Dynamics of Transboundary Ground Water Management: Lessons from North America

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Abstract

Transboundary ground water management in the North American countries of Canada, the United States of America, and Mexico is truly dynamic. Institutions such as the International Boundary and Water Commission (U.S.-Mexico) and the International Joint Commission (U.S.-Canada) were originally established to consider surface water. However, they have been adapted to consider ground water, and the North American Free Trade Agreement, implemented in 1994, may prove to be applicable to ground water, although in some cases may eventually prove inimical to the interests of border regions as the three countries attempt to manage their transboundary ground water resources. These institutions, coupled with the *ad hoc* approach of individual stakeholder groups, illustrate that transboundary ground water management is functioning quite well in North America. Eight case studies, involving both water quality and quantity, illustrate our premise. Seven of the studies describe very specific issues; the final one involves the ground water resources of the Great Lakes basin of the U.S. and Canada, and provides a brief discussion of some of the issues that might arise in this region.

1 Introduction

Our working hypothesis is that the degree to which governance is successful depends upon several essential elements. The first three of these, described as a trialogue, are effective scientific, governmental, and societal processes. But successful governance also requires not only the aforementioned elements but also effective interfaces among the three elements.

We will explore the postulated hypothesis in the context of transboundary ground water management in North America – Canada, the United States (U.S.), and Mexico (Figure 1). Insofar as this paper is concerned, “transboundary” is synonymous with “transnational”; we will not explore transboundary ground water issues within a single nation *unless* it has bearing on transnational issues.

Although all three countries are developed, Canada and the U.S. are more so than Mexico. Similarly, although Mexico is a democracy, it is not quite as mature as its two North American partners. If we assume that good governance and its essential elements are necessary for effective transboundary ground water management, then we would expect that North America would offer excellent examples of said management. The International Joint Commission (IJC) and International Boundary and Water Commission (IBWC) are two international institutions that provide the means for the countries to communicate and resolve problems based on both scientific findings and political compromises. The societal process is also a factor in the international arena, typically initiating the political process that leads to the involvement of the IJC or the IBWC, or creating a cooperative, transboundary interest group that addresses the issue before it reaches higher levels of government. These actions illustrate the presence of a society-government interface—societal processes can lead to involvement by the government. As we shall see, however, transboundary ground water management in the three countries is more of an *ad hoc* proposition due to the presence of, and relationship among, the government, scientific, and societal processes.

Fig. 1. Map of North America (U.S. CIA 2005).

2 International Laws and Institutions

2.1 The Boundary Waters Treaty of 1909 and the International Joint Commission

Transboundary water conflicts between the U.S. and Canada can occur all along the 8,000-kilometer border (Carroll 1986) (Figure 2). Rules concerning transboundary waters were created almost one hundred years ago with the signing of the Boundary Waters Treaty (BWT) of 1909.[1] This treaty created the International Joint Commission (IJC)[2] in Article IV of the BWT which is involved in administrative, quasi-judicial, arbitral, and investigative aspects of conflicts (Carroll 1983). This mature government process includes scientific investigations into one country's impact on the water in another country and illustrates the results of an effective interface between government and science. However, this government-science interface is not always appropriately balanced.

The inclusion of the Harmon Doctrine in Article II of the treaty has specific implications for the permissibility of the actions or plans of each country depending upon whether water flows to or from the country and can outweigh the scientific considerations of a country's actions. The Harmon Doctrine "…gives the upstream state exclusive control over the use of all waters on its own side of the line…[h]owever, the article [also]…gives…injured downstream interests rights to legal remedies equivalent to those in effect domestically (p. 43)" (Carroll 1983). This is important because it increases the power of the upstream state and can incite conflict where the upstream state wants to engage in development and the downstream state wants to preserve environmental values. The interface is unbalanced because there is

[1]A copy of the treaty can be found on the International Joint Commission's website <http://www.ijc.org/rel/agree/water.html>. For a description of the waters covered by the Boundary Waters Treaty, refer to Carroll (1983 p. 42). A summary of the principles outlined by the treaty is provided by LeMarquand (1986 p. 233).

[2] IJC (1997) provides a good introduction into the IJC's role in U.S.-Canada water issues.

Fig. 2. Map of U.S.-Canada border region. The United States is in green and Canada is in blue; The Great Lakes are between the province of Ontario and the USA. (created by authors using ArcGIS).

always greater value attached to the scientific results of the upstream country that wants to engage in development due to the underlying government process.

There is also a society-government interface present when stakeholder groups initiate government involvement that leads to involvement by the IJC. The IJC's power is limited to the role the governments want it to play—both governments must agree to request the IJC's intervention (Carroll 1983). This can lead to an unbalanced interface when one country's stakeholders fail to persuade its government to bring the issue to the IJC for resolution; the government processes are more powerful than the societal processes.

The absence of ground water from the treaty and the IJC's jurisdiction is a real issue. However, as Everts (1991) explains, there is a way that the IJC can include ground water in its deliberations in certain situations:

> …the IJC has no legal mandate to investigate and make recommendations on groundwater issues which are isolated from possible impacts on surface waters, unless both countries stipulate that the IJC may do so. However, the legal loophole utilized by the IJC to bypass the legal mandate issue in conducting groundwater impact studies in the Flathead River Basin could be the possible adverse effects that polluted groundwater might have on surface waters. By linking polluted groundwater as a possible cause to surface water degradation across the border, the IJC would not overstep its legal mandate under the BWT [Boundary Waters Treaty], but would be legally pressed to investigate the source of the degradation [Emphasis in Original] (p. 73-74).

This means that both countries must cooperate in order for ground water issues to be addressed. This has been done on a smaller scale, province to state, for the Abbotsford-Sumas Aquifer underlying Washington, U.S., and British Columbia, Canada.

Past water issues between Canada and the U.S. have set precedents for resolving future disagreements.[3] Schwartz (2000) discusses how current issues are "firmly rooted in historical precedents," and how the issues do not disappear, even after they are resolved. Even issues that result in a signed agreement on how to manage the resource, such as the Columbia River Treaty, have an expiration date and must be renegotiated. Both the Columbia River Treaty and the IJC's role in the Great Lakes highlight the successes of the IJC and the cooperation between the two countries.[4] The cooperation surrounding the Great Lakes is an example of continuous management of the water resource. "The initial emphasis was on navigation, switching later to hydroelectric power, and then to water quality (p. 204)" (Sweel et al. 1986). To update this chain of issues, it would be necessary to add water quantity in terms of water exports as well as ground water use (Schindler and Hurley 2004; Galloway and Pentland 2005). The IJC is an important institution that has the potential to be officially extended to transboundary ground water issues that arise along the U.S.-Canada border. The International Boundary and Water Commission plays a similar role along the U.S.-Mexico border.

