

VI

Comparative Analysis of Transborder Water Management Strategies: Case Studies on the U.S.-Mexican Border

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ABSTRACT

Under any circumstances the management of water supplies is a difficult task. When multiple jurisdictions are involved—especially when water flows across international boundaries—management complexities increase dramatically. Watersheds have come to be viewed as an excellent framework for integrating the social, ecological, and economic aspects of water management. The rapidly growing population in the U.S.-Mexican border region, with the concomitant increasing requirement for scarce water resources, demands that the two countries optimize their use of water. In many areas, the U.S.-Mexican political boundary divides the drainage basins. In order to overcome this fragmentation, it is essential that the two nations coordinate their efforts in addressing water problems within the framework of those watersheds that lie astride the border.

This chapter examines the approaches to binational watershed planning that are unfolding in three different parts of the border, namely, San Diego-Tijuana, Ambos Nogales, and El Paso-Ciudad Juárez. For each, water supply and demand issues, regional water challenges, and innovative cross-border cooperative efforts are examined.

San Diego-Tijuana

The San Diego-Tijuana region is unique in many ways within the border context. While both San Diego and Tijuana command comparatively high levels of development in their own national contexts, their economic asymmetries are quite large. Such differences have important implications in the financial capacity of governments on each side of the border to meet the water needs for its citizens. Both cities are dependent on imported water. In the case of San Diego, water imports from the Colorado River and Northern California account for nearly 90% of the yearly requirements. In comparison to San Diego, Tijuana's options to meet its present and future needs appear to be much more restricted. The water imported from the Colorado River represents the only real and dependable possibility for the city. Currently, this source provides approximately 95% of its yearly supply.

Water reuse is an essential part of the San Diego-Tijuana region's water future. The San Diego County Water Authority is preparing a Regional Facilities Master Plan for the county that analyzes a variety of alternative water sources such as seawater desalination, groundwater recharge, additional water from the Colorado River via a binational conveyance system, and the recycling of wastewater.

One characteristic of the San Diego-Tijuana region that is relevant to the region's water supply is the Tijuana River Watershed (TRW). The implications of the cross-border character of this watershed are numerous, for it poses challenging circumstances in terms of binational coordination and planning. As a result of natural drainage in the TRW, sewage flows from Mexico to the Tijuana River Estuary and the surf zone of the south coastal region have been a problem for many years. In 1997, the International Wastewater Treatment Plant (IWTP) was completed to provide for advanced primary treatment of Tijuana sewage. Despite improvements in the treatment of Mexican sewage, pollution from cross-border sewage flows continues to be a problem in the Tijuana Estuary and adjacent beaches.

During the past decade, a large number of binational efforts have been undertaken by universities, government agencies, and private organizations in the region. Some notable examples include:

1. The Tijuana River Watershed Program, an undertaking that began with the development of a watershed geographic information system (GIS) in 1994 and has made possible more than a dozen projects, most of which have been binational and focused on water quality and quantity problems. They include the Goat Canyon/Cañón de los Laureles Vulnerability Assessment, the Bight of the Californias project, and the Alamar River Corridor study.
2. In 1996, the San Diego Association of Governments (SANDAG) formed the Committee on Binational Regional Opportunities (COBRO) to develop a binational policy, framework, and action plan for addressing water and other problems in the San Diego-Tijuana border region. Through COBRO and under the auspices of the Border Liaison Mechanism (BLM), a Border Water Council (BWC) was established in 1997. Representatives of the San Diego County Water Authority (SDCWA) and la Comisión Estatal de Servicios Públicos de Tijuana (CESPT) are the co-chairs of the council. BWC's major effort has been to encourage the exploration of options for the conveyance of water from the Mexicali and Imperial Valleys to San Diego and Tijuana. To facilitate transborder approaches in SANDAG, a high-level position of Director of Binational Planning and Coordination and a Borders Policy Committee (BPC) have been created. With this new organization, COBRO will send policy recommendations regarding binational matters to the Borders Committee, which then can elevate them to the full board.
3. Toward the goal of insuring adequate water supplies for the San Diego-Tijuana region, the State of California and the SDCWA have funded the Regional Colorado River Conveyance Feasibility Study to explore potential routes for an aqueduct from the Colorado River to be shared by SDCWA and state agencies in California. The binational alignment options study is managed by a technical committee comprised of seven U.S. and Mexican agencies. The study of transborder options is based on a recognition that a conveyance facility may be more cost-effective if multiple agencies are involved. The joint study is an excellent example of how agencies from the U.S. and Mexico can work together to determine the most effective way of meeting regional water needs.

