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Paper Title: Technology and Adaptation: Framing Desalination in Northwestern Mexico

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Abstract:
Northwestern Mexico is a textbook example of “double exposure” to climate change and globalization processes. This case study focuses on urban water vulnerability in Puerto Peñasco, Sonora, a burgeoning coastal resort town near the U.S.-Mexico border. Cities in the semi-arid region view desalination as an adaptive strategy that can provide a potentially limitless source of water to support growth and buffer against increased rainfall variability due to climate change. Desalination is emerging as a technological solution to water scarcity, yet little critical research has been conducted to examine the implications of this technology. We question the framing of desalination as an adaptive strategy based on a current proposal to build a binational desalination plant promoted by water managers in Sonora and Arizona. This study is one of four linked case studies on water and adaptive capacity in the Arizona-Sonora region, supported by a NOAA-SARP grant, with additional funding provided by NOAA’s Climate Assessment of the Southwest Project and an Inter-American Institute for Global Change Research Project.

Authors’ Note: For the purposes of the ICARUS workshop, it may be useful for readers to take note of the structure of the paper. The first section of this paper presents a detailed empirical description of the case study area of Puerto Peñasco, Mexico. This includes an overview of the climate, climate change predictions, the socioeconomic context, current and future water demand, water supply and distribution, current and planned water management activities. The second section outlines the physical and social vulnerabilities of the region. The third section is the theoretical portion of the paper and provides a critical discussion of the *municipio’s* (county’s) proposal to build a desalination plant to meet their future water needs. This section draws on a paper co-authored by several members of our research team that will be forthcoming in the *Annals of the Association of American Geographers*.

INTRODUCTION

Puerto Peñasco is a burgeoning coastal resort town located in the state of Sonora on the Gulf of California. Environmental vulnerability in Puerto Peñasco is largely conditioned on its proximity to Mexico's border with the United States and the economic growth its location engenders for the coastal community. Just a 4.5 hour drive from Tucson, Arizona, Peñasco is a favorite beach and retirement destination for landlocked Arizonans, including thousands of students at the state universities and thousands of winter visitors (known as snowbirds) and retirees in Phoenix and Tucson. Peñasco is located between fragile estuaries and borders the southern end of several national biosphere reserves that provide rich habitat for multiple endangered species. The depleted groundwater aquifers can no longer support the growth that traditionally has been the economic engine of Peñasco. Many hotels already have their own desalination plants to generate water for particular resorts. Peñasco's municipal planners and officials have pinned their hopes on construction of a major desalination plant to serve municipal needs. The desalination proposal itself also has significant binational implications, since both Arizona and Nevada water authorities have plans eventually to utilize desalinated water from the Peñasco plant to provide water for urban dwellers in Phoenix, Tucson, and Las Vegas or farmers in Yuma.

In our linked case studies focused on science-stakeholder interaction, we define vulnerability as conditioned by socioeconomic, institutional, and political, as well as environmental factors, including climate (Adger et al. 2006). Assessing vulnerability requires consideration not only of exposure to climate change, but also of the risk associated with that exposure and the capacity of an individual, community, or nation to adapt to impacts of climate change (Adger et al. 2006). Vulnerability in the border region's water sector is thus a function of intensified socioeconomic processes—rapid growth, accelerated globalization—and environmental change. Socioeconomic vulnerability is also conditioned by age, ethnicity, gender, or class (Verchick 2008). We understand adaptive capacity to be a dynamic process based on social learning between and within institutions, rather than a static condition or set of attributes and outcomes (Pahl-Wostl 2007; Pelling et al. 2008. Lemos and Morehouse (2005) emphasize that the effective co-production of scientific knowledge and the potential for developing meaningful policy relies on a synergistic relationship among stakeholders and researchers. In their interactions, these networks ideally move beyond discussion to adapt and transform processes (Lemos and Morehouse 2005, p. 61). Sustained and dynamic interactions among these networks can create "usable science" and effective policy (61). Following on Pelling et al. (2008), we ask how institutions shape capacity to build adaptive organizations within the Arizona-Sonora border region.

This paper provides the background and context and some preliminary findings from our continuing research in Puerto Peñasco in the 2008-2010 period. In particular, we focus on desalination as the region's major adaptive strategy to enable growth, and we examine both the direct impacts of desalination (e.g., brackish discharge; environmental impacts on the estuaries) and its indirect impacts (e.g., implications for local community, equity and quality-of-life). While desalination may reduce Peñasco's vulnerability to water scarcity, we argue that the technology is not germane to the essential task of adaptation based on social learning. Desalination is likely to increase Peñasco's environmental vulnerability while creating more uneven development and inequality of access to clean, affordable water for local people. The binational proposals for desalination portend limited autonomy for the local community as binational authorities determine the legal framework for providing desalinated water across the border. This case study provides an overview of the physical and social characteristics of this rapidly growing urban center, with an emphasis on water availability and the water supply network. It also highlights the physical and social vulnerabilities that this community faces in light of growth and climate change challenges. This case study is based on qualitative data on the water management perspectives of local, state-level and national stakeholders and decision-makers that were solicited in a series of stakeholder workshops and interviews in 2008-2009 as well as archival and scholarly sources.