2.2 International Boundary and Water Commission (U.S.-Mexico)

The U.S. and Mexico share an international border of 3,110 kilometers with river boundaries making up around 66% of the border (Figure 3). The Rio Grande/Rio Bravo borders the U.S. state of Texas and the Mexican states of Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas for 2,020 kilometers. The Colorado River separates Arizona, U.S., and Sonora, Mexico for 27 kilometers of the international border. The international border between both countries was first established by the Treaty of Guadalupe Hidalgo in 1848, just prior to the end of the Mexican War.

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[3] Carroll (1983) provides an excellent description of the major issues of concern up to 1983. It covers the High Ross Dam-Skagit River, Champlain-Richelieu, Chicago Diversion, Cabin Creek, Garrison Diversion, Poplar River, Columbia River, and St. Mary and Milk Rivers issues.

[4] IJC (1997) includes succinct summaries about the issues and the IJC's role in the solution for the High Ross Dam-Skagit River, the Garrison Diversion, the Columbia River, the St. Croix River, the Flathead River (Cabin Creek), and the Milk and St. Mary Rivers.

The first border water issues dealt with the location of the international boundary. The Convention of November 12, 1884 was adopted to help deal with the ever-changing international boundary as a result of meandering by the Rio Grande and Colorado River (IBWC 1884). Five years later, the International Boundary Commission was created in 1889 (changed to the International Boundary and Water Commission (IBWC) in 1944) to specifically deal with boundary and water issues (IBWC, 2005). The IBWC is also a mature governmental process that incorporates both scientific and societal processes into its decisions and actions.

Water use for irrigation was important to both countries and controversies surfaced in the late 1800s and early 1900s about the equitable distribution of water. The Convention of May 21, 1906 was the first treaty regarding water quantity and stated that the U.S. must deliver 74 million cubic meters (MCM) per year to Mexico via the Rio Grande (IBWC 1906). The 1944 Treaty was more comprehensive and laid out specific actions that each country must take to reduce water sharing conflicts (IBWC 1944).

Water quality issues were addressed through the passage of “Minutes” or legally binding agreements between both countries. Specifically, water quality minutes addressed salinity from irrigation return flows and wastewater treatment plants on both sides of the border (IBWC 2005a; IBWC 2005b). Mexico’s farmers (stakeholders) were being affected by the poor water quality and the subsequent societal pressures led to scientific investigations and a permanent decision by the IBWC. In the steps to resolving the issue, there is again a slight imbalance within the three interfaces because the three processes are used at different points in time and do not carry equal weight. However, as with the IJC, all three are intertwined and the use of at least government and scientific processes are necessary for an issue to be resolved.

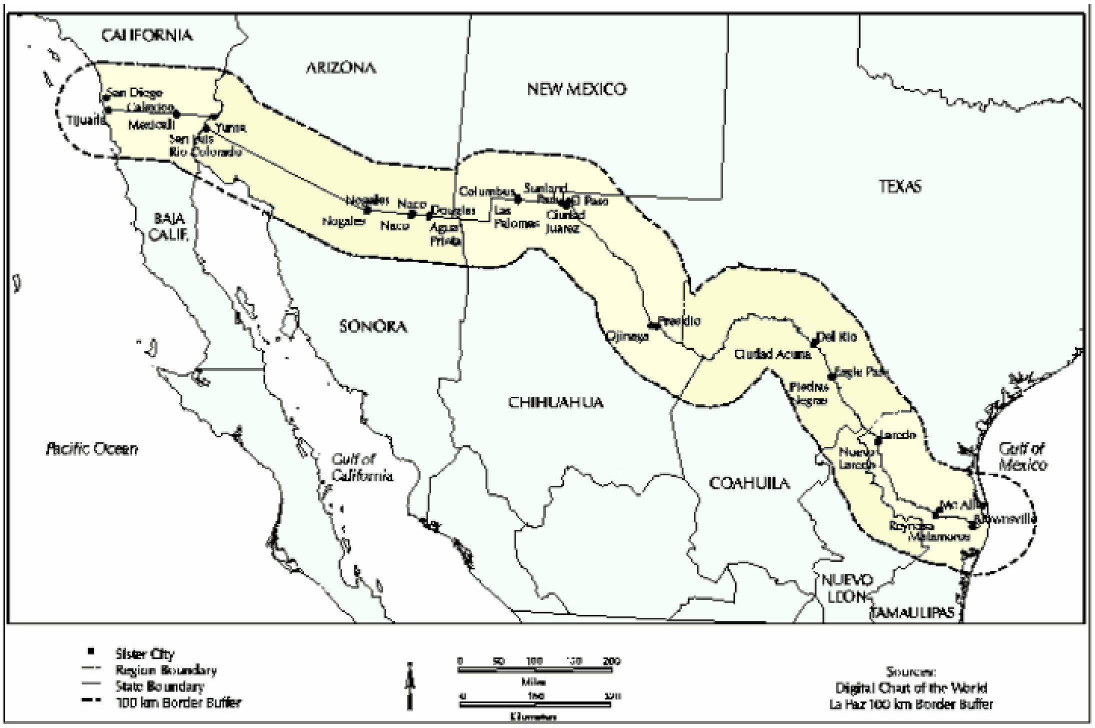

Fig. 3. Map of U.S.-Mexico border region (USGS n.d.).

2.3 North American Free Trade Agreement (NAFTA)

In 1994, the North American Free Trade Agreement (NAFTA) was adopted by Canada, Mexico, and the U.S. as a way of cooperating on trade issues. This agreement among the three countries essentially removed tariffs to facilitate increased trading which would lead to greater economic opportunities for all countries involved.

The successful passage of the 1992 constitutional amendment that allowed for increased water privatization paved the way for Mexican participation in NAFTA, as it was necessary for the government to let the private sector have some sort of autonomy to stimulate investment (Castro, 2004). However, the citizenry is cautious about these moves because of real and potential abuse by private companies. If the government decides it would rather let the market operate in the realm of water supply, it must actively enforce its own regulations to the benefit of its citizenry and the environment. If the government looks the other way and allows abuses, such as those alleged by urban water customers, then it might cause conflict if it does not act to regulate over-pumping of border aquifers and discharge of pollutants into streams and aquifers. The balance among government, societal, and scientific processes is vital to the success of applying NAFTA to ground water resources. Due to NAFTA's economic emphasis, it would be easy to make decisions which do not include the scientific process and only address some of society's concerns. The presence of balanced government-science and science-society interfaces is necessary to restrain NAFTA's influence.

The parts of Mexico that stood to benefit the most from NAFTA are the states that border the U.S. Any U.S. or Canadian corporation could open a factory on the Mexico side and benefit financially from cheaper labor costs. 'Maquiladoras' (foreign-owned manufacturing facilities) had already been operating in Mexico since the 1960s, but they were required to take manufacturing wastes back into the country of origin. After the passage of NAFTA, the wastes could remain in Mexico. Given the differing environmental standards, many believed that the border area would become a dumping ground for U.S. companies who wanted a cheaper way to dispose of manufacturing wastes. However, the adoption of treaties and subsequent 'Minutes' have attempted to regulate these practices. This is an example using the government-science interface to restrain the economic emphasis of NAFTA.

