A *lock-in* Transboundary Water Management Regime: the case of the Rio Grande/Bravo Basin

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Abstract

The study of the Rio Grande/Bravo (RGB) Basin water management demonstrates how the United States (US) and Mexico have consolidated a transboundary water regime based on groundwater sharing. Despite the lack of water management integration and common sustainable practices, both countries have succeeded in sharing groundwater resources in the past, but not for long. The transboundary water regime in RGB Basin is based on *fixed* groundwater extractions which do not match the ever increasing water demands and current adjustments for human and environmental needs, and the potential future natural conditions for a sustainable river system.

The aim of this paper is to discuss that despite the fact that the US – Mexico water regime has given good results in terms of water allocation; the system is imperfect due to a lack of consideration of current and future environmental, economic and socio-political drivers, as well as seeing the system as a whole, promoting a conjunctive use of surface water and groundwater. Findings of this study are based on a qualitative interview study conducted with stakeholders in the RGB Basin and an analysis of historic water demands. Our sample included 54 respondents across the basin, they addressed a multitude of concerns in the context of environmental problems, fragmented water management, and citizen participation.

This presentation elaborates on three key questions: (1) How the RGB water allocation regime can last with fixed water demands and without adapting to current changes in natural conditions? (2) What is the impact of this regime in the river ecosystem? (3) Does the RGB Basin water regime reflect a *lock in* situation that is blocking changes toward new water management practices? If so, how stakeholders can promote changes in the decision-making process? The situation of the RGB water regime can be explained through the concept of long-term predominance which results in a path-dependent process. This process helps to address sustained persistence and processes of institutions leading to a lock-in state. The RGB water regime needs major transformations, specifically in considering environmental, economical, and socio-political variables in groundwater management across the river basin, as well as the conjunctive use of surface and groundwater. A list of recommendations to enhance and optimize current water management regime is presented with a discussion of possibilities of dissolving binational organizational paths.

Keywords: water management, Rio Grande/Bravo Basin, regime, United States, Mexico, institutions.

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I. Introduction

An environmental and political study of the Rio Grande/Bravo Basin (RGB) demonstrates how the United States (US) and Mexico have consolidated a transboundary water regime based on binational groundwater resources distribution without connecting water resources management across the basin. The U.S. and Mexico share a nearly 3,200 km border. The Colorado River (CR) and the Rio Grande/Bravo (RGB) River are the two major rivers crossing and running along the border **(Figure 1).**

Figure 1. The US and Mexico Transboundary Rivers
[http://www.harc.edu/work/SERIDAS] 02/12/2015

The Colorado River rises in the US and its basin comprises sections from the states of Wyoming, Colorado, Utah, Nuevo Mexico, Arizona, Nevada and California. The CR stretches 2,730 km, 30 of which limit the border between the US and Mexico in covering some section in the Mexican state of Baja California and Arizona in the US. The last 160 km are totally located in Mexican territory before emptying in the Gulf of California (**(Figure 2).**

Figure 2. The Colorado River System
[http://blogs.ei.columbia.edu/wp-content/uploads/2012/12/CO-River-Basin-REVISED.jpg] 02/10 /2015

The CR does not have any tributary stream coming from Mexico. The totality of run-off originates in the US, mainly in the states of Wyoming and Colorado. Both, the Wyoming and Colorado states, contribute more or less than 80% runoff. Close to 625,000 km^2 (99.2%) is in the US, and 5,000km^2 (0.8%) in Mexico. The long term (1906-2011) mean annual natural flow of the CR is about 20.2 km^3 (16.4 million acre-feet), compared to the current mean annual water demands which are 18.9 km^3 (15.3 million acre-feet). However, the last CR drought (1999-2013) showed that the water supply system in this basin is vulnerable, cities as Las Vegas were on the verge to run out of water. In fact, it is expected that water demands exceed the water available in the basin by mid-century.[1]

The Rio Grande/Bravo (RGB) plays also an important and life-sustaining role in US and Mexico societies. The headwaters of the RGB are located in the state of Colorado and flows down through New Mexico until reaching Ciudad Juárez in the Mexican state of Chihuahua. The river runs down to the West until the mouth of the Gulf of Mexico. The RGB River is about 2,892 km long from its source to its mouth. Close to 2,034 km run along the US and Mexico border before emptying in the Gulf of Mexico **(Figure 3).**

