

Transboundary water management Game-theoretic lessons for projects on the US–Mexico border[☆]

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Abstract

Of the twelve million people who live within 100 km of the US–Mexico border, 90 percent are clustered in transboundary sister cities that share common water sources and pollution problems. New institutions created to address environmental concerns over NAFTA offer the promise of greater financial and technical assistance for water management in border cities. This paper reviews US–Mexico border water issues and institutions. Using insights from game theory, it draws policy lessons for institutions funding border water projects. We examine how the design of assistance programs, technical support, and pre-existing water rights and regulations affect project outcomes. The diversity and geographic dispersion of water conflicts suggests potential for applying the interconnected game approach to US–Mexico water negotiations. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Ninety percent of the 12 million people who live within 100 km of the US–Mexico border are clustered in 14 pairs of sister cities. Transboundary pollution control along the border is complicated by large income disparities between the two countries. This has led to disparities in the two countries' abilities to fund

water supply and treatment projects and to regulate pollution.

New agreements offer the promise of greater assistance to border cities facing water management problems. In 1983, the United States and Mexico signed the Agreement on Cooperation for the Protection and Improvement of the Environment in the Border Area (the La Paz Agreement). Its goal was to institutionalize cooperation on environmental problems in the US–Mexico border region, defined as the area within 100 km of the border. In 1994, as side agreements to NAFTA, the two nations established the Border Environmental Cooperation Commission (BECC) and the North American Development Bank (NADBank). The NADBank arranges financing of water, wastewater,

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and municipal solid waste projects that must be certified by the BECC, based on environmental, technical and financial criteria.

This paper reviews US–Mexico water issues and institutions. It then uses insights from game theory to draw policy lessons for institutions funding border water projects.

2. Border water issues

The main surface water sources on the border are the Colorado River, flowing from the United States into Baja California and the Rio Grande, forming the physical border between Texas and Mexico. Surface water rights in both river basins were established under the 1944 Treaty on Utilization of Waters of the Colorado and Tijuana and of the Rio Grande. The two nations have yet to apportion smaller rivers, where each country has acted unilaterally to capture streamflow.

Historically groundwater has been treated as a common pool resource, leading to groundwater depletion (Mumme, 1993; Kishel, 2000). Falling water tables have affected the quantity and salinity of the water in El Paso–Ciudad Juarez, where samples from Mexican wells have found total dissolved solids to be at levels considered unfit for human consumption (Hayes, 1996). The falling water table has left Nogales, Sonora residents vulnerable to water shortages in drought years (Ingram and White, 1993). In 1972, the United States and Mexico did agree to limit pumping within 5 miles of the border in the Yuma–San Luis Rio Colorado area where agricultural growth had led to overdrafting (Kishel, 2000). Despite this one instance of cooperation, there have been virtually no formal bilateral negotiations over groundwater use (Szekely, 1993a,b; Mumme, 1993).

The controversy over the All-America Canal signals a new era of US–Mexico conflict over groundwater. The canal diverts 3.5 million acre-feet (MAF) of Colorado River water to farmers in California's Imperial Valley. Because the unlined canal is built on sandy soils, 0.2 MAF of diverted water seeps into the ground annually. The United States plans to line part of the canal to reduce seepage. This, however, would reduce recharge and raise the salinity of the Mesa San Luis aquifer supplying groundwater to Mexican farmers in the Mexicali Valley (La Rue, 1999).

The 1944 Treaty allocated 1.5 MAF of Colorado River to Mexico annually, but did not address the quality of water Mexico would receive. Increased US diversions of water raised the salinity of the water flowing to Mexico. Between 1960 and 1962, the level of total dissolved solids (TDS) rose from 800 to 1500 ppm (Kishel, 2000). Kishel notes that water “with TDS greater than about 1000 is generally considered unfit for irrigation purposes (p. 707)”. During the 1960s and early 1970s, Colorado salinity was the most contentious US–Mexico waters dispute (Mumme, 1993).

In 1973, both sides reached an agreement, the Permanent and Definitive Solution to the International Problem of the Salinity of the Colorado River (IBWC, 1973; Minute 242). The TDS of water delivered to Mexico is to be within 115 ppm of the TDS of water at Imperial Dam in the United States. This agreement may prove less “permanent and definitive” than originally planned. While it may resolve the issue of the *relative* salinity of water used by the United States and Mexico, it does not address basin-wide increases in *absolute* salinity (Mumme, 1993).

The border's most serious public health problem is lack of access to safe drinking water and sewage treatment. Many people on both sides of the border lack access to potable water and connections to sewer systems. Johnstone (1995) notes that “Juarez, a city of over 1.5 million does not have any treatment facilities whatsoever (p. 44)”. In Texas and New Mexico, over 400 000 people live in *colonias* — low income, unincorporated subdivisions typically lacking electricity, paved roads, potable water, or sewage treatment (EPA, 1998a).

