan	82	2.68	2.75	0.48	-0.14	-0.23	0.00	-0.34	-0.88	3.79
Jordan	171	1.32	1.59	0.26	-0.06	-0.08	0.27	-0.35	-0.22	1.23
Jordan	92	0.70	1.03	0.14	0.05	0.12	-0.34	-0.25	0.28	-1.69
Jordan	449	0.37	0.50	0.07	0.05	0.12	-0.27	-0.10	0.28	-1.51
Jordan	449	0.37	0.50	0.07	0.05	0.12	-0.27	-0.10	0.28	-1.51
Kuiseb	383	1.47	1.83	0.26	-0.14	0.01	-0.99	-0.56	0.03	-3.83
Kunene	143	3.38	3.73	0.58	-0.08	-0.34	-1.11	-0.14	-1.09	0.68

Basin	TFDD ID	Literature Review Un-weighted Treaty Strength	Literature Review Weighted Treaty Strength	Literature Review Fully Weighted Treaty Strength	Model 1 Average Un-weighted Strength	Model 1 Average Weighted Strength	Model 1 Average Fully Weighted Strength	Model 2 Average Un-weighted Strength	Model 2 Average Un-weighted Strength	Model 2 Average Fully Weighted
La Plata	288	2.37	2.70	0.34	-0.02	-0.19	-2.15	0.00	-0.39	-6.94
La Plata	152	2.03	2.04	0.34	0.00	0.01	-0.49	-0.25	-0.32	1.78
La Plata	103	1.42	1.34	0.24	0.02	-0.05	0.35	-0.04	-0.51	3.38
La Plata	162	0.98	1.35	0.18	-0.03	-0.02	0.03	-0.15	-0.26	-1.32
La Plata	448	0.25	0.40	0.10	0.01	-0.04	1.05	0.01	-0.36	3.74
Lake Titicaca-Poopo System	98	0.92	0.97	0.16	0.06	-0.02	0.90	-0.09	-0.40	2.65
Maritsa	142	2.15	2.54	0.44	-0.07	-0.31	-0.15	0.02	-1.18	4.10
Maritsa, Nestos, Struma	276	0.25	0.40	0.10	0.01	-0.04	1.05	0.01	-0.36	3.74
Mekong	170	4.37	3.99	0.65	-0.27	-0.21	-1.43	-0.81	-0.92	0.04
Mekong	133	0.58	0.78	0.14	0.08	-0.04	0.67	0.22	-0.40	2.65
Mekong	436	0.57	0.54	0.07	-0.02	0.17	-0.43	-0.31	0.48	-2.92
Mekong	437	0.57	0.44	0.06	-0.02	0.17	-0.43	-0.31	0.48	-2.92
Minho/Miño, Guadiana	157	1.08	1.03	0.20	0.02	-0.05	0.43	0.12	-0.51	3.56
Minho/Miño, Guadiana	157	1.08	1.03	0.20	0.02	-0.05	0.43	0.12	-0.51	3.56
Minho/Miño, Guadiana	157	1.08	1.03	0.20	0.02	-0.05	0.43	0.12	-0.51	3.56
Minho/Miño, Guadiana	157	1.08	1.03	0.20	0.02	-0.05	0.43	0.12	-0.51	3.56

Basin	TFDD ID	Literature Review Un-weighted Trea-ty Strength	Literature Review Weighted Treaty Strength	Literature Review Fully Weighted Treaty Strength	Model 1 Aver-age Un-weighted Strength	Model 1 Average Weighted Strength	Model 1 Average Fully Weighted Strength	Model 2 Aver-age Un-weighted Strength	Model 2 Aver-age Un-weighted Strength	Model 2 Average Fully Weighted
Mississippi	181	3.50	3.90	0.59	-0.08	-0.38	-1.60	-0.14	-1.26	-0.24
Naatamo	76	1.45	1.76	0.26	0.03	0.03	0.92	-0.25	-0.36	1.23
Nelson-Saskatchewan	248	1.85	2.47	0.39	-0.08	-0.22	-0.31	-0.09	-0.77	0.86
Nestos	277	0.82	0.87	0.16	-0.07	-0.06	0.54	-0.20	-0.22	1.60
Niger	182	2.03	1.88	0.36	-0.07	-0.28	0.65	0.02	-1.01	6.11
Nile	110	2.72	2.76	0.38	-0.03	-0.23	-1.55	-0.04	-0.64	-3.34
Nile	359	1.12	1.32	0.21	-0.01	-0.12	0.07	0.12	-0.68	1.92
Nile	79	1.08	1.44	0.22	0.14	-0.06	0.66	0.27	-0.55	2.46
Oder/Odra	104	1.85	2.64	0.42	-0.08	-0.22	-0.31	-0.09	-0.77	0.86
Okavango	190	2.32	2.26	0.37	-0.01	-0.30	-0.49	0.22	-1.23	2.64
Orange	164	5.27	5.22	0.74	-0.04	-0.39	-2.92	-0.10	-1.28	-6.17
Orange	202	2.63	2.68	0.41	-0.13	-0.35	-0.51	0.01	-1.09	0.50
Orange	202	2.63	2.68	0.41	-0.13	-0.35	-0.51	0.01	-1.09	0.50
Orange	186	2.52	2.52	0.43	-0.08	-0.25	-0.50	0.01	-1.03	1.78
Pasvik	297	2.70	2.81	0.42	-0.17	-0.24	-1.28	-0.46	-0.69	-2.56
Pasvik	108	1.80	2.23	0.26	-0.02	-0.13	-1.74	-0.15	-0.38	-5.35
Pasvik	102	1.12	1.47	0.23	0.03	-0.02	0.13	0.01	-0.20	0.86
Po	395	1.35	1.63	0.22	-0.01	-0.12	-0.62	0.01	-0.32	-2.24
Po	395	1.35	1.63	0.22	-0.01	-0.12	-0.62	0.01	-0.32	-2.24
Rhine	360	3.08	3.23	0.49	-0.11	-0.38	-1.32	0.01	-1.15	-0.60
Rhine	361	1.97	2.38	0.31	0.04	-0.15	-1.37	0.06	-0.53	-4.25