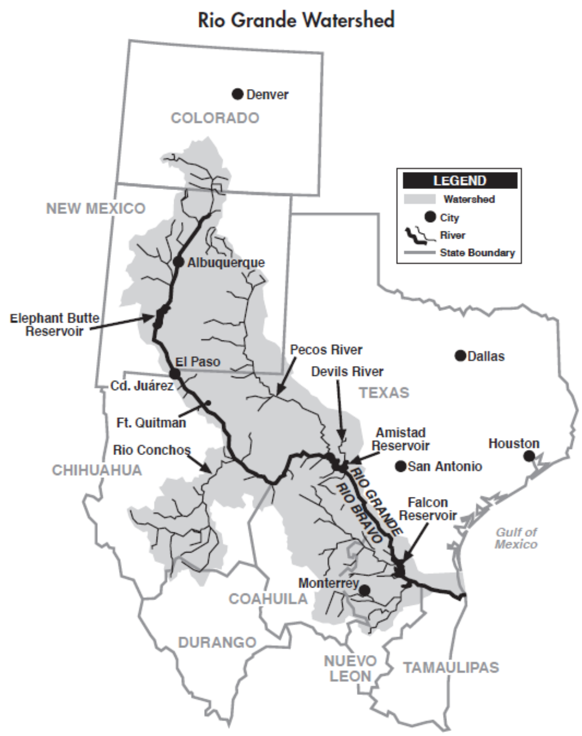

Figure 3. The Rio Grande/Bravo River System
[https://www.tceq.texas.gov/publications/sfr/057_12/availability] 02/10 /2015

The main US tributaries to the RGB are the Pecos and Devils Rivers. Its main tributaries in the Mexican side are the Río Conchos, Río Las Vacas, Río San Diego, Río San Rodrigo, Río Escondido, Río Salado, Río Alamos, and Río San Juan. The RG/RB basin drains a total area of 468,374 km^2. Close to 242,994 Km^2 (52%) is in the U.S and 225,380 Km^2 (48%) is in Mexico[2]. The most important tributary to the RGB system is the Río Conchos which originates in the Mexican state of Chihuahua in the arid/semi-arid Tarahumara range before reaching the RGB River at Ojinaga, Mexico. The Río Conchos supplies approximately "80% of the flows of the Lower Bravo/Grande River above the binational reservoirs of Amistad and Falcon".[3]

The mean annual natural runoff of the RGB system below Fort Quitman is 7.34 Km^3 (5.95 million acre-feet), and the present mean annual demands are 7.36 Km^3 (5.96 million acre-feet). Extended and severe drought (1992-2007) threaten the RGB water supply system.

The CR and the RGB river systems have been important in determining and defending political boundaries between the US and Mexico. Both transboundary river systems are important sources of water households, industry and agriculture. For both, the CR and the RGB, irrigation has been essential for any agricultural development, recreational use, and environmental conservation. Aridness, negligible total of annual precipitation, and critical maintenance of minimum environmental flows, invite into competition among the different uses and users into the water sector across and along the border. Water allocation regime between the US and Mexico "has been fairly successful in carrying out binational sharing water resources"[4]. Water allocation treaties in an arid region defy water and environmental equity leading to transboundary water disputes. A good example is the case of the US/Mexico transboundary water allocation regime.

This presentation, exclusively based on the case of the RG/RB river system, elaborates on three key questions: (1) How the RGB water allocation regime can last with fixed water demands and without adapting to current changes in natural conditions? (2) What is the impact of this regime in the river ecosystem? (3) Does the RGB Basin water regime reflect a *lock in* situation that is blocking changes toward new water management practices? If so, how stakeholders can promote changes in the decision-making process. The CR and the RGB River are subject to the same binational water regime. Binational water allocation regime has as a fundamental purpose based on policing water entitlements for both the US and Mexico.[5] This presentation will first address how the binational water regime came about and has been in force since 1944. Next, we will address water allocation regime and its perennial term without adapting to current changes in natural conditions. In this section, we will present an overview of the annual runflow and historic water demands, as well as a discussion based on stakeholders' insights. This communication will then discuss that despite the fact that the US – Mexico water regime has given good results in terms of water allocation; the system is imperfect due to a lack of consideration of environmental, economic and socio-political aspects. Finally, this communication will elaborate on how the transboundary water regime reflects a *lock in* situation that is blocking changes toward new binational water management practices, and recommend how the transboundary water regime should be enhanced and optimized in order to dissolve binational imperfection and institutional persistence paths.

II. Methodology

The RGB Basin transboundary water regime is based on perennial and ever growing groundwater extractions and a fragmented water allocation system. The transboundary water regime challenges both present and future human and environmental needs and prevents a sustainable future state of the environment and water resources system. Methodologically, this research employs a mixed-method approach in order to adequately address and decipher the research purposes and provide in-depth analysis and meaningful conclusions. The research utilizes various methodological approaches, including detailed case study analysis, and semi-structured interviews, and hydrological data analysis on environmental flows and historic water demands. The overall objective of this research, which personifies a qualitative approach, is to discuss that despite the fact that the US – Mexico water regime has given good results, most of the times, in terms of water allocation; the system is imperfect due to a lack of consideration of environmental, economic and socio-political aspects.

Detailed case study analysis and Semi-structured interviews

The case study approach is methodological component which aims to understand a case study from field data collection. If a case study "is deliberately chosen, there is an interest to generalize the conclusions".[6] Research on a particular case is highly related to "a general principle based on a set of concepts and related facts".[7] In other words, it has been through an inductive approach that we have achieved understanding of a case study from field data collection.