Untreated sewage is a major transboundary externality, as polluted water flows northward from Mexican to American cities. The city of Nuevo Laredo deposits 24 million gallons per day (mgd) of raw sewage into the Rio Grande (Johnstone, 1995). In Tijuana, over 10 mgd of untreated sewage, combined with industrial waste, flow into the Tijuana River and San Diego (Johnstone, 1995; IBWC, 1990; Minute 283). Flows of sewage into the ocean have led to frequent beach closures in San Diego (Ganster, 1996). The New River — flowing north from the Mexicali Valley, through the Imperial Valley, and into the Salton Sea — has the dubious distinction of being one of the most polluted rivers in the United States

(Kishel, 2000; Johnstone, 1995; Ganster, 1996). The Nogales Wash, a tributary of the Santa Cruz River, flows through Nogales, Sonora and Arizona. During summer rains, raw sewage flows into the Wash and through neighborhoods on both sides of the border (Ingram and White, 1993; Varady et al., 1995). Giardina and cryptosporidium have been detected in the Wash and the aquifer serving as the primary water source for both cities (Varady and Mack, 1995).

The rise of the *maquiladora* sector has raised concerns about hazardous waste production and disposal along the border (Udall Center, 1993; Johnstone, 1995; Hinojosa-Ojeda, 1999). Established in 1965, the *maquiladora* program allows firms located in Mexico to import production inputs duty-free to assemble or manufacture goods for re-export. The number of *maquiladoras* has grown from fewer than 100 plants in the 1960s to over 2000 today, with 60 percent located in the border region. *Maquiladora* employment grew by 65 percent between 1990 and 1996.

Mexican law requires that hazardous wastes produced by *maquiladoras* must be either treated in Mexico or returned to the country of origin. Yet, according to Hinojosa-Ojeda (1999), 85 percent of the hazardous wastes produced in Baja California are neither shipped to the United States nor treated in Mexico. Ganster points out, however, that:

“While *maquiladoras* are often singled out by critics as responsible for significant pollution, there is a notable lack of reliable data and studies to support this assertion. For example, a limited analysis of hazardous waste in Mexicali *maquiladoras* carried out recently by EPA failed to turn up significant polluting by these companies.”

Ganster also notes that Mexican domestic industries in Baja California produce significant pollution and that only a portion of this waste is disposed of properly.

3. Transboundary water management institutions

3.1. The IBWC

The 1944 Water Treaty established the International Boundary and Water Commission (IBWC) (Mumme, 1993). The IBWC is made up of US and Mexican Sections. The jurisdiction of the IBWC is specific and narrow, extending only to water management issues

that are fundamentally binational. The IBWC may address water sanitation problems, through projects mutually agreed upon by the two nations. These agreements are called “Minutes”. The Commission is primarily a technical agency, focusing on scientific appraisals and engineering solutions to water management problems. Although the Commission’s jurisdiction is limited in scope, on US–Mexico border water issues, its authority supercedes the claims of other domestic agencies. To alter the jurisdiction or authority of the Commission would require a new treaty approved by both governments.

The IBWC has received much praise for its ability to find cooperative solutions to border water problems and for its sheer longevity as a bilateral negotiation institution (Mumme, 1993; Szekely, 1993a). The IBWC has been the only permanent institution, conducting bilateral negotiations and planning of any kind, between the United States and Mexico. The Commission earned its reputation for effectiveness from its success in surface water management.

Demographic and institutional change have forced the Commission to address new problems in an increasingly complex institutional setting. Since 1944, the border population has increased 12-fold, placing stress on the region’s water treatment infrastructure. The Commission’s attention has been drawn increasingly toward water quality problems. Groundwater has also become an increasingly contentious issue. Minute 242, signed in 1973, gave the Commission authority to begin discussions toward a bilateral agreement on transboundary groundwater management. The Commission, however, has yet to initiate broad groundwater negotiations (Mumme, 1993; Szekely, 1993a,b). The creation of the EPA, along with passage of legislation such as the National Environmental Policy Act, Clean Water Act, and Safe Drinking Water Act, has increased the factors the Commission must consider.

More recently, the Commission has drawn criticism (Mumme, 1992, 1993; Ingram and White, 1993; Szekely, 1992, 1993a,b; Varady et al., 1996; Sprouse and Mumme, 1997). First, critics have complained that the Commission has been slow to address water quality and groundwater management issues. Second, ambiguities in the Commission’s mandate regarding water quality have hampered state and federal environmental agencies’ abilities to regulate water pollution. Third, it has focused too narrowly on structural, engineer-

ing solutions to immediate crises, without addressing underlying causes of problems or anticipating future problems. Fourth, its decision-making framework insulates it from public participation and comment.