3 International Transboundary Ground Water

3.1 Abbotsford-Sumas Aquifer

The Abbotsford-Sumas Aquifer (Figure 4), in the Fraser River Basin, underlies British Columbia (Canada) and Washington State (U.S.); its water flows southward from Canada to the U.S. The aquifer is unconfined and provides water for over 115,000 people (Mitchell et al. 2003; Cox and Liebscher 1999). The current concern is the high concentration of nitrate in the aquifer from agricultural practices in both British Columbia and Washington (Washington State Dept. of Ecology 2003; Mitchell et al. 2003). The presence of the Abbotsford-Sumas Aquifer International Task Force demonstrates the presence of cooperation (A-S Task Force, n.d.). This task force is the product of the 1992 Environmental Cooperation Agreement between the province and state and was created specifically to address transboundary problems concerning the aquifer (A-S Task Force, n.d.). The agreement covers the broad area of "ground water protection" which can be expanded to include future issues. There is a trialogue present in this ground water basin that uses all six of the elements and is illustrated by the example of the proposal to create Aldergrove Lake Regional Park.

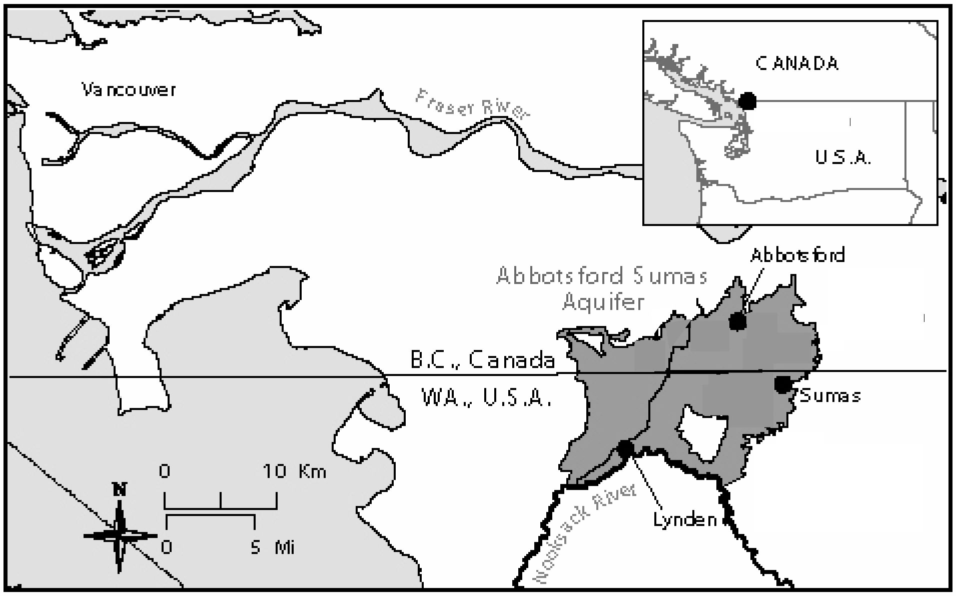

Fig. 4. Map of Abbotsford-Sumas Aquifer (Mitchell et al. 2005). Reprinted with permission.

A recent example of small-scale cooperation surrounding the protection of the aquifer is British Columbia’s proposal to reclaim a gravel pit and transform it into Aldergrove Lake Regional Park, which would use biosolids and biosolids compost to re-vegetate the area (Van Ham et al. 2000). The public on both sides of the border was concerned about the effects that biosolids would have on the aquifer’s water quality in general and specifically for regions of the aquifer that people rely on for their drinking water (Van Ham et al. 2000). In order to allay people’s fears, open meetings were held and stakeholders (elected officials, Abbotsford-Sumas Aquifer International Task Force, residents within a one-kilometer radius of the park, and local and U.S. interest groups) were informed about the project (Van Ham et al. 2000). The project, which was shown to potentially improve the aquifer’s water quality, was approved and demonstrates how open cooperation from the beginning of a project led to success. This open cooperation included government (the task force), societal (the initial concern and subsequent meetings), and scientific (the study on the impact of biosolids on the aquifer’s water quality) processes. In this case, the interfaces in the trialogue were balanced—everyone was satisfied with the outcome and no element was used in isolation or at the expense of another element.