Ambos Nogales

Preliminary population data from the 2000 census indicate that the current population in Ambos Nogales exceeds 200,000. Population increases are generating a growing need for water in the municipal and industrial sectors and a range of related water quality issues. Water resource management issues in Ambos Nogales include provision of water supply to sectors of society with competing needs, the needed infrastructure and “plumbing” to deliver water to major sectors of Nogales, Sonora, wastewater collection and treatment, and management of groundwater/surface water interactions.

Groundwater is the major source of water for the region. Wells in both the U.S. and Mexican portions of the basin affect groundwater availability and surface water flows in the river. Increasing urban groundwater extraction is impacting long-standing agricultural use of groundwater in the basin, and urban surface water is negatively impacting flows in the river. Both of these conditions raise questions concerning sustainable use of groundwater in the future. In addition, provision of drinking water is a particularly pervasive and immediate need in Nogales, Sonora, and this poses special challenges for regional approaches to regional water resource planning.

Presently, approximately 10 million gallons per day (MGD) of wastewater generated in Nogales, Sonora, are diverted to the Nogales International Wastewater Treatment Plant in the United States. The discharge of treated effluent from the plant has a major impact on surface water and groundwater dynamics within the downstream reaches of the river. The regular discharge of this effluent is the largest source of groundwater recharge in the region. Notably, while in Mexico, this wastewater is owned by the Mexican government. As wastewater, it lacks immediate value; once treated, however, this wastewater can have value as reclaimed water for a variety of uses. When the wastewater crosses the border and enters the plant on the U.S. side, it is owned by the International Boundary and Water Commission (IBWC) or the City of Nogales. After the effluent is treated and discharged into the river, it becomes an appropriate water resource within the State of Arizona.

Several significant efforts are underway in the region to address the area’s water supply problems and manage regional wastewater.

These include the following transborder efforts:

1. The facilities planning process (FPP) undertaken in the Ambos Nogales region is a binational planning effort that extends technical support to regional water resource planning agencies for the construction of needed wastewater management infrastructure. Within the facilities planning process, the IBWC and its Mexican counterpart, Comisión Internacional de Límites y Aguas (CILA); the Sonora state water authority (CoAPAES); the Arizona Department of Water Resources (ADWR); the City of Nogales, Arizona; and a range of private sector consultants have cooperated over the last few years on a regional water infrastructure effort. As a result of this cooperation, approval was given for increased treatment capacity at the existing Nogales International Wastewater Treatment Plant, upgraded treatment processes, and replacement of outfall facilities. Both wastewater treatment and potable water treatment facilities are also to be built in Sonora.
2. Two efforts have developed in conjunction with the Santa Cruz Active Management Area (SCAMA) that are of relevance to the water resource management issues in the reaches of the river below Ambos Nogales: the SCAMA Groundwater Users Advisory Council and the SCAMA Settlement Group. The Groundwater Users Advisory Council is an official governmental effort where by private citizens who are active users of groundwater resources regularly meet with SCAMA staff to discuss groundwater uses in the region and various means to manage these resources more effectively. A less formal effort is the SCAMA Settlement Group. The organization is comprised of private citizens who own water rights within SCAMA, attorneys representing the legal interests of large water rights holders in the region, and various staff members of ADWR. The goal and intention of the group is to work toward resolution of water rights adjudication in SCAMA outside the legal process that has been ongoing for many years.
3. During the 2002 legislative session, legislation was introduced in Arizona, the goal of which was to establish some manner of Santa Cruz Water Management Authority. Issues concerning the ability of the authority to generate revenues for projects, the

manner by which a guaranteed flow to Mexico could be effected, the management of the authority, and a lack of overall detail, resulted in the legislation not making it out of committee. However, there are plans to reintroduce the bill in future legislative sessions and for SCAMA and ADWR staff to take a more active role to help address some of the concerns about the most recent bill. Although the arrangement of water flows, ownership, and potential terms of exchange is quite complex, some form of Ambos Nogales binational groundwater replenishment and management district has considerable potential to meet regional water resource management needs well into the future. The potential for a binational recharge district clearly acknowledges the hydrologic connectivity of ground and surface waters and the manner by which this connectivity is an important element in the dynamics of water uses on both sides of the border.