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Rhine	134	1.95	2.11	0.35	-0.05	-0.03	0.35	-0.40	-0.43	2.69
Rhine	106	0.78	0.75	0.15	0.01	-0.13	0.51	0.01	-0.41	2.83
Rio Bravo/Rio Grande	55	3.62	3.74	0.56	-0.25	-0.31	-1.65	-0.71	-0.80	-2.75
Rio Bravo/Rio Grande	417	1.63	2.10	0.27	-0.01	-0.14	-1.70	0.01	-0.38	-4.80
Roia	138	1.68	2.11	0.28	0.01	-0.15	-1.01	0.01	-0.32	-2.61
Roia	138	1.68	2.11	0.28	0.01	-0.15	-1.01	0.01	-0.32	-2.61
Scudai, Tebrau	408	1.12	1.71	0.28	0.01	-0.02	0.67	-0.15	-0.32	1.96
Senegal	147	0.37	0.60	0.08	0.05	0.12	-0.27	-0.10	0.28	-1.51
Skagit	175	1.57	2.00	0.26	0.11	-0.17	-1.61	0.22	-0.52	-2.66
St. Lawrence	69	2.40	2.66	0.43	-0.05	-0.22	0.64	0.07	-1.13	3.42
St. Lawrence	83	1.08	1.03	0.20	0.02	-0.05	0.43	0.12	-0.51	3.56
St. Lawrence	145	0.95	1.33	0.21	0.02	0.00	0.32	0.01	-0.20	1.05
St. Lawrence	245	0.82	1.06	0.18	-0.07	0.05	0.78	-0.20	-0.12	0.92
St. Lawrence	245	0.82	1.06	0.18	-0.07	0.05	0.78	-0.20	-0.12	0.92
Struma	397	1.48	1.97	0.32	-0.04	-0.23	0.35	-0.04	-0.96	2.65
Tigris-Euphrates-Shatt al Arab	156	2.52	2.81	0.44	-0.18	-0.19	-0.45	-0.50	-0.88	0.86
Tigris-Euphrates-Shatt al Arab	257	1.48	1.41	0.24	-0.12	0.06	0.10	-0.30	-0.12	0.73
Tigris-Euphrates-	156	1.28	1.35	0.24	-0.05	0.01	0.26	-0.09	-0.32	2.15

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Shatt al Arab										
Tigris-Euphrates-Shatt al Arab	451	0.93	0.78	0.10	-0.05	0.12	-0.47	-0.46	0.42	-3.47
Tigris-Euphrates-Shatt al Arab	999	0.57	0.57	0.08	-0.02	0.17	-0.43	-0.31	0.48	-2.92
Tigris-Euphrates-Shatt al Arab	127	0.37	0.60	0.07	0.10	0.12	-0.02	0.11	0.13	-1.32
Torne/Tornealven	366	2.28	2.39	0.43	-0.10	-0.08	0.23	-0.34	-0.65	4.52
Torne/Tornealven	366	2.28	2.39	0.43	-0.10	-0.08	0.23	-0.34	-0.65	4.52
Vistula/Wista	130	2.35	2.63	0.44	-0.14	-0.23	-0.55	-0.19	-0.88	1.78
Vuoksa	149	1.83	1.85	0.31	0.07	-0.04	-0.33	-0.04	-0.51	3.19
Vuoksa	455	1.22	1.06	0.19	-0.21	0.04	0.21	-0.62	0.17	-1.23
Zambezi	176	3.97	4.02	0.66	-0.11	-0.23	-1.17	-0.24	-1.21	2.01
Zambezi	177	3.87	3.53	0.55	-0.14	-0.20	-1.48	-0.35	-0.85	-1.78
Zambezi	178	3.58	3.34	0.55	-0.27	-0.31	-1.42	-0.50	-0.96	0.72
Zambezi	81	0.95	1.25	0.20	0.00	0.02	0.63	-0.15	-0.20	1.23
Zambezi	81	0.95	1.12	0.18	0.00	0.02	0.63	-0.15	-0.20	1.23