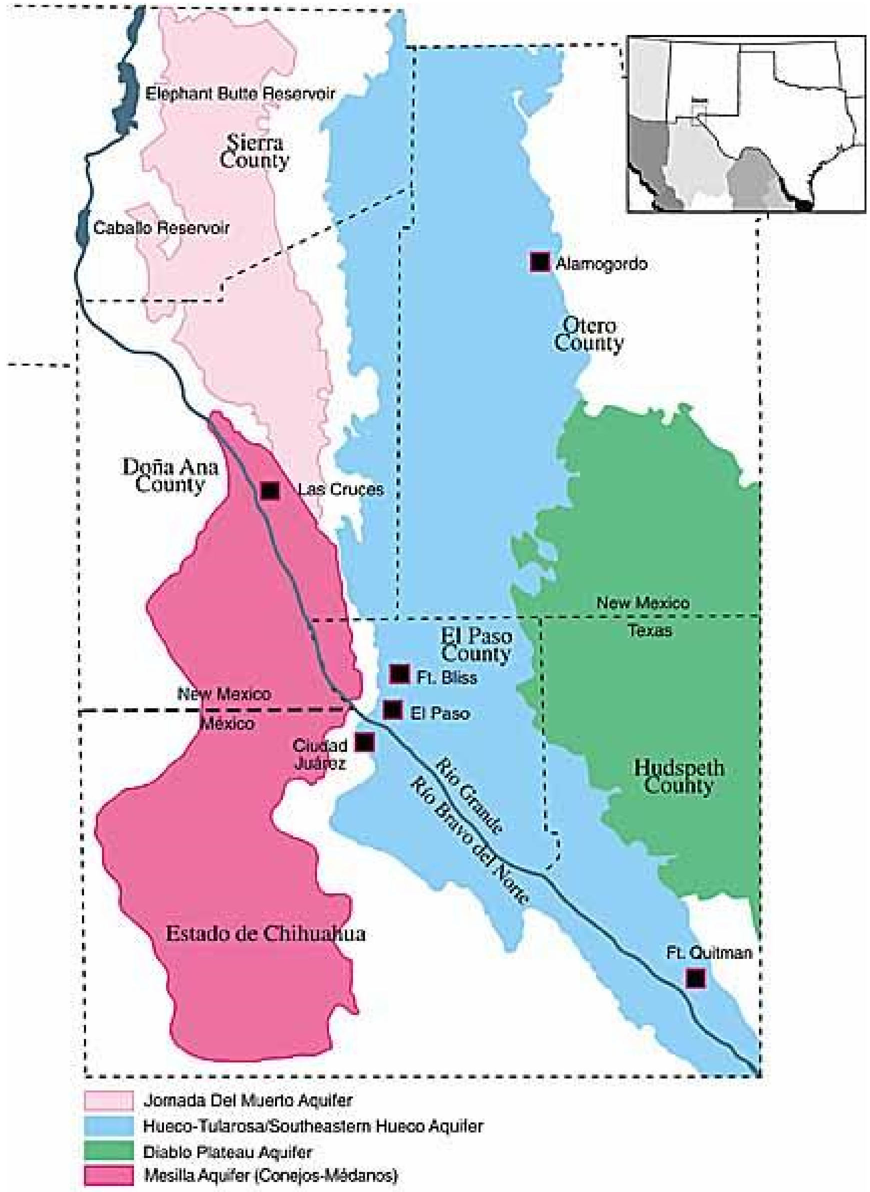

Fig. 5. Map of the Hueco Bolson and Mesilla Bolson Aquifers (McHugh 2005). Reprinted with permission.

3.2 Hueco Bolson and Mesilla Bolson Aquifers

The Mesilla and Hueco Bolsons are transboundary aquifers that span the U.S. states of New Mexico and Texas and the Mexican state of Chihuahua (Figure 5). The growing cities of El Paso (Texas) and Ciudad Juarez (Chihuahua), located adjacent to each other along the U.S.-Mexico border, use water from these aquifers and from the hydrologically-connected Rio Grande/Rio Bravo. The sharing of Rio Grande waters is addressed in the 1906 Convention and 1944 Treaty between the U.S. and Mexico; however, there has been no agreement about the sharing of the underlying transboundary aquifers.

Extensive pumping of the aquifers has led to large declines in the water table on both sides of the border. El Paso relies both on surface water from the Rio Grande and ground water. Ciudad Juarez relies primarily on ground water. The City of El Paso implemented a 40-year water plan in 2000 to help ensure future supplies. Ciudad Juarez, on the other hand, does not have a formal plan to deal with increasing demand (Chaves 2000).

Agricultural water use of the Rio Grande/Rio Bravo has degraded surface and ground water quality by increasing salinity. The saline waters seep into the ground, recharging both aquifers and increasing ground water salinity. Conversely, saline water from the shallow aquifer recharges the Rio Grande via irrigation drains (Walton and Olmacher n.d.). Due to these water quality and potential water quantity issues, a bill has been introduced in the U.S. Senate that will appropriate money to study the transboundary aquifers (Senate Bill 214 2005), which, if passed, may help prevent conflict and lead to future water sharing agreements.

The precursor to this bill was a joint effort by the U.S. and Mexico to create a ground water database for the El Paso-Ciudad Juarez area. The title of the work is ‘Transboundary Aquifers and Binational Ground Water Database.’ In 1998, studies completed on both sides of the border were brought into this database by the IBWC to help understand existing data gaps and make recommendations for future studies (IBWC 1998). This study is an example of cooperation of both countries by using government and scientific processes via the IBWC. Understanding the physical properties of the aquifers may minimize future conflict on both sides of the border since both cities will continue to grow and rely on the same source of water.

3.3 Nuclear Waste Sites

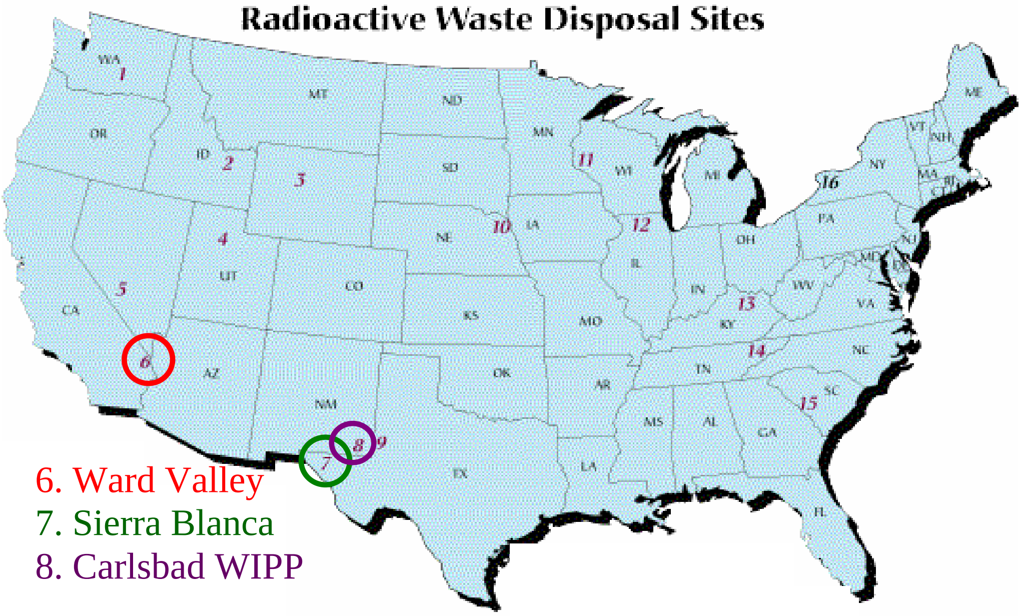

Fig. 6. Map of proposed and used nuclear waste sites (Woodard 1998). Reprinted with permission.

The issue of nuclear waste storage facility siting in the U.S. has created a great deal of tension between the U.S. and Mexico. In 1991, the U.S. state of Texas determined that a low-level nuclear waste repository would be built near the town of Sierra Blanca (Figure 6). This town is located approximately 25 kilometers north of the U.S.-Mexico border. The repository would store waste from Texas, and through an interstate agreement, low-level wastes from both Maine and Vermont (Boren 1997). Both U.S. and Mexican citizens heavily opposed this repository because it was to be located close to the international border in one of the most seismically active areas in Texas, right above an aquifer that discharges to the Rio Grande/Rio Bravo (Boren 1997).

Those within Mexico who opposed the repository used the 1983 La Paz agreement as an argument against it. They interpret the treaty as banning the siting of new pollution generating facilities. The U.S. Environmental Protection Agency (EPA) interpreted the agreement as requiring 'consultation and notification' (Boren 1997). In the end, the facility was not built in Sierra Blanca due to a lack of research into the geologic hazard and a lack of planning to understand the socioeconomic impacts to the 'surrounding community'.

Around the same time, a nuclear waste repository was proposed in Ward Valley, California (Figure 6). This site would have taken nuclear waste and placed it into dirt trenches above an aquifer that feeds the Colorado River. The proposed location of the repository was on U.S. Bureau of Land Management (BLM) land, adjacent to Indian tribal land. The potential for impacts to the Colorado River prompted Mexicans to join the tribes in opposing the repository (Greenaction 1999).