The shift from praise to criticism of the Commission coincides with water quality and groundwater supplanting surface water management as the major border water issues. Regarding border sanitation, the Commission has focused on immediate, engineering solutions in response to potential health crises. These crises are the result of market failures that have allowed industrialization and population growth to proceed without consideration of the full social costs of growth.

The ambiguity in the Commission's mandate over water quality has also been frustrating for environmental groups and state environmental agencies (Mumme, 1992). For example, hazardous waste affects water quality, yet it is not strictly a sewage or sanitation issue. This leaves open the question of whether the Commission can address this issue or whether it is the purview of EPA or state environmental agencies.

Other criticism arises because the IBWCs structure and decision-making system differs from other US resource management agencies. The 1944 Treaty does not require the Commission to hold public meetings or invite public comment. Because of the diplomatic aspect of negotiations, the Commission has gained a reputation for being secretive (Mumme, 1992). The binational structure of the Commission is another important difference from other environmental agencies. Mexico is a sovereign nation, so solutions to environmental problems take the form of Coasian bargaining rather than regulation.

3.2. *La Paz Agreement/Border XXI program*

The United States and Mexico signed the La Paz Agreement in 1983, establishing a framework to discuss environmental issues, share information and coordinate pollution control within 100 km of the border. The agreement calls for meetings at least once a year and coordination with state government agencies. It also established the EPA and the Secretaria de Desarrollo Urbano y Ecología to coordinate and monitor implementation of the agreement and future subsidiary agreements (called Annexes).

Despite a more participatory structure and broader scope, Border XXI has been criticized for its lack of enforcement authority (Mumme, 1992). The La Paz Agreement is not a formal treaty, but an Executive Agreement. It has no arbitration or enforcement mechanisms. Further, the coordinating agencies do not have administrative or budgetary control over many of the activities they oversee and activities are spread over several state and federal agencies.

3.3. *The BECC and the NADBank*

In 1994, as side agreements to NAFTA, the United States and Mexico established the BECC and the NADBank. The NADBank arranges financing of border water and municipal solid waste projects that must be certified by the BECC, based on environmental, technical and financial criteria.

A goal of these institutions is to address market failures that are at the center of border environmental problems. While the IBWC has focused on responding to border sanitation problems *after* they arise, its mandate and organization structure is not designed to address problems of market failures and incentive problems that lead to the water pollution crises in the first place. Firms located on the border have not had to pay the full social costs of their production and release of industrial wastes into water bodies.

A second problem has to do with the provision of water infrastructure needed to support the rapidly growing workforce on the border. Historically, firms have not paid much in the way of user fees or taxes to finance safe drinking water or sewer systems for the growing workforce. Local municipalities pay only a fraction of the cost of water treatment infrastructure. The US federal government's willingness to bail out border cities is an understandable response to immediate health concerns. However, because cities are not internalizing the full costs of border growth, population and sewage growth has outstripped local infrastructure (Johnstone, 1995; Ingram and White, 1993; Udall Center, 1993).

Yet, border cities are limited in their abilities to self-finance water infrastructure (Hinojosa-Ojeda, 1999). Because of risks associated with these investments, it is difficult to obtain long-term financing through international markets. In addition, Mexico's legal system limits the ability of local govern-

ments to issue bonds against user fees or real estate taxes.

The NADBank's purpose is to help border communities with long-term funding of water and solid waste projects. Capitalized by both the Mexican and US governments, NADBank can secure financing at lower commercial rates than would otherwise be possible for border communities. The bank also uses its funds to leverage other private loans and grants that local entities may not otherwise be able to secure. The NADBank is not a grant-giving agency (although it does help administer an EPA grants program). Water projects must be able to repay loans, raising funds through user fees or other mechanisms.

Before NADBank can finance projects, they must be certified by the BECC. The BECC certification criteria include human health and environment, technical feasibility, financial feasibility and project management, community participation, and sustainable development. Along with certifying projects for funding, the BECC provides technical assistance for local entities developing projects. In addition, it analyzes environmental and financial aspects of projects and helps to arrange public financing for projects (EPA, 1998b).

In its first two years, the BECC failed to secure NADBank funding for any of its certified projects. While there was great debate over the BECC's sustainable development criteria, proposed projects were not meeting NADBank's financial criteria (Varady et al., 1996). NADBank (1998a) identified five constraints limiting project development: (a) insufficient community resources for high cost projects, (b) lack of master plans and inadequate proposal preparation, (c) limited financial, administrative and commercial capabilities of local water agencies, (d) inadequate revenue for the sound operation of existing services and resistance to raising user fees and (e) lack of private sector involvement in environmental projects.

To address these constraints, the EPA and NADBank established the Border Environmental Infrastructure Fund (NADBank, 1998b). The fund receives and administers grants that may be combined with loans or loan guarantees. Grants may support municipal infrastructure, drinking water treatment plants, and treated water distribution systems. Funds may be used to allow user fees to be phased in over time. By the end of 1998, NADBank had approved \$105 million in loans for 14 water projects.