Paso del Norte

Regional water problems are closely linked to rapid population growth and high levels of poverty that have combined to create a situation where water distribution has not kept up with growth in water demand. One of the primary concerns is municipal water supply, which is where most of the growing need lies. As municipal and industrial demand has increased, groundwater basins are becoming contaminated or depleted such that serious shortages are expected in the near future. Estimates are that at El Paso's historic rates of withdrawal, potable water in the Hueco Bolson will be exhausted by the year 2025; Ciudad Juárez is expected to experience a major deficit by 2004. Water providers have been forced to look for means to extend the limited reserves in the Bolson, use surface water, and seek alternative supplies.

Competition for Rio Grande water, therefore, has increased significantly as growing urban areas face serious shortages and look to the river for replacement and new supplies. Ciudad Juárez and Las Cruces are still dependent on groundwater; El Paso is using the Rio Grande to meet demand during the irrigation season. Ciudad Juárez is currently investigating use of surface water for municipal needs.

Rising environmental concerns have also focused a need for water to be allocated for instream flows. Surface water allocation to agriculture has created friction over water distribution between use sectors. Although increased competition, to this point, has not resulted in an alteration of the allocation framework, small-scale transfers of water from agriculture to municipal use have been achieved through the leasing of water rights. Finally, because of asymmetry in growth and allocation, Mexican urban areas are experiencing pressure on water resources at a faster rate than U.S. communities. Under the current allocation structures, however, the potential for using agriculture waters to address municipal-industrial concerns is lowest in the Mexican portion of the Paso del Norte.

The past several decades have seen several cross-jurisdictional planning endeavors that have included the following:

1. The New Mexico-Texas Water Commission arose in 1991 out of the settlement of a lawsuit in which El Paso sued for the right to drill wells in New Mexico and pump that water to El Paso to meet municipal needs. The commission was established to look at methods to plan for surface water use between the parties. It successfully proposed the El Paso-Las Cruces Sustainable Water Project, which is a series of canal improvements, surface water treatment plants, distribution systems, and aquifer storage and recovery infrastructure. Although the clearly defined structure set up by the settlement agreement makes it difficult for other parties to join and for alternative concepts of water allocation, management, and planning to emerge, the Paso del Norte Watershed council was formed as a means to provide input on mitigation and other environmental issues associated with the Sustainable Water Project. The environmental impact process also has brought public input into the project. Mexico is still not a party to the commission, but commission members are seeking ways to incorporate Mexico into the dialogue.
2. The Paso del Norte Water Task Force (PdNWTF) attempts to promote the sharing of information and understanding among participants in order to encourage coordination in individual planning and management efforts. The PdNWTF was convened by the IBWC in 1999 and was initiated by the Houston Advanced Research Center with support from the Hewlett Foundation. The members of the PdNWTF are

binational stakeholders that have municipal, irrigation, and private water interests. An academic-scientific Support Team assists the Task Force. It has had initial success in a series of dialogues where members gained an in-depth understanding of other member's operations and concerns. At present, the PdNWTf Support Team has proposed a series of projects that will attempt to provide tangible results to address specific regional water concerns.

3. The Transboundary Aquifers and Binational Groundwater Database collaborative binational study included both sections of the IBWC, Junta Municipal de Agua y Saneamiento (JMAS), the U.S. Environmental Protection Agency (EPA), Texas Water Development Board, and the New Mexico Water Resources Research Institute. It was a multi-year, multi-agency effort that collected data on the groundwater hydrology, historic water levels, pumping trends, water quality, and current and future extration estimates. The report was published in 1997 and provided data and GIS-based maps for dissemination to all parties and the public. It did not, however, make a detailed analysis of the findings nor recommendations as to future groundwater management options. The official, State Department-level of this project made both the effort and the report important to collaborative regional efforts.