BACKGROUND AND CONTEXT

Puerto Peñasco is located just outside the southeastern boundary of the Upper Gulf of California and Colorado River Delta Biosphere Reserve and the southwestern boundary of the Pinacate and Gran Desierto de Altar Biosphere Reserve. It lies 100 km (62 mi) south of the U.S.-Mexico border and 543 km (337 mi) northwest of the Hermosillo, the capital of Sonora (Figure 1).

The town was settled in 1927 by fisherman who established the first permanent fishing camps in the region. In recent years, this once-quiet fishing village has been transformed into the most important tourist destination in Sonora and is targeted to become one of thirty-two major resort destinations in Mexico under "Agenda 21 Para el Turismo Mexicano," the national tourism and sustainable development plan (H. Ayuntamiento 2007a). Puerto Peñasco's proximity to the Arizona border makes the vast beaches and aquatic opportunities an appealing destination for vacationers, retirees and second-home buyers from the major urban areas of Phoenix and Tucson.

Vulnerability is constructed and experienced at distinct scales in Puerto Peñasco due to the town's dual personality. Like many Mexican resort towns, Peñasco boasts endless hotel and upscale residential developments along the most pristine parts of its coastline, while local people live inland in poor neighborhoods largely invisible to the tourist or new homebuyer. The greatest limiting factor to continued growth in the region is its scarce water resources, which are expected to be negatively impacted by projected climate change in the region.

Figure 1. Arizona—Sonora border region (Wilder et al., 2010).

CLIMATE CHARACTERISTICS

This region is an arid desert with hot temperatures, dry winters and torrential summer rains. The *municipio* of Puerto Peñasco receives an average of 93.7 mm (3.7 in) of rain per year. As part of the North American Monsoon annual precipitation pattern, the temporal distribution of this precipitation is very uneven. July and August are the wettest months, during which the rain typically comes in heavy torrents. The rest of the year, there is little rainfall and runoff. July, August and September are the hottest months with temperatures between 30ºC (86ºF) and 43ºC (109 ºF). The greatest rates of evaporation occur from May to September with an average monthly evaporation rate of 210 mm (8.27 in). In contrast, December, January and February are the coolest months with temperatures reaching below 11ºC (51.8ºF). The region experiences an average of 10 to 30 days of frost each year, typically in January and February (USTDA 2008, H. Ayuntamiento 2007a).

This region is highly vulnerable to intraseasonal, interannual and interdecadal climate variability that contributes to extreme climate events, including both floods and drought (Hallack-Alegria & Watkins, 2007; Magaña & Conde, 2000; Comrie & Glenn, 1998). In Puerto Peñasco, the wetlands and estuaries are particularly vulnerable to flooding because the flooding river water can mix with the tide water and expand the area of inundation. There are two areas that experienced historic flooding during heavy rains in 1984-85 (Estero Morou and La Pinta). Current development patterns do not take these sensitive estuary and wetland areas into account (H. Ayuntamiento 2007a).

Puerto Peñasco, like the rest of the region, is in an extended drought cycle. Decreased precipitation, in addition to increased groundwater pumping, has contributed to the overexploitation of the surrounding aquifers. The lower water table increases the amount of electricity needed to pump the water, thus increasing the cost of pumping water. Farmers in the few existing *ejidos*, or rural farms, near the city of Puerto Peñasco, have found the increased cost of groundwater pumping, along with reduced agricultural credit, have made farmer in the region prohibitive (personal communication, April 2009).

Although areas to the south of Puerto Peñasco are subject to tropical cyclones and hurricanes, the *municipio* is protected by the large mountain ranges on the Baja peninsula and two large islands (Tiburon and Angel de la Buarda) located in the Gulf of California which form natural barriers that protect the *municipio* from extreme storms. However, it is important to note that cyclones can develop in the Sea of Cortez, typically beginning in the latter part of July. From 1952-1992 there have been 12 hurricanes and tropical storms that affected the region. The estimated probability of a hurricane hitting the *municipio* is 0.05% and 0.10% for tropical storms (H. Ayuntamiento 2007a).

This region has been called “the front line of ongoing climate change” (Jonathan Overpeck, cited in Harrison 2009), which is expected to negatively affect this region with overall rising temperatures, increasing evaporation, increased variability of rainfall, and an increase in the length of dry spells (Seager et al. 2007, figure 2). Regional models predict that surface temperature may increase by 2ºC (3.6ºF) (Magaña and Conde 2000). Precipitation projections are uncertain, but there is likely to be an increased variability in the rainfall patterns, with increased precipitation during extreme events. Extreme weather events including floods, droughts, heat waves and interannual variability in precipitation are expected to become more intense and more frequent. Future climate change is projected to have deleterious impacts on water supply in northwest Mexico, with reduced water supply due to higher temperatures, reduced snowmelt, and longer, more severe droughts than those we have experienced in recent memory (Díaz-Caravantes and Wilder nd:23).