Collection of documents, also called documentary observation, is the most used information-gathering instrument in political science. According to this technique, we have been consulted various categories of documents[8] in order to improve our understanding on transboundary water allocation issues between the US and Mexico. In a qualitative analysis methodology, documentary information sources and review of literature are used to define the theoretical context of the research object and the general picture of the problem. Documents and reports are singular, always available and stable sources of information. They do not react to the researcher use.[9] The different categories of documents covered by the documentary observation come from different sources: libraries, database, research field, and logbooks.

Regarding the semi-structured interviews a total 54 were conducted across the RGB from October 2011 to February 2012. The interview is the data collection instrument that has allowed us to advance further in the understanding of the case study. The purpose has been to know the views and the contending perspectives of those involved in the study.[10]The descriptive, analytical and interpretative aspects of the qualitative methodology derives from the importance of the interview since one "has access to information, that is not found anywhere else, from people that has witnessed events related to the research project".[11]

Furthermore, recorded words are a source of insider information. Context detailed descriptions and what the interviewees say or do are the basis of the inductive analysis.[12] Consequently, interviews represent the most dynamic component of any qualitative research since they embody a conversation with stakeholders that have a thorough knowledge on the issue and contribute to the research with significant information.[13]

Taking into account the location of the actors, interviews were conducted on the basis of the availability of respondents, in places that they preferred, whether their workplace or a public place. In situations where travel was difficult, we conducted interviews by telephone and electronic mail. The participation of experts to the interviews was limited to lasting up to an hour and a half. **Table 1** shows the interviews distribution and the way they were carried out:

Table 1. Semi-structured Interviews Distribution

Country of Origin	**Interviews by telephone and electronic mail**	**Interviews in person**	***Total***
United States	9	31	40
Mexico	11	3	14
Total	20	34	54

Key actors in our sample, also called experts or respondents, are involved in different sectors, among others: academy, research, water management, irrigation, hydraulic infrastructure, policy and administration, citizen empowerment and natural resources conservation. But above all, they are affiliated with representative organizations that were created to address a specific problem in the field of water resource management. The goal with this selection of participants was to meet the main actors in each area of the watershed, to understand the functioning of organizations and to identify relationships and processes between watershed regions and areas of activity. The interviewee's perspectives summarized in this document focus on representative themes issues that challenge the transboundary water regime and sustainability practices across the basin.

Hydrological data analysis on environmental flows and historic water demands

Adolfo Orive[14] presented in 1945, an analysis of the natural water availability and water use for the RGB when the treaty was signed **(Table 2**). For *__Mexico__*, this analysis shows that for the 6 tributaries listed in the Treaty, there was more natural water availability (3,388 million m^3/year) than consumptive water use (1,965 million m^3/year). Thus, there was considered a positive balance of 1,423 million m^3/year between the natural water availability and the water use. In fact, one-third of the outflow (surplus) from the 6 tributaries was estimated to be 474 million m^3/year, slightly larger than the average annual treaty obligations (432 million m^3/year). Similarly, along the RGB mainstem, it was estimated that the natural water availability (2,420 million m^3/year) was greater than the water consumptive use (1,776 million m^3/year), a positive balance (called then *surplus*) of 644 million m^3/year was estimated to be available and left on the river, which could be beneficial for environmental purposes. For the *__United States__*, in the tributaries, the natural water availability (3,521 million m^3/year) was estimated to be larger than the water consumptive use (988 million m^3/year), resulting in a positive balance of 2,533 million m^3/year. The natural water availability for the US considered inflows of US tributaries, the gains along the main stem and the one-third of the 6 Mexican tributaries. The available water out of the U.S. tributaries (2,533 million m^3/year) was considered to be available for US water uses along the mainstem, and again larger than the water consumptive use (1,949 million m^3/year). Similar to Mexico, a positive balance of 548 million m^3/year was estimated between the available US water in the main stem and the consumptive use along the river. The remaining water, 644 (Mexico) and 584 (US) million m^3/year, was for conveyance losses, evaporation, mitigation of droughts, and drainage, among others.

Table 2 shows a similar analysis, from 1950 to 2004, considering evaporation losses in reservoirs for the water balance. For the 6 tributaries, there is a positive balance of 1,364 million m^3/year; one-third of the Mexican outflow (455 million m3/year) is slightly larger than the average annual treaty obligations. Notice that the mean natural water availability (3,506 million m^3/year) is larger than expected in the post-treaty analysis (3,388 million m^3/year); however, there are larger consumptive uses and evaporation. A positive balance of 1,560 million m^3/year has been estimated for all the inflows of Mexican tributaries and the gains along the main stem. Finally, a small negative balance of 16 million m^3/year is estimated between the available water for Mexican users along the mainstem (1,560 million m^3/year) and their consumptive use (1,576 million m^3/year). This slightly negative balance means that all the natural water available is already used throughout the basin.