Análisis Comparativo de Estrategias de la Gestión de Aguas Fronterizas: Estudio de Casos en la Frontera México-Estados Unidos

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RESUMEN

En cualquier circunstancia el manejo de recursos acuíferos es una tarea difícil. Cuando múltiples jurisdicciones están involucradas, como en el caso de aguas que fluyen a través de fronteras, estas complejidades se incrementan dramáticamente. Las cuencas acuíferas han venido a ser los marcos idóneos para integrar los aspectos sociales ecológicos y económicos del manejo de recursos acuíferos. El rápido crecimiento de la población en la frontera México-E.U. con el consiguiente incremento en la demanda de recursos acuíferos ya de por sí escasos, requiere que los dos países optimicen el uso de éstos. En muchas regiones la frontera política divide las cuencas de drenaje. Para resolver esta problemática es esencial que las dos naciones coordinen sus esfuerzos hacia la solución de estos problemas dentro del contexto de estas cuencas binacionales.

En este texto examinamos las maneras en que se esta llevando a cabo la planeación en tres partes de la frontera: Ambos Nogales, Tijuana-San Diego, y El Paso-Ciudad Juárez. Para cada uno consideraremos: abastecimiento y demanda de agua, desafíos en aguas regionales, y esfuerzos innovadores binacionales.

San Diego-Tijuana

La región San Diego-Tijuana es única en el contexto fronterizo de diferentes maneras. Aunque ambas ciudades sostienen niveles relativamente altos de desarrollo dentro de sus contextos nacionales, las asimetrías económicas son bastante grandes y tienen implicaciones importantes en la capacidad financiera de respuesta a las demandas de abasto de agua. Ambas ciudades dependen de agua importada. En

el caso de San Diego importaciones del Río Colorado y del norte de California representan el 90% de los requerimientos anuales. En contraste, Tijuana parece tener menos opciones para atender las demandas presentes y futuras. El Río Colorado es la única fuente segura real para el abasto de la ciudad y representa el 95% del abasto anual de agua.

La reutilización del agua es parte esencial del futuro del agua en esta región. El *San Diego County Water Authority* está preparando un plan maestro para el condado que analiza una variedad de fuentes alternas de agua como desalinización de agua marina, recarga de mantos acuíferos, agua adicional del Río Colorado por medio de convenios binacionales y tratamiento de aguas residuales.

Una característica relevante al abasto regional de agua es el *Tijuana River Watershed* (Cuenca del Río Tijuana). Las implicaciones del carácter transfronterizo de esta son numerosas y poseen retos únicos en términos de planeación y coordinación binacional. Como resultado del drenaje natural de la cuenca del Río Tijuana, las aguas residuales fluyen de México al estuario de este río y la zona de *surf* de la región de la costa sur ha sido un problema por varios años. En 1997 se completó la planta binacional de aguas residuales para proveer tratamiento primario avanzado de las aguas residuales de Tijuana. A pesar de mejoras en el tratamiento de aguas residuales mexicanas, la contaminación generada por el drenaje transfronterizo sigue siendo un problema en el estuario y playas adyacentes.

Durante la década pasada un número importante de esfuerzos binacionales han sido llevados a cabo por universidades, agencias gubernamentales y organizaciones privadas de la región. Algunos ejemplos más notorios son los siguientes:

1. Programa de la cuenca del Río Tijuana comenzó con el desarrollo de un sistema de información geográfica (GIS, por sus siglas en inglés) de la cuenca en 1994 y ha hecho posible la ejecución de más de una docena de proyectos, la mayoría binacionales y enfocados en problemas en la calidad y cantidad de agua. Entre ellos están: Estudio de vulnerabilidad del Goat Canyon/Cañón de los Laureles, el proyecto del *Bight of the Californias*, y el estudio del corredor del Río Alamar.
2. En 1996, la asociación de gobiernos del San Diego (SANDAG, por sus siglas en inglés) formó el comité de oportunidades

regionales binacionales (COBRO, por sus siglas en inglés) para desarrollar una política binacional y un plan de acción para enfrentar ciertos problemas incluyendo los del agua en la región San Diego-Tijuana. A través de COBRO y del mecanismo fronterizo enlace (BLM, por sus siglas en inglés), un consejo del agua fronteriza (BWC, por sus siglas en inglés) fue establecido en 1997. Representantes de la autoridad del agua en el condado del San Diego (CWA, por sus siglas en inglés) y la Comisión Estatal de Servicios Públicos de Tijuana (CESPT) son los co-gerentes del consejo. El esfuerzo mayor del BWC ha sido a estimular la exploración de las opciones para el transporte del agua de los valles Mexicali e Imperial a San Diego y Tijuana. Para facilitar los enfoques a través de la frontera en SANDAG, se creó una posición del director de planeación y coordinación y un comité de políticas fronterizas (BPC, por sus siglas en inglés). Con esta organización nueva, COBRO mandará recomendaciones políticas con respecto a asuntos binacionales al comité fronterizo lo cual se puede elevar al consejo.