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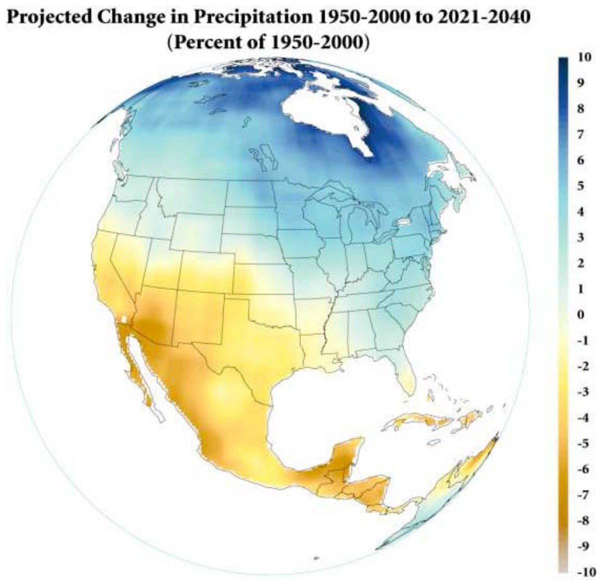

Source: Seager, R. and M.F. Ting, et al. 2007.
Science 316 (5828):1181-1184 (pending copyright permission)

SOCIOECONOMIC CONTEXT OF PUERTO PEÑASCO

This region is “doubly exposed” (Leichenko and O’Brien 2008) to the challenges of climate change and growth pressures associated with economic globalization. The border region is one of the most rapidly growing areas within both Mexico and the U.S. The state of Sonora has experienced higher than average growth rates due mainly to the accelerated border industrialization affects of the North American Free Trade Agreement (NAFTA) (Ray et al. 2007). In the 1990s, the capital city, Hermosillo, experienced an annual growth rate of 3.13%, as compared to the national average of 2.0%, while the border city of Nogales grew at a rate of 4.0% per year (*ibid*). The burgeoning coastal resort town of Puerto Peñasco has experienced similar trends, although the main driving force of growth has been in the tourist sector, rather than industrialization. In recent years, growth has increased dramatically due to immigration and touristic development (Plan de Desarrollo Ubano 2007) (Table 1). The growth rate has jumped from 1.6% from 1990 to 2000, to 6.64% during 2000 to 2005 (INEGI 2005). The current population of the *Municipio* of Puerto Peñasco is 44,875 (INEGI 2005, figure 3). It is primarily an urban *municipio* with 98% of the population living in the city of Puerto Peñasco. The *municipio* estimates that by 2030 the population could more than double to 98,000 habitants (H. Ayuntamiento 2007b).

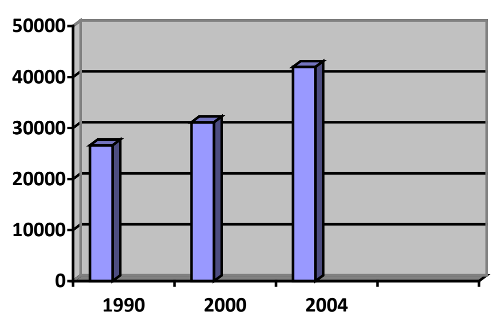

Figure 3. Population growth in Puerto Peñasco 1990-2004 (from H. Ayuntamiento 2007a, INEGI 2005)

The economy of Puerto Peñasco is based primarily on the fishing and tourist sectors. There are 12 seafood packing plants that produce over 3,000 tons of seafood annually, most of which is exported to Arizona and California (USTDA 2008, H. Ayuntamiento 2007a). The *municipio* has 125 large fishing boats and 300 smaller fishing boat and the fishing industry provides over 1,300 jobs (H. Ayuntamiento 2007a). The marine resources of Puerto Peñasco make the state of Sonora one of the main producers of seafood for both domestic consumption and international export. The fishing opportunities also make the town a popular destination for sport fishing.

Tourism and real estate development have also quickly become important economic sectors. According to the Association of Puerto Peñasco Developers, more than a million tourists visit Puerto Peñasco each year (USTDA 2008). As of 2005, there were 10,924 hotel rooms, 30% of which are hotels and 70% are time-share vacation homes and condominiums. The most recent information available on construction from 2005 indicates that construction trends are likely to accelerate in the future. As of 2005, there were projects either in construction or authorized to begin construction that would build an additional 26,002 rooms for a total of 36,000 rooms. Another 22,839 rooms had been authorized, pending completion of the sales permits that would result in a total of 59,765 rooms. Two major projects were identified that could potentially add another 105,554 rooms (Mayan Palace and Sandy Beach Resort) for a total of 165,289 if completed (H. Ayuntamiento 2007a). RVs are also an important part of the tourist industry. There are 1,626 spaces at 11 different trailer parks. There are several restaurants and bars associated with the tourist industry (H. Ayuntamiento 2007a).

The high tourist season runs from March to May, with another peak in October. Visitors mainly come from Phoenix (24%), Mexicali (11%) and Tucson (10%). Puerto Peñasco is located in the "free zone" which does not require international visitors to obtain a visa. Data collected by the *municipio* shows that visitors to Puerto Peñasco spend an average of $50 per day. This is significantly lower than nearby resorts where visitors spend an average of $96 per day in Rosarito and $450 in Los Cabos (H. Ayuntamiento 2007a).