4. Border water management as a bargaining game

4.1. IBWC project development as a cooperative game

The US and Mexican Sections of the IBWC have reached several agreements (Minutes) on pollution control projects. Minutes specify the scale and siting of wastewater collection systems and treatment plants and allocate costs between countries. Once approved by both countries, a Minute becomes a binding agreement with the force of the 1944 Water Treaty behind it.

Because the IBWC framework allows the two nations to make binding commitments, one can model negotiations as a cooperative game, using for example, the Nash (1953) solution. The Nash solution maximizes the product $N = [u_m - \underline{u}_m][u_u - \underline{u}_u]$ with respect to the terms being bargained over. The u_m and u_u terms are the payoffs to the two nations (m for Mexico, u for United States), while \underline{u}_m and \underline{u}_u are the countries' disagreement payoffs that reflect the status quo.

The Nash solution has several desirable features. The outcome is pareto efficient. For two agents bargaining over division of treatment effort to meet a drinking water quality standard, the Nash solution guarantees that the standard is achieved at the least cost (Frisvold and Caswell, 1995). Finally, despite its simplicity, the Nash solution can closely approximate solutions to more sophisticated dynamic strategic games (Binmore et al., 1986).

This approach can be used to examine negotiated outcomes of pollution control projects in three border metro areas: San Diego–Tijuana, Calexico–Mexicali and Laredo–Nuevo Laredo. Our analysis suggests that, after some earlier missteps, outcomes have made significant progress toward economic efficiency.

The IBWC negotiated construction of the first joint US–Mexico sewage treatment facility in 1951 to serve Ambos Nogales. The IBWC recommended apportioning costs in proportion to benefits (Mumme, 1993). The downstream position of the United States, combined with its greater willingness to pay for water sanitation, meant that the United States would derive relatively larger benefits from the project. The United States therefore assumed a higher share of the project costs. This policy of apportioning costs in proportion

to benefits was used as a guideline in subsequent negotiations for over 30 years (Mumme, 1993). In 1984, however, the Reagan Administration adopted the position that the Mexican government should finance half the cost of jointly developed pollution control projects (Mumme, 1993).

Requiring joint projects to be equally funded will generate efficient solutions only in special, and given the realities of border water problems, highly unlikely cases. Commission engineers frequently make recommendations about the siting and scale of waste collection and treatment systems based on the principle of minimizing cost to achieve particular objectives. Such objectives might be to minimize the quantity of untreated waste flowing into a water body or to insure that effluent from a treatment plant complies with a water quality standard. Once the cost-minimizing infrastructure is identified, the bargaining problem simplifies to one of allocating costs. The Nash product becomes $N = [u_m(\beta b - \alpha c) - u_m][u_u((1-\beta)b - (1-\alpha)c) - u_u]$, where b and c are total project benefits and costs, β is Mexico's share of benefits, and α is Mexico's share of the costs. The US share of benefits and costs are $(1-\beta)$ and $(1-\alpha)$. If the project objective and least-cost means of meeting that objective are agreed upon, then b , c and β are exogenous and the sole bargaining parameter is α , Mexico's cost share. If an equal cost sharing rule is a binding constraint, however, the bargaining process takes the form of choosing b , c , and β to maximize N subject to $\alpha = 0.5$.

For projects whose main purpose is to control transboundary wastes flowing into the United States, β will be small. Here, Mexico would only accept an agreement where $\alpha \geq 0.5$ if the overall cost benefit ratio of the project as a whole were exceedingly high. To illustrate, assume that $\beta = 0.2$ and $u_m = u_m(0)$. For $\alpha \geq 0.5$, the benefit–cost ratio b/c would have to be greater than 2.5 to exceed Mexico's reservation utility. For $\beta = 0.1$, it would have to be greater than 5. The equal cost sharing rule will tend to force the outcome to the non-cooperative solution $N = [u_m][u_u]$ in cases where transboundary externalities are significant (β small). To the extent that benefit–cost ratios are higher for small projects, the constraint $\alpha \geq 0.5$ is more likely to be binding for large projects. The equal cost-sharing rule is biased against finding a cooperative solution for projects with high relative benefits for the United States (β small) and where

absolute benefits are large (to the extent that b/c is closer to 1 for projects where $b - c$ is large).