3. Con el objetivo de asegurar el abastecimiento de agua adecuado para la región San Diego-Tijuana, el estado de California y el SDCWA han apoyado un estudio regional de la factibilidad del transporte del Río Colorado para explorar rutas potenciales del Río Colorado que sería compartido entre SDCWA y agencias estatales de California. El estudio de las opciones de alineación está dirigido por el comité técnico integrado por siete agencias estadounidenses y mexicanas. El estudio de opciones a través de la frontera está basado en el reconocimiento que un medio de transporte sería más económico con varias agencias involucradas. Este estudio conjunto es un ejemplo excelente de la efectividad de agencias de Estados Unidos y México y como pueden colaborar para determinar la manera más efectiva de cumplir con las necesidades del agua en la región.

Ambos Nogales

Los datos preliminares del censo 2000 indican que la población actual de ambos Nogales excede 200,000. Los aumentos en la población generan aun más necesidad del agua en los sectores municipales e industriales y un rango de asuntos relacionados de la calidad del agua. Asuntos relacionados al manejo de los recursos del agua en ambos Nogales incluyen una provisión de abastecimiento de agua a los sectores de la sociedad con necesidades opuestas, una provisión de la infraestructura y “plomería” para llevar el agua a los sectores de Nogales, Sonora, una provisión de la colección y tratamiento de aguas residuales y el manejo de las interacciones de aguas subterráneas y superficiales.

El agua subterránea es la fuente mayor de agua en la región. Los pozos a ambos lados de la cuenca afectan la disponibilidad de aguas subterráneas y el flujo de aguas superficiales hacia el río. El aumento en la extracción de agua subterránea disminuye la disponibilidad para el uso agrícola del agua de la cuenca y los usos urbanos también influyen negativamente en el flujo de aguas superficiales hacia el río y es una causa de alarma para la sustentabilidad futura del uso del agua subterránea. Adicionalmente, la provisión de agua potable es una necesidad generalizada e inmediata en Nogales, Sonora, y esto posee desafíos especiales para la planeación de los recursos acuáticos en la región.

Actualmente aproximadamente 10 millones de galones diario (MGD) generados en Nogales, Sonora se divierten a la planta internacional de tratamiento del agua residual en Nogales en Estados Unidos. La descarga del efluente [o agua residual] tratado de la planta tiene un impacto mayor en la dinámica del agua superficial y subterránea del río. La descarga regular del efluente es la fuente de recarga más grande en la región. Cabe destacar que mientras el agua residual está en México esta agua pertenece a México. Como agua residual, le falta valor. Una vez tratada, sin embargo, esta agua tiene valor como agua reciclada para usos de mucha variabilidad. En cuanto cruza la frontera y entra en la planta en Estados Unidos, esta agua pertenece al IBWC o la ciudad de Nogales, Arizona. Después de que el efluente es tratado y descargado en el río, se vuelve un recurso del agua dentro del estado del Arizona.

Varios esfuerzos significativos están en proceso en la región para resolver los problemas regionales de abastecimiento de agua y para el manejo de aguas residuales. Estos incluyen:

1. El proceso de planeación de facilidades (FPP en inglés) que comenzó en la región de Ambos Nogales es parte de un esfuerzo que extiende el apoyo técnico a las agencias regionales de planeación de recursos acuíferos para la construcción y el manejo e infraestructura de aguas residuales. Dentro del proceso de facilidades, las secciones esta dounidenses y mexicanas del IBWC-CILA, Comisión de Agua Potable y Alcantarillado del Estado de Sonora (CoAPAES), el departamento de recursos acuáticos del estado de Arizona (ADWR), la ciudad de Nogales, Arizona, y el rangode con sultores del sector privado han cooperado en los últimos años en un esfuerzo infraestructural regional. Como resultado de la cooperación, se aprobó el aumento de la capacidad en la planta internacional de tratamiento de aguas residuales, procesos mejorados de tratamiento, y el reemplazo de instalaciones de descarga. También se construirán más plantas de tratamiento de aguas residuales y potabilizadoras en Sonora.
2. Se han desarrollado dos esfuerzos en conjunto en el área del manejo activo de Santa Cruz (SCAMA en inglés) que son relevantes a los asuntos en el manejo de recursos acuáticos en el río debajo de Ambos Nogales, los cuales son el consejo de usuarios del agua subterránea de SCAMA y el grupo de acuerdo de SCAMA. El consejo de usuarios del agua subterránea es un esfuerzo oficial del gobierno en que los particulares que utilicen los recursos subterráneos se reúnen regularmente con personal de SCAMA para discutir los usos del agua subterránea en la región y las maneras de manejar los recursos más eficazmente. Un esfuerzo menos formal es el grupo de acuerdo de SCAMA. Esta organización está constituida por propietarios particulares dentro de SCAMA, abogados que representan los derechos legales de los dueños de los derechos grandes en la región, y varios miembros del departamento de recursos acuáticos de Arizona. El objetivo del grupo es solucionar el adjudicamiento de los derechos acuáticos en SCAMA aparte del proceso legal que ha durado años.

3. Con el objeto de establecer regulaciones en el del manejo del agua de Santa Cruz se propuso una legislación en la Legislatura Regular 45 del Estado de Arizona. Asuntos acerca de la capacidad de la Autoridad para generar ingresos para proyectos de manera tal que afectaría el flujo hacia México, el manejo de la Autoridad, y la falta de detalles en general del plan, resultó en que la legislación no se aprobara. Hay planes de reintroducir la misma legislación en futuras sesiones, con personal del SCAMA y ADWR dirigiendo los asuntos problemáticos para aumentar las posibilidades de que se apruebe. Aunque el arreglo de los flujos del agua, posesión y términos potenciales de la transferencia del agua es bastante complejo, una forma de *“Ambos Nogales Binational Groundwater Replenishment and Management District”* tiene un potencial considerable para cumplir con las necesidades del manejo del agua en el futuro cercano. El potencial de un distrito de recarga binacional reconoce claramente la conectividad hidráulica de aguas subterráneas y superficiales y la manera por cual esta conectividad es un elemento importante en la dinámica de los usos del agua a ambos lados de la frontera.

Paso del Norte

Problemas regionales del agua están relacionados con el crecimiento rápido de la población y con los niveles altos de pobreza que se han combinado para crear una situación en cual la distribución del agua no ha podido satisfacer las demandas crecientes de agua. Uno de los asuntos municipales primordiales es el abastecimiento de agua, el cual es donde se concentra la mayor necesidad de crecimiento. Mientras la demanda municipal e industrial aumenta, cuencas del agua subterránea se están contaminando o agotando; se esperan faltas mayores en el futuro cercano. De acuerdo con proyecciones basadas en velocidades históricas de extracción de agua, el agua potable en el Hueco Bolsón será agotada en 2025 y se espera que Juárez sufrirá una falta del agua por el año de 2004. Se han esforzado proveedores del agua en buscar una manera de extender sus reservas limitadas en el Bolsón, utilizar agua superficial y buscar abastecimientos alternativos.

La competencia por el agua del Río Bravo ha aumentado sensi-

blemente a la vez que regiones urbanas experimentan faltas graves del agua mientras buscan abastecimientos nuevos del agua. Ciudad Juárez y Las Cruces todavía dependen del agua subterránea. El Paso utiliza el agua del Río Bravo para cumplir con la demanda durante la época de irrigación. Juárez está investigando la utilización de agua superficial para usos municipales. El aumento de asuntos ambientales ha causado la necesidad del enfoque de almacenar agua para el regreso a los tributarios. La asignación de agua superficial para la agricultura ha creado fricciones en la distribución entre los sectores que la usan. Aunque haya un aumento de competencia, hasta ahora no ha resultado en la alteración del armazón de distribución, en menor escala transferencias del agua de uso agrícola a municipal se ha realizado mediante pagos de alquiler. Finalmente como no hay una simetría entre el crecimiento y distribución del agua, las regiones urbanas en México se ven más presionadas en la distribución de los recursos del agua que las comunidades en los Estados Unidos. Sin embargo, con la estructura de asignación actual, el potencial uso de aguas agrícolas para asuntos municipales-industriales es más baja en la parte mexicana del Paso del Norte.