Local political leaders recognize that water scarcity is one of the most important limiting factors for long-term growth in the *municipio* (USTDA 2008). However, as indicated by the increasing number of permits approved for new hotel developments, the *municipio* is not scaling back the level of touristic development. Therefore, it is important to consider the water demands of the tourist industry. The *municipio* calculates that the tourist sector uses approximately 599 liters per day per capita and 320 liters per day per room (H. Ayuntamiento 2007a). In addition to the hotel itself, resorts often build a golf course, which use an average of 30 liters per second (or 9 million liters annually) for maintenance. Currently, all of the residual and treated water is used to irrigate resort golf courses (CEA, n.d.). In 2000, nine new hotel developments were approved, five of which proposed to build a golf course (Pencky 2000).

In addition to the current and proposed resorts, the *municipio* is making, or plans to make, significant investments in infrastructure to facilitate growth. These include a recently completed highway, known as the "Carretera Costera," which connects Puerto Peñasco with San Luis Río Colorado. This improved, more direct route may increase domestic tourism by residents in nearby Mexicali, as well as international visitors from the San Diego area. The Carretera Costera will extend south to Guaymas for a total of 600 km (373 mi) of new roads. Also, a newly upgraded international airport opened in November 2009. This facility will bring in flights from nearby states in Mexico and the U.S. and is expected to broaden the range of visitors.

There has been discussion of constructing a number of mega-projects in the region. These include a proposal to build "Corredor CANAMEX," an integrated highway that would run through North American connecting tourist destinations from Canada to Mexico. There is also a proposal to build a "Nautical Ladder" ("*Escalera Nautica*"), or series of connected ports throughout the Sea of Cortez to facilitate the visitation by yacht, sailboat and cruise lines. Lastly, there has been discussion of building a mega-resort in Puerto Libertad, south of Puerto Peñasco, which would develop a 72-square mile area into a complex of hotels, condominiums, golf courses, an equestrian center and

Formula One race track. However, environmental concerns have, for the moment, put the latter two projects on hold.

ENVIRONMENTAL HISTORY OF WATER IN THE REGION

The *municipio* of Puerto Peñasco is located within the Sonoyta River watershed, which begins northwest of the city in the Sierra del Pozo Verde and discharges into the Sea of Cortez 23 km (14 mi) east of the city. Puerto Peñasco is part of the Hydrologic Region #8 as designated by the national water commission (CONAGUA). There is a relatively long history of monitoring the groundwater in this coastal region by the federal agency. Historic records indicate that in the early 1970s a series of new wells were drilled which led to overdrafting of the aquifer, creating a global water balance deficit of 20.81 hm^3 in 1978. Overdrafting has led to saline intrusion into some parts of the aquifer and threatens to cause land subsidence in some areas. The most recent water balance study for the Sonoyta-Peñasco aquifer conducted by CONAGUA in 2005 indicates that the water deficit is less than it was thirty years ago, but the water balance is still a negative 4.94 hm^3. The main uses of groundwater from the Sonoyta-Peñasco aquifer (which includes the *municipios* of Puerto Peñasco, Plutarco Elías Calles, Caborca and Altar) are agriculture (40%), urban uses (37%), fisheries (6%) and other (17%) (CONAGUA 2005). The report concludes that, given the on-going water balance deficit and overdrafting of the aquifer, new wells should not be permitted to tap the aquifer. To support new growth in the region, namely in Puerto Peñasco, the state water agency (CEA) has mandated that new water sources and/or conservation measures be implemented.

Currently, the *municipio* obtains its water supply from 11 deep wells, ranging from 58m (280ft) to 200m (656) ft in depth. However, only 8 of the 11 wells are operational. These wells are located just outside the boundaries the *ejidos* Ortiz Garza (23 km/14.4 mi from the city) and John F. Kennedy (about 45 km/28 mi away). Approximately 360 liters per second (lps) of water are pumped out of both water well fields.

WATER NETWORK DISTRIBUTION, EFFICIENCY, AND COSTS

The water supply system for the *municipio* of Puerto Peñasco is a 40 year old system composed of 30' pipes that extends for 71 km (44 mi). Due to the age of the infrastructure and lack of investment, the *municipio* loses 60% of its water to leaks in the pipes (CEA n.d.). There are 14,422 registered water users connected to the municipal water supply system (USTDA 2008, H. Ayuntamiento 2007a). According to 2000 Census, 91% of the houses in the municipality have water, which is better coverage than the state of Sonora (88%) and the nation as a whole (89%) (H. Ayuntamiento 2007a). Most of the registered water users are charged a fixed fee for services (93%). The remaining users (7%) are connected to water meters and are charged based on a tiered-fee system (USTDA 2008) (see Table 1).