The equal cost rule impeded a cooperative solution to border sanitation problems in San Diego–Tijuana (Mumme, 1993). In 1980s, IBWC engineers recommended a gravity flow collection system, with the main treatment plant located in San Diego. The objective of this system was to eliminate uncontrolled sewage flows into the Tijuana River and San Diego. Mexico balked at paying half of the estimated \$730 million project cost. Instead Mexico acted unilaterally, building a smaller, less expensive, self-financed system in Tijuana (IBWC, 1995; Minute 270). Rapid growth in Tijuana soon outstripped the capacity of the first of two facilities to be built and Mexico developed plans to construct a secondary treatment plant at the Rio Almar. US engineers, however, considered the proposed plant “suboptimal and less reliable as a mechanism of managing Tijuana's growing sewage production (Mumme, 1993, p. 117)”.

In 1990, the Commission agreed to pursue the larger joint sewage collection and treatment project along the lines originally proposed, a gravity flow system with the treatment facility site in San Diego (IBWC, 1990; Minute 283). Under Minute 283, equal cost sharing was abandoned:

“The cost corresponding to Mexico shall be in an amount... equal to that which would have been used in the construction, operation and maintenance of the treatment plant planned for the Rio Almar (IBWC, 1990; Minute 283).”

Minute 283 improves on the earlier non-cooperative outcome. The US Section believes that the scale and siting of facilities will allow it to comply with domestic water quality standards cost-effectively. The Mexican government will incur no greater costs than those associated with its disagreement point, yet it will derive benefits from the more efficient larger system.

The equal cost constraint also affected Minute 274, Joint Project for Improvement of the Quality of the Waters of the New River at Calexico, CA–Mexicali, BC. The principal engineers were asked to develop plans for a jointly funded project to improve the waters of the New River “utilizing funds to be provided in equal parts by the Governments of the United States and Mexico (IBWC, 1987; Minute 274)”. The result was a small project that the engineers

conceded was “but a small part of the total works required for solution of the border sanitation problem (IBWC Joint Report of Principal Engineers, 1987)”. They also noted that some project features were abandoned because they fell outside the Mexico’s budget constraint. Subsequent Minutes regarding the New River have dropped language about equal cost sharing.

In 1997, the Commission signed Minute 297, apportioning the costs of a wastewater treatment project for the Rio Grande at Laredo–Nuevo Laredo (IBWC, 1997). Here, the externalities of untreated wastewater affect the two countries more symmetrically. The project expanded collection and treatment capacity in Nuevo Laredo, Mexico. The project’s goal was to prevent discharges of untreated sewage into the Rio Grande and to have discharges from new treatment facilities conform to US water quality standards, which are higher than the standards required by Mexican law. The United States agreed to pay Mexico for the incremental cost of operating and maintaining the project to meet the higher US effluent standard. The US Section believes that expanding facilities in Nuevo Laredo is a more cost-effective way to meet US standards than to unilaterally build infrastructure in the United States. Mexico, in turn, is compensated for its incremental costs of meeting the higher US standard.

4.2. Environmental grant development as a strategic game

The experience of the IBWC suggests that coordinating construction of infrastructure across borders can significantly reduce project costs. Given high fixed costs, there are gains from avoiding duplication of treatment facilities. Local geography determines the optimal location of conveyance systems and treatment plants. This may involve developing projects across borders. Yet, thus far, border cities seeking NADBank loans or environmental grants through the BECC process have done so unilaterally. Varady et al. (1996) argue:

“BECC does not seem to have assisted these linked communities to develop comprehensive, binational approaches to environmental decision making. Environmental policy within these communities remains relatively isolated vis-à-vis their partners

across the border. If BECC adopts a more active and comprehensive position in identifying and alleviating environmental degradation, then facilitating local binational decision making should be high on its list of priorities.”

This section considers the problem of two border cities seeking external financing of a jointly developed water project. Joint project development could be a condition of the funding agency. For example, the Border Environmental Infrastructure Fund’s criteria states that projects must have a US interest and that priority will be given to projects which benefit both countries (NADBank, 1998b).

Negotiations over terms of a proposal may be modeled as a sequential bargaining game with exogenous risk of breakdown. One player makes an initial proposal that specifies how grant funds will be allocated. The other player accepts or rejects the offer. Players make counter proposals until they reach an agreement or negotiations end without agreement. Bargaining could end if the funding agency decides to fund competing proposals. Delays in reaching an agreement increase the probability that funds will go to other projects instead.

Binmore et al. (1986) have shown that, in this type of bargaining game, the outcome is approximated by the Nash solution. Negotiations over the grant proposal can then be modeled as a Nash bargaining game of the form:

$$N = [v_m(\mathbf{x}, \alpha A) - \underline{v}_m(\mathbf{x}, \alpha A = 0)]^\beta \times [v_u(\mathbf{x}, (1 - \alpha)A) - \underline{v}_u(\mathbf{x}, (1 - \alpha)A = 0)]^{1-\beta}$$

where: (a) N is the Nash product, (b) v_m and v_u are the city’s utilities if they receive the assistance, (c) \underline{v}_m and \underline{v}_u the city’s utilities if no agreement is reached, (d) A a measure of the value or size of the assistance package, (e) α the city m ’s share of the assistance package, (f) \mathbf{x} the vector of bargaining parameters, (g) \mathbf{x} the values of parameters in the event negotiations breakdown or the granting agency decides not to consider the project, and (h) β a parameter measuring the bargaining power city m relative to city u .