For the US, in the tributaries, the natural water availability (2,280 million m^3/year) is larger than the consumptive water use (836 million m^3/year), for a positive balance of 1,444 million m^3/year. This surplus is considered available for water uses along the mainstem. Similar to Mexico, a small positive balance of 2 million m^3/year is estimated between the available water for US users along the mainstem (1,444 million m^3/year) and their consumptive use (1,442 million m^3/year). Again, all the water has been allocated and used leaving no surplus water for the environmental purposes. Overall, evaporation losses in reservoirs account for 23% (1,702 million m3) of the mean annual naturalized flows (7,343 million m3) in the basin, which is a significant amount of water.

The slightly negative balance of water along the RGB main stem shows the high state of stress of the system. **Figure 4** shows the historical water consumption in the basin. For all Mexican tributaries (**Figure 4.c),** there was a linear increase in consumption from 1950 to 1994. Likewise, Mexican consumption along the Rio Grande/Bravo (**Figure 4.a**) increased linearly from 1950 to 1994. In contrast, US consumption along the RGB (**Figure 4.b)** has been close to the mean value, except for 1989 when more than 2,000 million m3 were consumed. This description shows the problem of over-consumption of water, mostly in Mexico.

Table 2. Mean annual water balance, Pre and Post treaty Analysis

	Orive (pre-1944)			Historic (1950-2004)			
	Nat. Availab. (million m^3)	Consump. Use (million m^3)	Surplus (million m^3)	Nat. Flows (million m^3)	Consump. Use (million m^3)	Evaporation (million m^3)	Surplus/Deficit (million m^3)
MEXICO	5,338	4,694	644	5,063	3,968	1,112	-16
6 Tributaries							
1 - Rio Conchos	2,045	1,275	770	2,255	1,267	281	707
2- LV, SD, SR and ES[1]	418	128	290	410	49	5	356
3.- Salado	925	562	363	841	383	157	301
Total 6 Tributaries	3,388	1,965	1,423	3,506	1,699	443	1,364
Surplus MX: 2/3 of 6 Tributaries			***949***				***909***
Surplus US: 1/3 of 6 Tributaries			***474***				***455***
Tributaries & Gains							
I - 6 Tributaries	2,914	1,965	***949***	3,061	1,699	443	***909***
II - Alamo and San Juan	1,557	953	604	1,236	693	339	204
III - Gains along Rio Grande/Bravo	867	---	867	776	---	330	446
Total Tributaries & Gains (I + II + III)	5,338	2,918	***2,420***	5,063	2,392	1,112	***1,560***
Along the Rio Grande (MX)							
Projects Along Rio Grande/Bravo	***2,420***	1,776	**644**	***1,560***	1,576	---	**-16**
UNITED STATES	3,521	2,937	584	2,280	1,688	590	2
I - 6 Tributaries	***474***	---	***474***	***445***	---	---	***455***
II - PE, DE, GE, AL, TE, SF and PI[2]	2,180	988	1,192	1,049	246	76	727
III - Gains along Rio Grande/Bravo	867	0	867	776	0	514	262
Total Tributaries & Gains (I + II + III)	3,521	988	***2,533***	2,280	246	590	***1,444***
Along the Rio Grande (US)							
Projects Along Rio Grande/Bravo	***2,533***	1,949	**584**	***1,444***	1,442	---	**2**