Type of water user	Users charged a fixed fee	Fee based on water metered
Domestic	11,763	659
Commercial	844	248
Industrial	15	81
Tourism related	758	54
Totals	13,380	1,042

Table 1. Types of water users and fee system (from USTDA 2008:15)

Following the 1992 water decentralization reforms, the responsibility for managing water has been shifted to the local level. Nevertheless, decentralization exists largely on paper with most strategic decisions and budget capacity remaining centralized in Mexico City (OECD 2003). Decentralized authority has been limited by lack of financial and technical resources (Pineda 2005).

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In Puerto Peñasco, the potable water service and sewerage is managed and operated by the Organismo Operador Municipal del Sistema de Agua Potable, Alcantarillado, y Saneamiento (OOMAPAS). OOMAPAS bundles the water supply and wastewater management services into a single bill based on the volume of water used. Like many water agencies, OOMAPAS struggles to recover the full cost of its services. It is estimated that about 20% of water users do not pay their water bills (USTDA 2008:4, table 2). In addition to collecting payment, OOMPAPAS has introduced a new tier scheme for water users who have a water meter to encourage water conservation. Additionally, there are substantially different prices for the different sectors. Domestic households with meters pay $45 pesos ($3.50 USD) for 1 to10 m³, plus $5 pesos ($0.39USD) for each additional cubic meter from 11 to 20 m³. Commercial metered users pay $98 pesos ($7.60USD) for 1 to10 m³, plus $10 pesos ($0.78USD) for each additional cubic meter from 11 to 20 m³. The metered tourist industries have a minimum quantity of 20 m³ and pay $279 pesos ($22USD) for 0 to 20 m³. They pay an additional $11 pesos ($0.85USD) for the next additional 21-30m³.

	Water/wastewater charges, pesos	Collected, pesos, %	% Collected	Uncollected, pesos, %	% Uncollected
2003	28683137.01	21782813.76	76%	6900323.25	24%
2004	31019946.49	25334093.38	82%	5685853.11	18%
2005	35024069.08	28402541.95	81%	6621527.13	19%
2006	45047589.51	35674073.53	79%	9373515.98	21%

Table 2. Cost Recovery for Water Service Provision in Puerto Peñasco (from USTDA 2008:15)

The *municipio* has a lower than average sewage connection rate, with 69% of the houses connected to the drainage system, as compared to the nation as a whole (78%) (H. Ayuntamiento 2007a). Of those connected in Puerto Peñasco, about 85% are domestic, 10% commercial, 1.10% commercial and 3.04% tourism. The sewerage system collects and transports about 240 lps (USTDA 2008). There are 2 wastewater treatment facilities. The first is an oxidation pond system operated by the Mayan Palace, and is for the exclusive use of the private tourist resort. The second is an activated sludge system operated by a group of tourism businesses. Treated effluent from both facilities is used for the irrigation of golf courses and green spaces (USTDA 2008, H. Ayuntamiento 2007a).

CURRENT AND FUTURE WATER DEMAND

The state water agency (CEA) and the *municipio* have estimated present and future water demands in Puerto Peñasco. The current population of nearly 49,000 inhabitants uses 3000 liters per person per day. The total average demand is 313.5 lps. The tourist sector accounts for 90 lps of this demand. The current water system can supply 430 lps. However, 60% of the water is lost due to leaks in the deteriorating distribution network. The city receives a water flow of 270 lps (CEA n.d.). The *municipio* estimated the water demand for 2030 based on a projected population of 98,000 inhabitants using 300 liters per person per day. Planners expect tourist demand to increase significantly to 343 lps (over three times the current rate of 90 lps) and total demand will average 785 lps. As noted above, due to the global water balance deficit of the aquifers, it is not possible for the *municipio* to simply drill more wells and extract more groundwater to meet the growing water demands. Instead, these demands will have to be met by alternative management strategies that focus on supply side and/or demand side management.

INFRASTRUCTURE AND MANAGEMENT IMPROVEMENTS

The OOMAPAS office, as managed by the previous administration of Puerto Peñasco (2006-2009) emphasized 5 programs to improve water management in the *municipio*. These programs include education and conservation efforts, legal and economic incentives, and investment in physical infrastructure. The first program, "*Cuidado del Agua*" ("Watch the Water") is a water conservation education program based in primary and secondary schools, as well as at the university level. The program trains young people to become "inspectors" who keep an eye out for misuse of water in their *colonia* (neighborhood). These student "inspectors" can report incidences of water misuse to OOMAPAS for further legal action.

The second program is "*OOMAPAS en tu Colonia*." ("OOMAPAS in your Neighborhood"). This is also a water conservation education program, but aimed at adults. OOMAPAS employees visit various *colonias* and talk about how OOMAPAS operates and how citizens can help to conserve water.

A third program takes a regulatory approach and imposes fines for the misuse of water such as: overwatering the landscaping, using water to clean down the sidewalk or patio, using too much water to wash a car, or not fixing a leak within a specified time period. Residents are typically given three warnings before a fine of $700 pesos ($54USD) is levied.

A fourth program, which began in 2008, has promoted the installation of water meters. Initially, many of the *colonia* residents were against the meters because they were accustomed to a fixed rate and feared metering would increase their monthly water bill. OOMAPAS has struggled to implement the metering program because residents often destroyed the meters or collect petitions to have the meters removed. There are currently four *colonias* with meters, and although this is an unpopular program, OOMAPAS hopes to expand the network of meters.