Out of the opposition came a group called the "Binational Coalition against Radioactive and Toxic Waste Dumps" that pressured lawmakers to amend the La Paz treaty to explicitly ban siting of nuclear waste facilities near the border. Also mentioned was that if the Sierra Blanca site was to be approved, the tribal and environmental groups would sue under the NAFTA environmental side agreement (Borderlines Updater 1998). These actions did not happen, but brought attention to the volatile issue of siting nuclear waste facilities near the international border.

One site that was on the radar, and did eventually open, was the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico (Figure 6). This site is located about 1.5 kilometers from the Pecos River, which eventually drains into the Rio Grande, shared by both the U.S. and Mexico.

Mexico is at a disadvantage because it is downstream of any proposed site that is hydraulically connected to a surface water source. In the case of Sierra Blanca and Ward Valley, public opposition was great enough to prevent the movement of wastes to these locations. However, the southwestern U.S. will continue to be looked at for long-term nuclear waste disposal due to favorable hydrologic conditions. The current science supports the government actions but there is always the possibility of future technical difficulties.

A case in point is the opening of the WIPP in southeastern New Mexico. This site could have the potential to contaminate water that eventually reaches Mexico. Because nuclear waste is hazardous thousands of years before it decays to innocuous levels, the potential negative effects of a failed repository make Mexico vulnerable to nuclear waste policy decisions made by the United States. However, the influence of the public opposition groups in the government decisions points to a very powerful societal process in decisions regarding nuclear waste disposal, no matter how the government entities interpret the agreements.

3.4 Hermosillo Basin

The Hermosillo Aquifer is located in the state of Sonora, Mexico (Figure 7). This aquifer does not straddle the U.S. and Mexico border. However, its use for agricultural production as a result of NAFTA has caused local conflict due to competing demands. This region typically grew crops for local consumption; however, after the removal of trade barriers, many higher valued fruits and vegetables replaced these traditional crops and are primarily shipped to the U.S. for consumption. The change in what was produced led to the consolidation of many farms in the region with larger farms controlling most of the acreage. The resulting shift in agricultural production has placed a strain on the coastal aquifer with sea-water intrusion threatening many wellfields (Rodriguez 2002; Steinich et. al. 1998). At the same time, the municipal government has decided to expand its industrial sector and needs water to do so. The government proposed pumping salt-water from coastal wells and desalting the water; however, this has created tension with the growers who hold the current monopoly over the coastal aquifer.

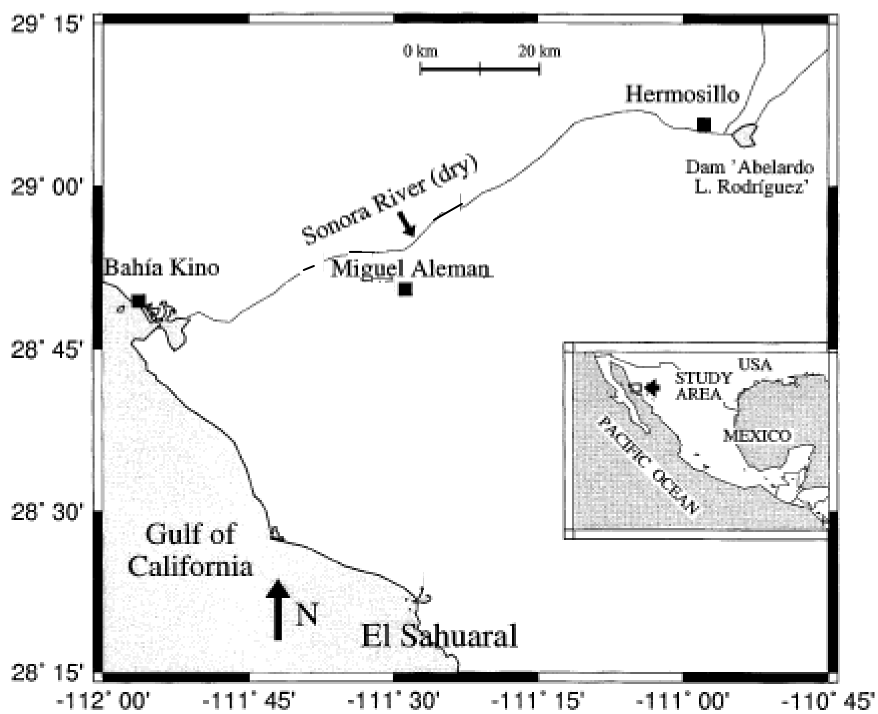

Fig. 7. Map of the Hermosillo basin (Steinich et al. 1998). Reprinted with permission.

This example shows the relationship among government, science, and society and how the decision will affect the different areas. This tension, as a partial result of trade between the U.S. and Mexico, leaves the aquifer vulnerable to over-exploitation and is a direct result of economic growth in the Hermosillo Valley. Any expansion can further reduce ground water quality by drawing in more sea water. The government will have to decide if the value of new industry outweighs existing agricultural exports, and it may be that a switch to a different industry has a positive effect on the aquifer but might bring in less money to the region.

The government knows the scientific and potential societal impacts of its decisions and must determine how to manage the aquifer in a “sustainable” manner so that the entire region does not suffer.

3.5 San Pedro River Basin

The Upper San Pedro basin is the location of a unique desert ecosystem that has international importance (Figure 8). The watershed originates in Sonora, Mexico, and water flows north across the international border into the U.S. state of Arizona; 1,900 square kilometers of the basin are located in Mexico and 4,500 are located within the U.S. (Arias 2000). Ground water in the basin flows from Mexico to the U.S. (Arias, 2000). This watershed has a large number of migratory birds that use the riparian area of the San Pedro River before continuing their journey. Due to the importance of this ecosystem, a portion of the riparian area in the U.S. has been given special status as the San Pedro Riparian National Conservation Area (SPRNCA). Current water use in the basin occurring on both sides of the border is for irrigation, mining, municipalities and domestic purposes. These uses are primarily satisfied by ground water pumping, which exceeds recharge by an estimated 6-12 million cubic meters (MCM) per year (Varady et. al. 2001).

This transboundary basin is the subject of a multi-national study spearheaded by the Commission on Environmental Cooperation (CEC), which is under the North American Agreement on Environmental Cooperation (NAAEC)—the environmental side-agreement to the North American Free Trade Agreement (NAFTA). The main purpose of this study is to determine the impacts of ground water pumping on riparian areas of the San Pedro River and devise a way to protect this migratory bird corridor (Varady et al. 2001). This area is undergoing large population growth, especially within the U.S., and is a case study for trying to balance environmental values with increasing human needs. What makes it more complicated is the transboundary nature of the basin.