[1] Las Vacas, San Diego, San Rodrigo and Escondido

[2] Pecos, Devils, Goodenough, Alamito, Terlingua, San Felipe and Pinto

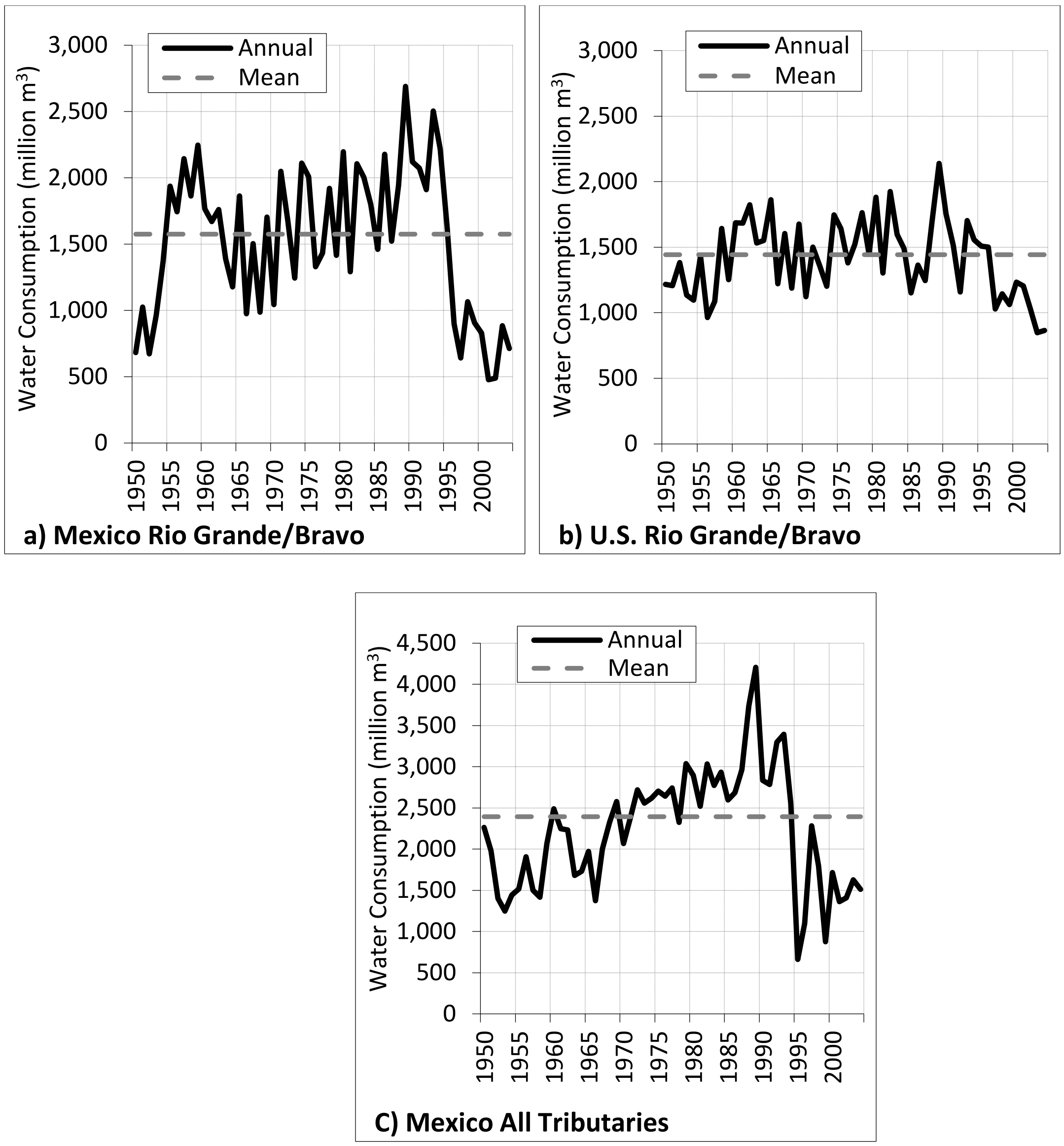

Figure 4. Historic water consumption for Mexico (a and c) and the United States (b)

Along the RGB basin, there have been some attempts to estimated environmental flows in tributaries[15] and along the mainstem.[16] However, there has been no enforcement to provide this water for environmental purposes. Both problems described in this section, over-allocation of water and no environmental flow policy, are a common problematic mentioned for the interviewees, as shown in the following sections.

Together, detailed case study analysis and semi-structures interviews, and hydrological data analysis on environmental flows and historic water demands, are the methodological tools that we have used in order to deciphering present and future dynamics and processes of transboundary water allocation between the US and Mexico.

III. Findings

A) A binational water regime that has been in force since 1944

The main component of the institutional framework of the current water allocation regime in the RGB Basin is based on the enacted agreements, treaties and compacts that have been agreed by the US and Mexico to allocate transboundary water resources. As a whole, these documents represent a set of institutions that translate into a set of formal rules regulating stakeholder behavior by facilitating cooperation[17]. In the case of agreements and treaties, federal states are the concerned stakeholders; while federated states have a stake on the compacts. These institutions across the RGB Basin regulate the system and provide a platform to manage the problems that result from the interdependencies between stakeholders[18]. The institutional framework in the RGB Basin is composed by two federated states compacts (the Rio Grande Compact and the Rio Pecos Compact), and two binational agreements (the Convention of 1906, and the Treaty of 1944). The aggregated institutional framework aims to regulate, control, and manage groundwater allocation among the signatories.

A brief description of each institution is given chronologically. The *Convention between the United States and Mexico providing for the equitable distribution of the waters of the Rio Grande for irrigation purposes (Convention of 1906)* is an institution on the amount of water that must be delivered by the US to Mexico for the sole purpose of irrigation. The 1906 Convention envisions the equitable distribution of surface waters of the Rio Grande watershed, within the international segment of the river located between the El Paso-Ciudad Juárez and Fort Quitman.[19] The U.S. must deliver a total of 60,000 acre-feet/year (74 million m^3/year) to Mexico at the diversion point called Acequia Madre, located close to Ciudad Juárez, Mexico.