The Nash solution maximizes N with respect to \mathbf{x} . The vector \mathbf{x} could represent a host of different variables (the quantity and quality of water flowing from the upstream to the downstream country, use of effluent by each country, the level of pre-treatment required

by each country's industries, the costs borne by each country for treatment systems, etc.).

4.3. Bargaining power and technical assistance

The bargaining power parameter β will depend on the time preference of each player (Binmore et al., 1986). In this model, β increases if country u is more impatient than country m . This might be the case if u is downstream and there is a serious border sanitation problem such as risk of a hepatitis outbreak. The model suggests that downstream cities should be pro-active, developing joint project proposals before crises emerge.

Binmore et al. (1986) have also shown that β will depend on the time it takes for each player to respond to proposals and make counter proposals. Negotiators who can formulate and evaluate proposals more quickly will have greater bargaining power. The ability to assess the benefits and costs of each offer requires evaluation of complex hydrologic, environmental and economic relationships. Organizations without access to data or the technical expertise are more likely to get less out of joint development projects. Third parties can balance asymmetries in bargaining power by ensuring that access to information and technical expertise is not monopolized.

Border institutions have explicit policies to provide technical assistance to communities seeking project financing. The BECC has established a \$10.5 million Technical Assistance Grants Program, funded primarily by EPA, to help disadvantaged communities prepare project proposals to meet BECC certification criteria (Varady et al., 1996). BECC provides staff and consultants to help organizations conduct planning studies, environmental assessments, and financial evaluations and to prepare certification applications. IBWC Minute 294 (1995) established a Facilities Planning Program funded by the EPA, the program assists border communities in developing wastewater infrastructure plans that meet BECC criteria. The IBWC provides expert technical assistance to local water agencies. Funds may also be used for economic and environmental impact studies, and public information dissemination. Communities receiving support must demonstrate that they have insufficient funding to advance plans for BECC certification.

4.4. Water rights and environmental regulations

Water rights or environmental regulations influence outcomes even if they are non-binding constraints. For example, an element x_i of \mathbf{x} might be a city's surface water use, effluent use or level of pre-treatment of industrial wastewater. One player's payoff may be increasing in some of these parameters, while another's is decreasing. Water rights and environmental regulations place guarantees and limits on the values bargaining parameters can take. A city may be guaranteed a minimum allocation of surface water, the right to use effluent, or its firms may be required to provide a minimum level of wastewater pre-treatment. Under a cooperative solution, however, a city may forgo some of its water rights or supply water of a higher quality than the minimum required by law. This may be in exchange for a concession by the other city. In this case, the water right or environmental standard may determine \underline{x}_i , the value of x_i in the event negotiations break down. Altering water rights or environmental standards will affect a player's disagreement payoff. A player's payoff in a Nash bargaining game rises with its disagreement payoff. Altering water rights or standards affect the bargaining outcome, even if a city is not using its full water entitlement or is providing environmental clean-up in excess of the minimum standard.

Non-exercised rights can be important bargaining chips. For example, the US and Mexico maintain the right to return and reuse effluent from treatment plants corresponding to each country's sewage inflows. Currently, Mexico does not use its share of the effluent from the Nogales International Wastewater Treatment Facility. The treated effluent flows into the normally dry Santa Cruz River, raising nutrient levels, encouraging growth of riparian vegetation and providing wildlife habitat (Hamson, 1996). Mexico has the right to claim the effluent, but currently does not (IBWC, 1967). The possibility that Mexico might exercise its claim does influence IBWC negotiations over water project development in Ambos Nogales (Ingram and White, 1993).

4.5. Interconnected games

Many externalities on the US–Mexico border, when viewed in isolation, are unidirectional (the lining of

the All-American Canal, Colorado River salinity, sewage flows from Mexican to US cities). Bennett et al. (1997) note that game-theoretic solutions to unidirectional externalities tend toward victim pays outcomes. Bennett et al. (1997) find victim pays regimes unsatisfactory because they run counter to the polluter pays principle accepted in the international community and because countries may wish to avoid appearing to be weak negotiators. We add a third criticism. With extreme income disparity, a downstream country may not be able to offer side payments to discourage the upstream country from polluting or diverting transboundary waters.

An alternative to side payments or accepting externalities is to link negotiation issues. In the 1944 Water Treaty, Mexico achieved a better allocation of Colorado River water, where it was the downstream country, by linking negotiations over water in the Lower Rio Grande, where it was the upstream country (Ragland, 1995).