Associated with the metering program, OOMAPAS has changed the tariff rates to encourage water conservation. OOMAPAS tries to assure residents that metering will actually work in their favor because residents were previously charged a flat rate for using 0 to 20 m^3. The average water bill for a two-month period in a non-metered flat-rate household was $370-$390 pesos ($29-30USD). But the new tariff system allows residents to pay for smaller blocks of water beginning with a minimal charge for 0 to10m^3. According to OOMPAPAS, most metered residents use less than 10m^3 and now pay only $45-$70 pesos ($3.50-$5.40USD) for a two-month period.

The fifth program undertaken by the previous administration was a water-sectorization project (Sectorizar Informe Hydraulic). One of the *municipio's* greatest challenges has been maintaining adequate water pressure to reach the center of the city, which is furthest from the uptake wells. The sectorization program was initiated by the CEA based on their water balance study of the Sonoyta-Peñasco aquifer which prohibited the drilling of additional wells. The goal was to get the same amount of pressure throughout the city by grouping different regions of the city together for water distribution. In 2007, the city spent $49 million ($3.8 million USD) to install 18.5 km of 30'' PVC pipe and large water tower with 8,000 m^3 storage capacity. In 2008, the main water line, which was the cause of most leaks, was replaced with a new 30 in PVC pipe. Due to decreased leakage and water loss, the water pressure jumped from 270lps to 550lps. However, there was a large amount of sand that had been sucked in at the intake wells was present in the system. The increased pressure in the new main line pushed this sand through the network and discharged into residents' household plumbing systems and caused many pipes to clog. Since the sand is too fine to be filtered out at the pumping stage, the city decided to build a supply tank. Now, the water is pumped and allowed to settle so that the particulates will congregate on the bottom and can be scraped out prior to water distribution.

The water infrastructure and management priorities for the *municipio* include: repairing leaks and replacing deteriorating pipes, expanding the water conservation education programs, improving the administrative procedures to ensure collection of water bills from all users, adopting policies for regulating further development along the coast and estuaries, studying the possibility of installing an automated water supply system using SCADA to improve efficiency, and determining the feasibility of building a desalination plant to augment water supplies (USTDA 2008, H. Ayuntamiento 2007b). Of these potential future water management issues, the option that has received the most attention is that of developing desalination technology. This is due, in part, to binational interest from water authorizes in Arizona in water augmentation through desalination that could benefit both Sonora and Arizona.

MEETING FUTURE WATER DEMANDS THROUGH DESALINATION

In February 2008, the *municipio* of Puerto Peñasco contracted with the U.S. Trade and Development Agency (USTDA) to conduct a study to determine the feasibility of building a desalination plant near the city. The *municipio* is interested in pursuing a desalination plant to meet the water needs of the city, as well as to support the growing tourist sector in the region. The previous president of the *municipio*, Heriberto Rentería Sánchez, is "'convinced' that seawater desalination is the only option for this desert community at this point in time" (USTDA 2008:20). The new president who took office in October 2009 agrees that desalination is the best option for the *municipio*.

The coordinators of the desalination project describe the proposed plant as the "the largest desalination plant in Latin America" (Ayala and Reed, personal communication, 2008). The plant would be constructed in phases, with the first phase producing 1,000 liters of freshwater per second. Produce this quantity of water will require a significant supply of energy. The coordinators have been in contact with researchers at the Arizona Research Institute for Solar Energy at the University of Arizona to explore the energy provisioning aspect of the project. The coordinators would like to build a 50 megawatt concentrated solar energy facility. To manage the saltwater concentrate, Ayala and Reed (personal communication, 2008), state that the long-term goal is to completely capture all of the saltwater concentrate. They discussed the possibility of using the waste water to grow halophytes for commercial sale. However, for the first phase of the project, it is more likely that a saltwater dispersal system would be implemented, and saltwater concentrate recapture would be attempted in the second phase of the project. The USTDA (2008) report determined that there is potential funding for this $35 million project from both the Inter-American Development Bank (IADB) and the Export-Import Bank of the United States (Ex-Im Bank).

Although the initial aim of the Puerto Peñasco municipal government's desalination project proposal is to meet the city's own water needs, the coordinators of the project note that water managers in Arizona have also expressed interest in a binational desalination plant. There are two ways that investment in a binational desalination plant in Puerto Peñasco, Sonora, Mexico could help the state of Arizona meet its water needs. First, if Arizona invested in a desalination plant to provide Puerto Peñasco with freshwater, it could then exchange Mexico for an equivalent amount of its Colorado River allocation. Instead of allowing 1.5 million acre-feet of Colorado River to reach the Mexico border, Arizona could take over the rights to some (or all) of this water. Second, but less cost effective, Arizona could also invest in a series of aqueducts and pump the freshwater from the Puerto Peñasco desalination plant to the Imperial Dam near Yuma, Arizona. This water would then be available for use by either agricultural users in the southern part of the state or moved elsewhere in the Colorado River Basin for use or exchange for other Colorado River rights (Ayala and Reed, personal communication, 2008).