The second instrument and water allocation framework is the *Rio Grande Compact*. Signed in 1929 and revised in 1939, provides for the equitable sharing of the Rio Grande surface waters between the US states of Colorado, New Mexico and Texas. Within this institution, the three US states agree on the amount of water to which they are entitled on the RG section ensuring that Mexico water is completely allocated. In the transboundary region, the Rio Grande Compact is designed to permit an average normal release from Elephant Butte Reservoir of 790,000 acre-feet per year. This release is for irrigation purposes in the Rio Grande Project in New Mexico and Texas, as well as the 60,000 acre-feet delivered to Mexico under the 1906 Convention framework.[20] The Rio Grande Compact provides for debts and credits to be carried over from year to year until relinquished under the provisions of this agreement.[21]

The third institution is the 1944 Treaty. In 1944, the US and Mexico agreed on sharing surface waters in the border section of the Rio Grande/Río Bravo. The 1944 Treaty allocates water within the international segment of the Rio Grande downstream of Fort Quitman, Texas to the Gulf of Mexico. This Treaty authorized the construction and operation of two reservoirs, Amistad and Falcon, along the mainstem of the RGB. It allocates one-third of the water reaching the RGB mainstem from 6 tributaries originating in Mexico to the U.S. and two-thirds to Mexico. The third shall not be less than 350,000 acre-feet/year (432 million m^3/year), calculated as an average over a treaty cycle of five consecutive years[22]. Besides, the 1944 Treaty has been considered as fairly successful in carrying out its mandate of policing allocation of shared water resources between the US and Mexico.[23] The Treaty also has favor the implementation of the Commission as a binational organization with specific mandates on shared water resources.[24]

Finally, water of the Pecos River, the largest U.S. tributary of the RGB, is allocated between New Mexico and Texas through the Pecos River Compact.[25] Its purpose is to promote inter-state collaboration and remove the causes of current and future water resources controversies. Both Compacts, the Rio Grande and the Pecos River, aim to promote development within US states and facilitate the construction of infrastructure for the recovery of water, its effective use, and protection against floods.[26]

The, the two binational institutions between the US and Mexico (the 1906 Convention and the 1944 Treaty), cover different basins and are quantitatively based groundwater resources sharing. The 1906 Convention applies to the Upper Rio Grande from Colorado to Fort Quitman where the U.S. sovereignty over surface waters is recognized, and management of these waters corresponds to the state federated appropriation system; and the 1944 Treaty applies to the Lower Rio Grande downstream Fort Quitman. Surface waters sharing regulation was inexistent until the signing of this treaty in 1944. Moreover, there is no agreement for the joint or binational management of shared aquifers.[27] But that is not all, the content of the aforementioned documents lack awareness of sound environmental practices, which must be addressed in order to face current sustainable river basin challenges. **Figure 5** shows the four institutions regulating water resources in the RGB Basin.

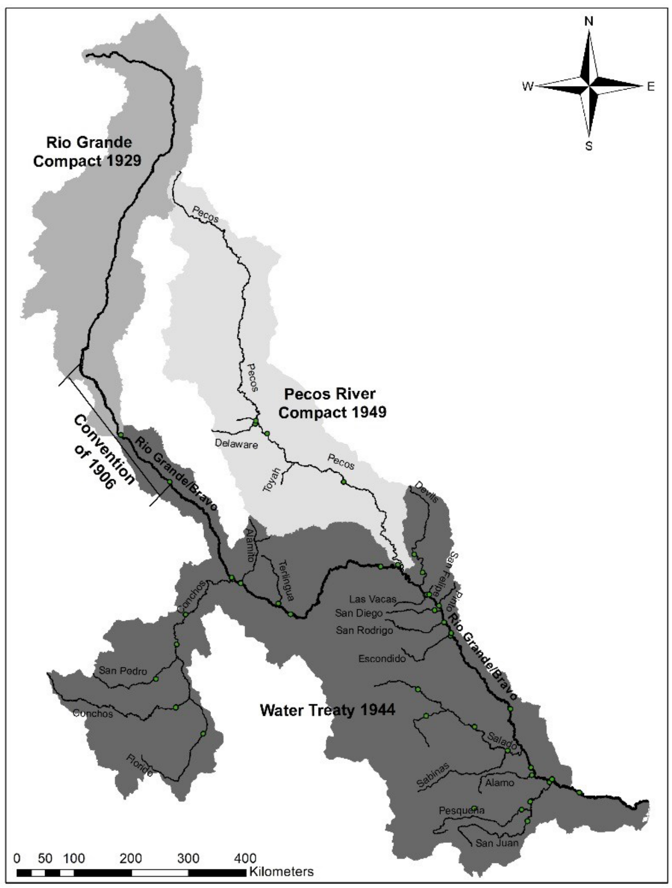

Figure 5. The institutions regulating water resources in the RGB Basin

RGB Basin factual background

The RGB river system is an essential source of fresh water for more than 13 million people living in the southwest of the United States and the north of Mexico.[28] From Colorado and to the Gulf of the Mexico, the river flows through primarily arid environments which, over time, have been appropriate and hydraulically developed for economic activities. Surface waters are distributed to a multitude of users. Their main use has always been irrigation in order to enhance the desert and to make it habitable and productive. However, today, the water uses of the river exceeds its natural water availability; its utilization accentuates the fragility of its environmental condition and bring to light the water management approaches, the water uses and the normative sharing of water resources.