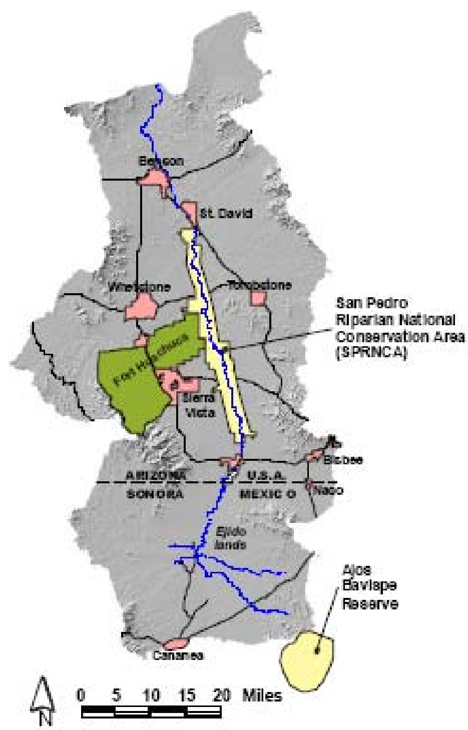

Fig. 8. Map of the San Pedro basin (Harris et al. 2001).

The CEC report proposed solutions based on ‘three categories of acceptability,’ with the first category, “Measures that are hydrologically effective and economically achievable,” (CEC 1999) proving to be the most controversial due to calls for reduction of irrigation on both sides of the border (Arias 2000). The CEC recognized that there are large data gaps on water use and aquifer properties on the Mexican side of the border, but believed that it should not stop conservation by both countries in order to protect the resource (CEC 1999).

The initiation of this CEC study created a great deal of conflict among groups in the U.S., as they felt that growth should not be restricted and irrigation should not be curtailed. Some of the largest U.S. water users besides irrigation include municipalities and a military base. On the Mexican side, the largest water user is a copper mine and there is not as great of an interest in protecting habitat for migratory birds as in the U.S. (CEC 1999).

No major decisions have been implemented as a result of this study, but it has helped stakeholders on both sides of the border understand the tradeoffs of protecting one ‘use’ of water for another and brought about bi-national communication and cooperation between local agencies and advocacy groups (Varady et. al. 2001). This study demonstrates the government-science interface: the findings of the scientific study have led to international cooperation. In addition, there is also the presence of a science-society interface because the science has informed citizens of the situation. The basis for the future decision will illuminate the balance between the three elements.

In order for any agreement regarding ground water to take place, the IBWC must be involved. It has been mentioned that the IBWC has been unwilling to apply Minute 242 (Varady et. al. 2001), which when written in 1973, called for consultation between both countries if ground water development in one country may ‘adversely affect the other country’ (IBWC 1973). Application of this Minute to any decision-making in the Upper San Pedro basin may cause conflict between both countries. Because Mexico is the upstream state, it holds an advantage over the U.S. in terms of water use. However, if U.S. groups that support riparian habitat by reducing ground water pumping advocate implementation of Minute 242, it may significantly reduce future development of ground water in Mexico. Minute 242 would apply differently to the U.S. because it is the downstream state and ground water use does not currently threaten Mexican supplies. However, if Mexico becomes more concerned about protecting riparian habitat and sees U.S. ground water pumping as a future threat, then it could argue for the application of Minute 242 to the detriment of the United States.

3.6 Santa Cruz River Basin

The border cities of Nogales, Arizona (U.S.) and Nogales, Sonora (Mexico) were the subject of a study completed by the Binational Technical Committee, headed by the Border Environment Cooperation Commission (BECC). This group, comprised of local, state and federal water agencies, developed a plan to mitigate wastewater runoff originating in Mexico and flowing into the U.S. (BECC 2004). The purpose of this project is to fix existing leaky wastewater pipes on the Mexican side, which will in turn improve water quality in the Nogales Wash that flows into the U.S. These actions used both government and scientific processes.

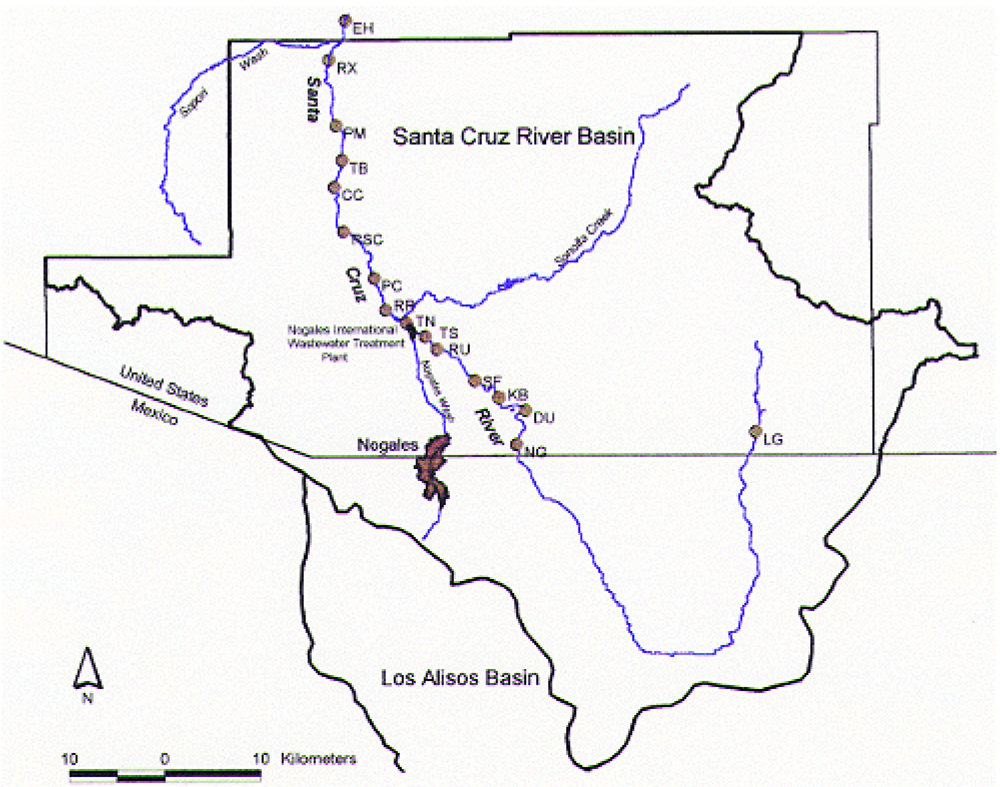

Fig. 9. Map of the Santa Cruz River basin (Patten et al. 2000). Reprinted with permission.

The project is jointly funded by the U.S. Environmental Protection Agency (EPA) and the Mexican government, and is an example of cooperation between both countries in response to deteriorating water quality on both sides of the border, and public health issues that arose due to the presence of untreated wastewater. This area was also the subject of the first binational ground water quality monitoring project between the two countries and set the stage fixing the wastewater leaks in Nogales, Sonora (Castaneda 1998).