In interconnected games, negotiations over separate issues are joined in a repeated game. Each country's action in one game is conditional on the outcome of another. This allows for equilibrium solutions not attainable in isolated games that may yield higher joint payoffs. Solutions may also avoid side payments when isolated solutions do not (Folmer et al., 1994; Bennett et al., 1997).

Linking water negotiations with other water or environmental issues may be attractive to Mexico. While the United States has entered into agreements involving side payments, Mexico is less able to do so. Kishel has suggested linking negotiations over the lining of the All-American Canal to issues such as construction of a Yuma–Mexicali pipeline, groundwater banking, rights to treatment plant effluent, and water conservation technology transfer.

The La Paz/Border XXI program could become a vehicle for identifying issues amenable to linked negotiations. Bennett et al. (1997) discuss how the interconnected game approach can identify issues for linkage simply by identifying issues with payoffs of the same order of magnitude and where the games have asymmetric prisoner's dilemma structure. Their approach could be used as a relatively low cost method of screening issues for potential linkage. The different Border XXI workgroups could help supply information for this screening process.

5. Conclusions

Rapid industrial and population growth along the US–Mexico border has placed great stress on the area's water and wastewater infrastructure. It has also shifted attention from surface water management to water quality and groundwater management. Adaptations by the IBWC and the establishment of the Border XXI program, the BECC and the NADBank represent institutional innovations in response to rising population and greater competition for scarce water resources.

Because the IBWC is able to make binding commitments, we examined their negotiations over border water projects as a cooperative game. Politically imposed constraints on the bargaining process in earlier years prevented cooperative solutions from being reached or led to projects too small to address stated goals. In recent years, negotiated outcomes have made significant progress toward economic efficiency.

While the IBWC focuses on engineering solutions to border sanitation problems, its mandate and organization structure is not designed to address problems of market failures that lead to the water pollution crises in the first place. The BECC and NADBank were established to help address these broader issues by certifying the environmental and financial soundness of border water projects and establishing user-fee based supply of water services. We next considered the problem of border cities seeking external financing of jointly developed water projects that could address broader, non-structural issues such as user fees or groundwater pumping charges. Development of the joint grant proposal was modeled as a sequential bargaining game. The model results highlight the role of technical assistance in affecting the bargaining outcome — disadvantaged groups may need “aid in getting aid”. An innovative feature of border water institutions is their recognition of this fact and their establishment of funds and resources to provide such aid.

Finally, we considered the scope for using the interconnected game approach to identify border environmental negotiations that might be linked. Border XXI could become an important vehicle for identifying issues amenable to linked negotiations. The interconnected game approach can identify issues for linkage simply by identifying issues with pay-

offs of the same order of magnitude and where the games have asymmetric prisoner's dilemma structure. This approach could be used as a relatively low cost method of screening issues for potential linkage. The Border XXI workgroups could supply valuable information for such screening.