The RGB Basin is characterized by a low level of storm rainfall and a high concentration of pollutants. Its climate is dry, and the regions that it drains are characterized by a semi-arid climate. Over time, moisture regime of the RGB Basin has been severely damaged due to the development of infrastructures intended primarily for irrigation and the quantitative sharing of the resource. The number of facilities for irrigation and municipal water supply have increased quickly without real coordination between the drained territory, and the users and uses of water.[29]

Both, water quantity and water quality, are a problem in this basin. Higher water demands for irrigation and drinking water in the US and in Mexico, and prolonged drought are causing a deterioration of the quality of available water.[30] The presence of metals and pesticides, phosphate and nitrate, as well as mercury and aluminum, has been identified sporadically throughout the RGB Basin. Nutrient levels are also elevated in the RGB Basin. The basin is also characterized by a constant level of salinity, a significant level of turbidity, and low levels of oxygen. High fecal coliform densities are found in RGB downstream of major cities located along the border between the US and Mexico because of the Texas waste treatment facilities, and untreated sewage in Mexico. Chloride, sulphate, and concentrations of dissolved solids are also multiplying in the basin due to the repeated use of water for irrigation, especially in the western part of the basin in Texas.

Due to environmental alterations and the progressive degradation of the basin, quantitative terms of water sharing becomes more and more difficult to accomplish. Stakeholders must cope with these crises and try to respond to the normative requirements of water-sharing. Quantitative water allocation accentuate the environmental degradation of the river system, given the stress exerted on the availability of the resource and the environmental balance of the watershed. This represents an institutional challenge which federal governments and riparian federated states must face to ensure the amounts of water and to preserve the environment.[31] Stakeholders are therefore called upon to coordinate their actions with the aim of dealing with challenges posed by water scarcity, sustainable use of the water resource in the basin, and the perennial institutional water allocation framework.

B) Water allocation regime and its perennial term without adapting to current changes in natural conditions

A recent analysis[32] shows that the water availability (7,343 million m^3/year) is about the same as the water uses and evaporation (7,358 million m^3/year) in the basin. Currently, there is no water available for any other use, including the environment. In fact, there is a lot of competition for this scarce and highly valued resource in the RGB.

All those interviewed in this assessment agreed with water resources importance and vulnerability in an arid context. Interviewees argued that water is magic when living in a desert but its availability influences the equitable water sharing among all users and makes its sustainability harder. People interviewed recognize that the environment needs more water but with the current water sharing terms and all water uses, sometimes that's not that simple. In fact, under the 1944 Treaty, all the water is appropriated and allocated to the federal and federated states. Full allocation of water resources defies any attempt at sustainability on the river system.

The RG/RB Basin is highly managed, highly developed, and over appropriated. The dams and the way water is managed have completely changed the dynamics of the hydrology. Because of the system of dams, the river goes dry. A clear example are the very different rivers above and below Elephant Butte Dam. Above Elephant Butte Dam, the Middle Rio Grande is still gorgeous. Down from Elephant Butte Dam, the River is nothing but a modified channel. Moreover, if the river goes dry, it is because all of its water belongs to somebody and is being allocated to someone, but not the environment. The remaining question is then what would be a sustainable use and an allocation system in the RGB Basin.

About sustainable development in the RGB Basin, those interviewed do not find an agreement on what is sustainable and how sustainability should be promoted across the basin. For some, it is very difficult to talk about sustainability and to make it operational. Some others will avoid using the notion of sustainability because it’s very ambiguous and doesn’t have a stationary definition. Instead, they would prefer to refer to a very specific issue, for example, preventing long term declining ground water wells and modifying agricultural production. In this regard, participants consider that growing cotton and alfalfa in the RGB is not ecological-based because of their high consumption of water.

Interviews show that sustainable development depends on its implementation and on its range of practical possibilities. In the RGB, sustainable development implies a set of *ad hoc* approaches to tackle regional and local issues. The river basin is so big that it requires separately application of specific actions to solve one-off problems. Nevertheless, drought and over use of ground water are considered as the two major issues defying sustainability in the river basin.

Despite the importance of such context, different interviewees placed greater emphasis on the persistent 1944 Water Treaty. The 1944 Water Treaty is recognized as an effective allocation water resources instrument between the US and Mexico. Within its framework, both countries measure exactly how many cubic meters of water are being transferred over to the United States and to Mexico. However, this instrument does not comprise any sustainable or environmental concern. The reason for this could be that the notion of sustainable development did not come up in when water allocation was defined among these two countries. Sustainable development is in fact a modern term, and in spite of facing higher water demands, lower water availability, and consequently water quality degradation, the 1944 Water Treaty has not being updated since its entry into force seventy-one years ago.

In fact, experts interviewed pointed out that political will to revisiting the 1944 Treaty is null and void. According to them, the US is not interested in and Mexico has never requested to make any changes. In parallel, immigration, drugs tracking, border security have now become interconnected issues that prevent both countries to expand the binational agreement on water resources allocation to some other areas. In this regard, binational gains in trust, derived from the 1944 Water Treaty, have been very small.

C) The system is imperfect due to a lack of consideration of environmental, economic and socio-political aspects.