Other aspects of this project, known as the 'Acuaferico Project,' will eventually bring more water to those on the Sonoran side by increasing ground water pumping (Walker and Pavlakovich-Kochi 2003). However, some in Arizona are worried that growing water use on the Sonoran side will lower water tables on the Arizona side, increasing pumping costs (Walker and Pavlakovich-Kochi 2003). The direction of water flow in the transboundary aquifer is from south to north, with those in Sonora having the ability to use water first before it flows across the international border (Figure 9). This places those in Nogales, Arizona, vulnerable to the increasing population in Nogales, Sonora, especially since there is no agreement on the apportionment of ground water. While government processes exist, an agreement would create more specific government processes in managing the transboundary ground water in the Santa Cruz River basin. In addition, concerns by citizens on ground water use may result in future societal processes playing a role in the management and instigating scientific studies on the impact of ground water use by each country on the water table levels. This basin has all the factors required to create a trialogue, but only a couple are currently in use.

3.7 Tijuana River Basin

A major water quality issue has existed for quite some time on the U.S.-Mexico border in the Tijuana basin. The Tijuana River originates in Mexico and flows across the international border into the city of San Diego, California (U.S.) (Figure 10). The river then discharges into the Pacific Ocean just south of Imperial Beach. Raw sewage had been dumped into the Tijuana River, which has led to closures of Imperial Beach due to health concerns. This created conflict between both countries that led to the 1997 installation of a wastewater treatment plant (WWTP) in the U.S. to treat municipal discharge before it enters the ocean (Sign On San Diego 2005a). However, effluent from this treatment plant does not meet U.S. water quality standards and led to a U.S. Federal Court order mandating construction of a new sewage treatment plant capable of treating wastewater to secondary standards, by 2006.

Fig. 10. Map of the Tijuana River basin (SDSU 2004). Reprinted with permission.

The South Bay International Wastewater Treatment Plant is currently undergoing a National Environmental Policy Act (NEPA) review and is in the Draft Environmental Impact Statement (DEIS) phase (Parsons 2004). This DEIS has an alternative that is in response to the court order that calls for construction of a new WWTP. The WWTP would be constructed in Mexico with effluent piped directly to the existing South Bay outfall. Even though this may alleviate the water quality issue near Imperial Beach, it does not entirely deal with the source of sewage since the WWTP will treat only wastewater transported by existing sewage infrastructure. New developments near the Tijuana River in Mexico have no sewer infrastructure and raw sewage can still affect the river and cause water quality concerns near Imperial Beach (Sign On San Diego 2005b).

One consequence of pollution in the Tijuana River is the impact to the underlying aquifer. Currently, Tijuana only uses about 5% of available ground water supplies and the quality is poor due to surface pollution and salt-water intrusion. At best, the aquifer could be used to augment existing surface water supplies or used to store treated wastewater for future use (U.S. EPA 2005). On the U.S. side, San Diego has plans to develop approximately 3.1 MCM of water from the San Diego Formation in the lower Tijuana River Valley (SDCWA 1997).

To help assist in the planning process, San Diego State University published an atlas of the Tijuana River watershed to allow decision-makers access to the same information (Sign On San Diego 2005b). The atlas was created through collaboration with universities and agencies on both sides of the border and will help those involved with the international watershed that deal with environmental issues ranging from water quality to ecosystems (SDSU 2005).

Currently, cooperation in the Tijuana River basin has led to efforts that have helped clean up surface water in the Tijuana River in Mexico and near Imperial Beach in the United States. With completion of the new WWTP, water quality near Imperial Beach will continue to improve, as sewage will be treated to secondary standards. One problem that remains is the lack of sewer connections on the Mexico side of the Tijuana River watershed. Unless new development is connected to a WWTP, there will be continued degradation of surface and ground water. At present, municipalities on both sides of the border rely primarily on surface water. However as population increases, municipalities may start relying on ground water. Unless pollution issues are dealt with, this source may not be available to either country.

This case study illustrates two components of a trialogue: government and science. The role of internal U.S. laws (federal water quality standards) and an atlas that reports scientific information about the basin contribute to cooperation and conflict resolution within the basin.

3.8 Great Lakes Basin

No treatment of transboundary ground water in North America is complete without at least some mention of the Great Lakes, which straddle the U.S.- Canada border (Figure 2). Although the Great Lakes represent the largest reservoir of liquid fresh surface water in the Western Hemisphere – almost 23,000 km^3 (Galloway and Pentland 2005) – little attention is paid to the ground water resources of the region, whose volume is approximately equal to that of Lake Michigan, 4168 km^3 (Grannemann et al. 2000). Despite the large amount of ground water in storage, ground water provides only about 5% of the total water use in the basin and relatively little is known of the quality and quantity of ground water in the Great Lakes region (IJC 2000). However, evidence indicates that ground water is an important component of the water balance of the Great Lakes, either directly as seepage into the lakes or indirectly as baseflow of streams which discharge into the lakes (Holtschlag and Nicholas 1998; Grannemann et al. 2000). Baseflow contributions to streams entering the lakes range from a low of under 20% on the Canadian side to about 42% to both Lakes Ontario and Huron. Low contributions in Canada are the result of less permeable ground water reservoirs (Holtschlag and Nicholas 1998). Lake level changes can effect changes in the ground water flow into/out of the lakes.

As mentioned in Section 2.1, the Boundary Waters Treaty is silent on the issue of ground water, although there is a way the IJC can consider ground water (Everts 1991). Certainly, the ground water resources of the Great Lakes basin will come under increasing scrutiny as the competition for water becomes more intense among the basin riparians – two Canadian provinces and eight U.S. states. Climate change may also affect water availability. In the case of water transfers outside the basin, all the aforementioned provinces and states must concur. Not only will there be quantity issues, but also water quality and ecosystem health issues. Galloway and Pentland (2005) suggested that, by 2050, a variety of issues – climate change, unfettered diversions, overuse, pollution - could mount to the point that the social and economic fabric of the region would be adversely affected. The problems may be daunting, but the potential for solving them in the context of the trialogue exists. Indeed, Great Lakes transboundary ground water issues may be the trialogue's ultimate test.

4 Summary

The majority of the examples presented demonstrate cooperation between two countries—they are voluntarily collaborating and using the institutions available to them in that region as well as creating new institutions to deal with specific problems and to work together more effectively. These institutions tend to incorporate a trialogue in identifying and resolving transboundary ground water issues. A task force was created for the Abbotsford-Sumas Aquifer to address water quality issues impacting both Canada and the U.S. Additionally, Mexico and the U.S. are funding a study to address water quality problems in the Santa Cruz River basin on the U.S.-Mexico border. The use of a trialogue creates relationship between the three elements; however, that interface relationship is not always balanced.