SOCIAL VULNERABILITY

As noted by Ray et al (2007), the U.S.-Mexico border is a highly vulnerable region due to climate variability, population growth, water scarcity, uneven access resources, and social inequalities. The *municipio* of Puerto Peñasco faces these same challenges as the region at large, but emphasis on touristic development in recent years poses additional challenges and vulnerabilities, as well as opportunities. A 2004 report determined that Puerto Peñasco had a socioeconomic index of 0.92, making it a *municipio* with a "very high" level of development. The *municipio's* human development indicator is 0.821, which is slightly higher than both the state (0.818) and national averages (0.801).

The infant survival rate in Puerto Peñasco is 0.86, higher than both state and national levels (.80). The level of schooling index of .85 is slightly lower than the state (.9) and national (.86) indices. In sum, these indicators suggest that the *municipio* offers a good quality of life in terms of health, education and GDP per capita (H. Ayuntamiento 2007a).

Despite the recent investments in the tourist sector, the economic statistics for Puerto Penasco remain at or below the state level. The per capita income of 28,400 pesos ($2,185USD) is significantly lower than the state per capita average of 45,600 pesos ($3,508USD). Within the *municipio*, among the most common and best paying jobs are in the fishing industry with average per capita salaries of 34,200 pesos ($2,631USD). Salaries in the tourist industry are below the municipal average (27,700 pesos or $2131USD). The most highly paid jobs are in the real estate sector, with per capita incomes of 60,100 pesos ($4,624USD), but there are very few opportunities in this sector.

The civil protection service (*Protección Civil*) is charged with maintaining order during and after natural disasters. But the agency suffers from a lack of resources and personnel capacity. The *municipio* would like to improve their personnel training, databases and equipment and expand the rapid emergency response program.

Preliminary analysis of transcripts from interactive stakeholder workshops and follow-up interviews with local water managers, emergency responders, government officials, and university researchers indicate that the managers feel that the lack of weather stations, long-term weather data and climate information, along with insufficient institutional capacity to process climate information, is a source of social vulnerability.

Interviews with local *ejiditarios* near Puerto Peñasco suggest that a combination of decreased access to credit to pay for agricultural inputs and groundwater pumping costs, along with prolonged drought, has limited their ability to maintain rural livelihoods. For example, the *ejido* John F. Kennedy used to support 47 *ejiditarios* who produced maize, alfalfa, and wheat and grazed cattle and goats on 100 hectares of irrigated land. Now, there is no agricultural production and only two older men continue living in the *ejido*. The rest of the families have moved to nearby urban areas or migrated to the U.S. to seek agricultural work in California and Arizona (personal communication, April 2009). During this same period, as rural agricultural production has declined, the *municipio* drilled new wells just outside the boundaries of the *ejidos* Ortiz Garza and John F. Kennedy to increase the water supply for the city of Puerto Peñasco. As Díaz-Caravantes and Wilder. (n.d.) have noted, the uneven power relations between *ejidos* and urban centers in northern Mexico is a sources of social vulnerability for many of the poorest and most marginalized residents living in the peri-urban areas.

PHYSICAL VULNERABILITY

The principal physical vulnerabilities were outlined in the climate section above. To summarize, the North American Monsoon precipitation pattern results in highly variable intraseasonal, interannual and interdecadal precipitation patterns contributing to frequent and intense floods and droughts. The estuaries and coastal wetlands are particularly vulnerable to flooding and sea level rise. The high temperatures can create dangerous heatwave conditions. Overdrawn aquifers cause saline intrusion and create the potential for land subsidence. Continued growth adds further pressures on the limited resources. A lack of planning and regulation allows development in ecologically sensitive wetland areas. Tourist and domestic development also increase the amount of solid waste and sewage that must be treated and disposed of. In addition to the ecologically sensitive zones within the city, it is important to note that the *municipio* is located near two important biosphere reserves (Upper Gulf of California and Colorado River Delta Biosphere Reserve Pinacate and Gran Desierto de Altar Biosphere Reserve).

VULNERABILITIES IN THE WATER SECTOR

In addition to these general aspects of social and physical vulnerability, our stakeholder workshops and interviews have highlighted specific vulnerabilities in the water sector in Puerto Peñasco. Preliminary analysis of the transcripts indicates the following sources of vulnerability:

- Short term 3-year planning horizons, with no planning for long-term investments
- Short-term political appointments in management agencies, rather than longer-term civil service appointments results in high turnover and limits long-term planning capacity
- Water scarcity
- Increasing water demands, including hotels and golf courses
- Inefficient water use in the agricultural sector
- Lack of water conservation by users
- Difficulty in collecting payment for water services from all water users
- Overdrawn aquifers, saline intrusion and land subsidence
- Negative impact of climate change on water supplies and precipitation patterns
- Sea level rise
- Difficulties in transferring water rights and water uses
- Limited ability to evaluate damage and needs during extreme meteorological events
- Water management with scarce financial resources
- Deteriorating or sub-optimal water infrastructure
- Lack of infrastructure to capture run-off during extreme precipitation events
- Lack of alternative supply strategies such as water reuse or rainwater harvesting
- Water-Energy nexus