Despite the fact that the US – Mexico water regime has given good results in terms of water allocation; the system is imperfect due to a lack of consideration of environmental, economic and socio-political aspects. First at all, water allocation regime responds to economic and societal objectives which date of the year 1944. These priorities have not been modified since affecting potential benefits for improving the environment. For instance, it has been scientifically proved that it is possible to improve water supply for environmental purposes while not affecting (or even improved) water supply for other water users, such as agriculture.[33] However, the fixed water allocation regime does not allow the inclusion of these policies because the system does not respond to today's societal objectives.

Second, the current RGB Basin water allocation regime is imperfect due to a lack of consideration of environmental, economic and socio-political aspects. In fact, drought and groundwater management might be the most important challenges to be faced by the U.S. and Mexico policymakers and all stakeholders. Projections of drought suggest that at the end of the century, Mexico will experience extreme drought and U.S. will also experience some important droughts. Droughts similar in extent to the *Dust Bowl* are very likely to frequently occur.[34] In this concern, some regions of the shared rivers are almost always experiencing drought at some level. Drought management will continue to be incomplete and inefficient until the term of "extraordinary drought" included in the 1944 Treaty is clearly defined for both, the Rio Grande and the Colorado River. The vagueness of extraordinary drought is in fact, the most important failure of the 1944 Water Treaty.[35]

Third, groundwater along the U. S. and Mexico border is both scarce and necessary. However no legal binational agreement addresses allocation of these resources[36]. The challenge related to groundwater is to develop studies on its recharge, watershed mapping, and aquifer formations[37], and on equitable apportionment of shared aquifers.[38] In fact, in 2006 the U.S. Congress approved a bill to foster hydrogeological characterization, mapping, and modeling program for priority transboundary aquifers in U.S. - Mexico border region. The purpose is to identify priority aquifers for assessment based on technical and political criteria. The Transboundary Aquifer Assessment Bill led by the U.S. Geological Survey has authorized a total amount of 50 million USD over ten years to conduct program activities, including the binational collection and exchange of scientific data. The total amount includes funding to Mexico. This initiative is essential to come to a binational agreement on transboundary groundwater. IBWC plays an important role on this project since it is the agency responsible for coordination data collection in Mexico.[39]

Despite this binational effort, the U.S. – Mexico border faces some socio-political challenges. Illegal immigration, drug trafficking, and high crime rates occurring along the border attempt at cooperation to ameliorate the management of the constantly shifting border demarked by the meandering rivers.[40] This situation represents a concern for policymakers on both sides of the border, who also need to foster research on water resources through interdisciplinary expertise in order to bring together natural and social sciences, and to develop scenario planning.

And last but not least, consideration of the most important drivers' forces (socio-political and economic) of the shared water system and climate uncertainties are both an essential challenge in transboundary water resources management between the US and Mexico.

Moving toward sustainability in transboundary water management regime will enable the U.S. and Mexico to alleviate water resources allocation and enhance shared waters sustainability, and will reflect binational political will to deal more effectively with water border issues. Fostering sustainability is an opportunity to allocate and manage water resources in a more equitable and reasonable manner, and to cooperate on building binational institutional capacity.

IV. Conclusions

The transboundary water regime reflects a *lock in* situation that is blocking changes toward new binational water management practices. There are three main issues, currently and in the future, related with the success or failure of the water management in the RGB. First, the problem of over allocation of water rights, there is simply no more surface water available for any other consumptive water use, there is no room for error in this area. As a consequence, every user is trying to maximize its allotment, however, non-consumptive uses, such as environmental flows, are just simply not considered because of the misconception that water for the environment consumes water, which is not, it is only used to provide habitat when the water is moved from upstream to downstream reservoirs. Second, environmental flows, there is no legal framework for protecting/restoring the environment through environmental flows. This make really difficult its discussion and implementation. Third, groundwater availability and use, there is no good understanding of groundwater resources and the way these are used and in some part of the basin over drafted. There is a need for a coordinated groundwater management from both countries, and well as an integrated water resources management of surface water and groundwater resources in the basin.

Moreover, transboundary water resources regime between the US and Mexico is facing increasing uncertainty and vulnerability due to drought conditions and socio-economic development. Institutions and agencies, currently working on any domain related to water resources need to adapt in order to deal with climate change conditions and human and environmental water demands. It is important to raise the importance of shared waters binational cooperation in order to foster environmental protection, promote sustainable water utilization, and to secure water across the river basin. With this aim, the US/Mexico transboundary water regime can be enhanced and optimized if data collection, information gathering and transparency are improved in order to prepare for drought events, and foster, eventually, the creation of a binational water market and a water bank to improve water uses and allocation, and to promote environmental conservation across the RGB Basin.

In closing, to dissolve binational imperfection and institutional persistence paths, the US and Mexico are urged to expand the scope of the 1944 Water Treaty, to increase the US and Mexico water use efficiency, and to reach an agreement on binational protection[41] and conservation of the river basin through better water resources allocation, environmental flows allocation process, and reduction of environmental damage to river system.

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