The IJC and the IBWC are both the products of bilateral treaties between the U.S. and Canada, and the U.S. and Mexico, respectively, but have different roles and powers over transboundary water resources. The IJC has limited power because it cannot become involved in disputes until both countries refer the matter to the Commission. Even then, the IJC acts as an information-gathering body and its decision on the matter, while carrying weight, is not binding, but respected. The IJC's jurisdiction is also limited to surface water, but has bypassed this limitation in specific cases where the surface water problem was directly related to ground water resources.

The IBWC, in contrast, is not just a mediator, but also an active participant in the apportionment and utilization of the transboundary water resources. The actions of both Commissions require consent by the two sovereign governments which constrain their effectiveness as an institutional entity. In addition, IBWC's decisions are not binding, which means that both countries (USA and Mexico) need to be willing to abide by their treaty obligations—this is true for the IJC as well. The IBWC's role in constructing water storage and conveyance systems can be seen as a symbol of cooperation between the two countries because they are two riparian countries that completely share the use of the river.

These two mature institutions are based on a trialogue. The societal process instigates the government process which uses scientific processes to resolve an issue. However, the interfaces between these three elements are not always balanced. The fact that the three elements are used in a process does not mean that they carry equal weight. Societal processes may initiate concern and involvement by the government and/or scientific community but may not play as large a role in the outcome as the science or government processes. NAFTA, by way of the CEC, also plays a role in U.S.-Mexico transboundary issues and allows for the resolution of disputes on a more local level, and has the potential to play a bigger role in Canada-U.S. transboundary issues.

Some of the more emergent issues have to do with the sharing of ground water in transboundary aquifers and creating more specific government processes for each basin. There have been no direct conflicts between both countries as the water levels in transboundary aquifers have not lowered to a point to where a country's use is threatened. Minute 272 was set in place to deal with ground water but it has not been utilized in sharing the resource; another option is the Bellagio Draft Treaty (Hayton and Utton 1989), which was written to help promote dialogue over transboundary aquifers. Just recently, the scientific element has been included with the completion of studies on these transboundary aquifers, which should help decision-makers with future apportionment issues and define the relationship between science and government. Examples include the Upper San Pedro River in Arizona and Sonora and the aquifers underlying the cities of El Paso and Ciudad Juarez. What has been consistent in these projects is that the U.S. portion of the aquifer has been studied extensively but the Mexican portion is relatively unknown. When the study phase of the aquifers is complete, decision-makers should look at ways to 'sustainably' apportion water from these transboundary aquifers.

One of the most complicated issues that can impact the quality and use of transboundary waters is the implementation of NAFTA. The three conflict and cooperation examples that have NAFTA implications have added another layer to the agreements already set forth by U.S. and Mexico through the IBWC. NAFTA has created tension over the Hermosillo aquifer in Mexico. Although it is not a transboundary aquifer, many of the agricultural products grown with water from the Hermosillo aquifer are in high demand due to the easing of trade restrictions. This increased demand has created internal conflict over the rights and use of the Hermosillo aquifer. In this case, the people must decide between the benefits of exporting high-valued agricultural products over the use of water for other local purposes, such as commercial and industrial development. However, NAFTA's power has the potential to create an unbalanced government-society interface and severely limit the scientific process. The interface has the potential to be unbalanced because the societal processes are constrained by NAFTA which only recognizes economic uses of water and disregards environmental and/or ecological uses of water. This focus on economics also has the potential to limit the scientific process by only acknowledging the results of science when an economic value can be attached to the results that outweighs other economic considerations.

The outliers are the cases of the Sierra Blanca and Ward Valley nuclear waste facilities. The siting of nuclear waste is a water quality issue that has the ability to strain relations between both countries if not handled carefully. It is difficult enough to site a facility within the U.S. due to the unknown future impacts to water quality in both streams and aquifers. Even more difficult is siting a facility near the U.S.-Mexican border because the largest surface water bodies in the southwestern U.S. flow into Mexico. A few of these controversial projects that could have impacts to U.S. and Mexican water quality were scrapped due to public opposition on both sides of the border. It remains to be seen how these projects will strain binational relations in the future; however because of the highly volatile nature of storing nuclear waste, there will undoubtedly be conflict over a facility that has the threat to impact water that flows into Mexico. These are cases where societal processes (i.e., public opposition) play a powerful role in the outcome.

The structure of the IJC and IBWC is such that any action taken is a reflection of the perceived or actual harms to each country due to their relative position—upstream or downstream. In general, Canada and the U.S. are typically proactive when it comes to water quality issues, especially when they are the downstream country, as in the case of the Abbotsford-Sumas aquifer. Examples along the southern border include the Tijuana watershed dispute over dumping of raw sewage in the Tijuana River where the U.S. was the downstream recipient and the Mexicali sewage flowing into the U.S. via the New River. In these situations, the U.S. was reactive in approaching the IBWC for solutions in these types of water quality. The U.S has become more proactive initiating the involvement of NADBank (North American Development Bank) for projects within Mexico that have the potential to affect downstream communities in the U.S.

Ground water has been dealt with on a local level and has been party to cooperative scientific efforts to delineate the physical and chemical properties and understand human impacts to the resource. The nature of ground water is such that human impacts have recently been the focus of attention, and the problems that have surfaced do not have a quick fix. Their solutions therefore have been undertaken through local concerns, and in the case of transboundary ground water resources, this has led to task forces and international exchange of data to prevent future crises associated with the quantity and quality of the resource. These actions have acknowledged that successful cooperation requires using a trialogue (government, scientific, and societal processes) that recognizes the importance of making decisions that incorporate and weigh multiple factors and concerns.

5 Conclusion

The adaptability of institutions such as the IBWC and the IJC and their ability to resolve bilateral disputes and promote cooperation between the countries is demonstrated in the examples of conflict and cooperation. Cooperation is demonstrated by the voluntary use of the institutional entities available to each country such that effective management of transboundary ground water resources is accomplished. Institutions like the IJC and IBWC, while not specifically established to consider ground water, have managed to function properly whenever ground water is an issue, thus effecting transboundary ground water management, if on an *ad hoc* basis. There is no predetermined process that clearly defines the role of government, science, and society in transboundary ground water management; however, at least two of the three trialogue elements are usually used in making decisions and agreements. NAFTA has also shown that it, too, can treat ground water, although in the U.S., NAFTA's approach to ground water as an economic good may jeopardize the use of scientific processes.

The majority of the examples from North America demonstrate that there is a trialogue working to manage transboundary ground water resources. The cooperation surrounding the Abbotsford-Sumas Aquifer demonstrates the strongest presence of the trialogue. However, trialogues are also in use in the Hueco Bolson-Mesilla Bolson aquifers, nuclear waste sites, Hermosillo basin, San Pedro River basin, and Santa Cruz River basin. The Tijuana River basin example shows very strong government and scientific processes at work; however, there seems to be very little societal input, aside from the exercise of society's desires through laws, at this time. It is evident, however, that more attention needs to be paid to ground water and its unique characteristics and not try to "fit" ground water into existing surface water compacts and agreements.

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