STAKEHOLDERS PERSPECTIVES ON DESALINATION AS AN ADAPTIVE STRATEGY

Given the emphasis on desalination as a potential strategy for augmenting water supplies in Puerto Peñasco, we asked workshop participants to share their perspectives on this technology. Water managers, emergency responders, mangers of protected areas, environmental NGOS, and government officials addressed various pros and cons of desalination technology. In general, the proponents of the technology emphasized the benefits of the technology, including:

- Reliability
- A guaranteed water supply will encourage continued investment and growth in the region
- Reduced pressure on groundwater resources

Stakeholders expressed concern regarding the following aspects of desalination:

- Environmental impacts, particularly of brine discharge and possible contamination of groundwater aquifers
- Energy requirements and source of energy
- High cost of the project
- Impact of sea level rise on a new desalination plant
- Equitable distribution of desalinated water (i.e., How much of the water produced will benefit Peñasco and how much will be transferred to other urban centers such as Hermosillo?)
- Investment in a new desalination plant will override the need to focus on the efficiency of the distribution network (i.e., current leaks need to be fixed before more money is invested in a desalination plant, otherwise very expensive water will be wasted)

A survey completed by 48 stakeholders indicates that half the respondents (51%) believe it is likely that their city will receive desalinated water in the near future to meet needs, while 40% disagree with this statement. Sixty-five percent of respondents view desalination as just one of many options for future water management, while 29% disagree with this statement. Finally, 66% of respondents agreed that desalination is an appropriate strategy for confronting the water availability challenges of this arid region, while 16% disagree with this statement.

FRAMING DESALINATION AS AN "ADAPTIVE" STRATEGY

The purpose of this case study is to highlight opportunities and constraints for improving the region's adaptive capacity to climate change, particularly in the realm of water management. Following Pelling et al. (2008), our theoretical framework for assessing the adaptive capacity of desalination is based on whether or not this technology facilitates social learning and the development of social networks. We understand adaptive capacity to be a dynamic process based on social learning between and within institutions, rather than a static condition or set of attributes and outcomes (Pahl-Wostl 2007; Pelling et al. 2008). Given that the proposal to build a desalination plant in Puerto Peñasco has binational implications, it is important to evaluate the project and associated adaptive capacity in this transboundary context. This includes shared learning over multiple institutional scales, from individuals and local agencies to state, federal, and binational actors. Using a process based understanding of adaptive capacity, we employ three indicators: (a) dynamic, structured opportunities for social learning, (b) emergence of formal and informal networks, and (c) potential for development of adaptive pathways.

When subjected to this analysis, desalination does not rank high in our measures of adaptive capacity. While it is technological feasible to meet the region's growing water needs with desalination, it does not require a sustainable change in water users' behavior under climate change. In fact, desalination, if not coupled with conservation measures, enables a "business-as-usual" water culture—averse to social learning—and discourages sustainable water use.

The environmental consequences of the proposed desalination plant are largely unknown. There is concern about the impact of the brine, or concentrated saltwater waste, which is a by-product of the desalination process. There are currently no laws that regulate how a desalination plant operates in Mexico (López-Pérez 2009). Also, it is unclear where the energy to run the plant would come from. It is likely to be a carbon intensive process that will contribute to further greenhouse gas emissions.

Those in favor of the desalination project argue that augmenting existing groundwater sources would reduce pressures on the already overdrawn aquifers and potentially allow them to recover to nearer equilibrium levels. However, proponents of the project also perceive desalinated seawater as a "limitless" resource that would enable further growth. This additional growth is likely to negatively impact the fragile estuaries and fisheries of the Gulf of California. Furthermore, if the binational component of the project is implemented, it is likely that an aqueduct would be built through the Pinacate and Gran Desierto de Altar Biosphere Reserve. Moreover, because Arizona and Nevada would continue to use their full Colorado River allotments *plus* desalinated supply, it is unlikely that any net gains to the aquifers or to Colorado River allocations would be achieved.

In summary, we conclude that desalination, as an augmentation strategy, has a low adaptive capacity. When assessed against the indicators of social learning, network development, and creation of adaptive pathways, we find that the desalination proposal does not involve structured opportunities for social learning or changes in institutional culture or policy priorities. Data-sharing would be in the context of formal contract-based exchanges, rather than more permeable, fluid, relational kinds of knowledge exchanges such as those identified by Cash et al. (2003). New communities of practice are not anticipated to emerge from desalination strategies and binational relationships will be straitjacketed within a bounded legal framework. The desalination strategies are not only unlikely to add to adaptive capacity, they could lead to more of the entrenched, legalistic relations that have sometimes hampered cooperative, binational water management in the past. Absent a conservation strategy, these strategies enable a status-quo water culture that views desalted seawater as a limitless substitute for freshwater. Ironically, increased interdependence will ensue under the proposed desalination strategies, requiring improved cooperation between the U.S. and Mexico, yet these strategies do little to foster better communication and enhanced collaboration, and therefore could actually increase vulnerability.

DRAFT

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