References

- Bennett, L., Ragland, S., Yolles, P., 1997. Facilitating international agreements through an interconnected game approach: the case of river basins. In: Parker, D., Tsur, Y. (Eds.), *Decentralization and Coordination of Water Resource Management*. Kluwer Academic Publishers, Boston, MA, pp. 61–85.
- Binmore, K., Rubinstein, A., Wolinsky, A., 1986. The Nash bargaining solution in economic modelling. *Rand J. Econ.* 17, 176–188.
- Environmental Protection Agency, 1998. *Colonias Facts*. USEPA, Office of International Affairs, Washington, DC, March 1998.
- Environmental Protection Agency (EPA), 1998. BECC and NADBank: Promoting Environmental Infrastructure on the US–Mexico Border. USEPA, Office of International Affairs, Washington, DC, July 1998.
- Folmer, H.P., van Mouche, P., Ragland, S., 1994. Interconnected games and international environmental problems. *Environ. Resour. Econ.* 3, 313–335.
- Frisvold, G., Caswell, M., 1995. A bargaining model of water quality and quantity. In: Dinar, A., Loehman, E. (Eds.), *Water Quantity/Quality Disputes and their Resolution*. Praeger Press, Westport, CT, pp. 399–407.
- Ganster, P., 1996. Environmental issues of the California–Baja California border region. *Border Environment Research Reports* No. 1. Southwest Center for Environmental Research and Policy, San Diego, CA.
- Hamson, D.V., 1996. The Santa Cruz river basin: best practices for maintaining its health. *Border Environment Research Reports* No. 4. Southwest Center for Environmental Research and Policy, San Diego, CA.
- Hayes, D.F., 1996. Drinking water quality in the US/Mexico border region: assessment of water supplies, treatment and distribution. In: *Proceedings of the Technical Conference of the Southwest Center for Environmental Research and Policy*. Southwest Center for Environmental Research and Policy, San Diego, CA.
- Hinojosa-Ojeda, R., 1999. From NAFTA debate to democratic and sustainable integration: potential implications of the North American Development Bank. Mimeograph. School of Public Policy and Social Research, University of California, Los Angeles, CA.
- International Boundary and Water Commission (IBWC), 1967. Enlargement of the international facilities for the treatment of Nogales, Arizona and Nogales, Sonora sewage. Minute 227. El Paso, TX, September 5, 1967.
- IBWC, 1973. Permanent and definitive solution to the international problem of the salinity of the Colorado River. Minute 242. Mexico, DF, August 30, 1973.
- IBWC, 1987. Joint project for the improvement of the quality of the waters of the New River in Calexico, California–Mexicali, Baja California. Minute 274. Ciudad Juarez, Mexico, April 15, 1987.
- IBWC, 1987. Joint report of principal engineers proposing technical basis for jointly funded new river water quality improvement measures in Mexicali, Baja California, Ciudad Juarez, Mexico, February 9, 1987.
- IBWC, 1990. Conceptual plan for the international solution to the border sanitation problem in San Diego, CA/Tijuana, Baja California. Minute 283. El Paso, TX, July 2, 1990.
- IBWC, 1995. Recommendations for the first stage treatment and disposal facilities for the solution of the border sanitation problem at San Diego, CA–Tijuana, Baja California. Minute 270. Ciudad Juarez, Mexico, April 30, 1995.
- IBWC, 1995. Facilities planning program for the solution of border sanitation problems. Minute 294. El Paso, TX, November 24, 1995.
- IBWC, 1997. Operations and maintenance program and distribution of its costs for the international project to improve the quality of the waters of the Rio Grande at Laredo, TX–Nuevo Laredo, Tamaulipas. Minute 297. Ciudad Juarez, Mexico, May 31, 1997.
- Ingram, H., White, D., 1993. International boundary and water commission: an institutional mismatch for resolving transboundary water problems. *Nat. Resour. J.* 33, 153–176.
- Johnstone, N., 1995. International trade, transfrontier pollution, and environmental cooperation: a case study of the Mexican–American border region. *Nat. Resour. J.* 35, 33–62.
- Kishel, J., 2000. Lining the all-American canal: legal problems and physical solutions. *Nat. Resour. J.* 33, 697–726.
- La Rue, S., 1999. US Water-Saving Plan Roils Mexican Officials: Lined Canal Would Harm Mexican Farmers They Say. *San Diego Union-Tribune*, San Diego, CA, February 28, 1999, p. A3.
- Mumme, S., 1992. New directions in United States–Mexican transboundary environmental management: a critique of current proposals. *Nat. Resour. J.* 32, 539–562.
- Mumme, S., 1993. Innovation and reform in transboundary resource management: a critical look at the international boundary and water commission, United States and Mexico. *Nat. Resour. J.* 33, 93–120.
- Nash, J., 1953. Two-person cooperative games. *Econometrica* 21, 128–40.
- North American Development Bank, 1998. *Current Status and Outlook*. NADBank, San Antonio, TX.
- North American Development Bank, 1998. *Border Environmental Infrastructure Fund*. NADBank, San Antonio, TX.
- Ragland, S., 1995. International environmental externalities and interconnected games. Ph.D. Dissertation. University of Colorado, Boulder, CO.
- Sprouse, T., Mumme, S., 1997. Beyond BECC: envisioning needed institutional reforms for environmental protection on the Mexico–US border. In: Paper presented at the Meeting of the Association of Borderland Scholars. Western Social Science Association Meeting, Albuquerque, NM, April 23–26, 1997.
- Szekely, A., 1992. Establishing a region for ecological cooperation in North America. *Nat. Resour. J.* 32, 563–622.

- Szekely, A., 1993a. Emerging boundary environmental challenges and institutional issues: Mexico and the United States. *Nat. Resour. J.* 33, 33–46.
- Szekely, A., 1993b. How to accommodate an uncertain future into institutional responsiveness and planning: the case of Mexico and the United States. *Nat. Resour. J.* 33, 397–403.
- Udall Center for Studies in Public Policy, 1993. *State of the US–Mexico Border Environment: Report of the US EPA US–Mexico Border Environmental Plan Public Advisory Committee*. Udall Center, University of Arizona, Tucson, AZ, 1993.
- Varady, R.G., Mack, M.D., 1995. Transboundary water resources and public health in the US–Mexico border region. *J. Environ. Health* 57, 8–14.
- Varady, R.G., Ingram, H., Milich, L., 1995. The Sonoran Pimería Alta: shared environmental problems and challenges. *J. Southwest* 37, 102–122.
- Varady, R.G., Colnic, D., Merideth, R., Sprouse, T., 1996. The US–Mexico border environment cooperation commission: collected perspectives on the first two years. *J. Borderlands Stud.* 11, 89–119.