Esfuerzos innovadores binacionales incluyen:

1. La comisión del agua Nuevo México-Texas se creó en 1991 con la resolución de un conflicto en el cual El Paso le demandó a Nuevo México el derecho de perforar pozos en y bombear agua hacia El Paso para uso municipal. La comisión fue establecida para investigar métodos de planeación cooperativa para uso entre los dos estados. Propuso con éxito el Proyecto del Agua Sustentable en El Paso-Las Cruces, lo cual incluye una serie de mejoramiento de canales, plantas del tratamiento de aguas superficiales, sistemas de distribución y abastecimiento de acuíferos e infraestructura de recuperación.
2. Paso del Norte grupo operativo del agua (PdNWTF, por sus siglas en inglés) se trata de promover el flujo libre de información y comprensión entre los participantes para estimular coordinación en los esfuerzos de planeación y manejo. El PdNWTF fue convocado por el IBWC en 1999 y fue iniciado por el Centro de Investigaciones Avanzadas con apoyo de la Fundación Hewlett. Los miembros del PdNWTF pertenecen a un grupo pequeño binacional que incluye gente con intereses

municipales, de irrigación y de aguas privadas. Un equipo de apoyo científico-académico ayuda el grupo de trabajo. Al principio tuvo éxito en una serie de diálogos en los cuales se informó a los miembros de las operaciones y asuntos de otros miembros. En la actualidad, el equipo de apoyo del PdNWTf ha propuesto una serie de proyectos que intentarán proveer resultados fijos para asuntos regionales específicos del agua.

3. Base de datos del agua subterránea y acuíferos binacionales esto es un estudio cooperativo que incluye ambas secciones del IBWC-CILA, La Junta Municipal de Agua y Saneamiento, La Agencia de Protección Ambiental de Estados Unidos, El Consejo de Administración del Desarrollo del Agua en Texas, y el Instituto de Investigaciones del Agua en Nuevo México. Fue un esfuerzo que duró varios años e involucró varias agencias en el cual recogieron datos hidráulicos de aguas subterráneas, niveles históricos del agua, tendencias de bombeo, calidad del agua y estimaciones de extracciones del presente y del futuro. El reporte fue publicado en 1997 y proveyó mapas basados en datos y sistemas de información geográfica para diseminar a los varios miembros y al público. Lo que el proyecto no cumplió, sin embargo, fue en hacer un análisis de los descubrimientos ni de hacer recomendaciones de las opciones del agua subterránea del futuro.

INTRODUCTION

Overview of Transborder Water Management

The physical qualities, various uses, and geopolitical nature of water make management a difficult task. When multiple jurisdictions are involved—especially when water crosses international borders—management complexities increase exponentially. Accordingly, much of the focus in transboundary water management concerns the manner by which different management styles, use practices, and national policies that can fragment surface and groundwater systems can be addressed. Cooperative water management is viewed as crucial for the optimization of resources in these shared systems. In trans-

boundary basins where water supplies are stressed, tensions over quality and supply are often heightened and regional problems can become national issues (Ingram, Laney, and Gilliam 1995). Therefore, as pressures on supplies grow and as quality is degraded, there is an increased need to manage basins and aquifers cooperatively for sustainable use and relieving of regional tensions (Salman and Boisson de Chazournes 1998). As such, contemporary water management philosophy advocates watershed-based planning and management as a tool to optimize water for the benefit of both human and ecological systems (Heathcote 1998; U.S Environmental Protection Agency [EPA] 1993).

In this chapter, three different sub-regions in the U.S.-Mexican border region are examined from a watershed perspective, specifically asking questions concerning the manner by which institutions within each region interact to advance regional water resource management. Before posing research questions in these regions, there is a brief review of the history of international watershed management and the manner by which water resource management in the U.S.-Mexican borderlands has occurred. Also introduced are the details and strengths of a comparative study of regions, especially the examination of U.S.-Mexican border twin cities. The three case studies are then explored in detail.

Since the early 1990s, watersheds have been viewed as “the best framework for integrating social, ecological and economic aspects of water and water-related management issues” (National Research Council 1999). One of the prime strengths of a watershed approach is that it is a multidisciplinary concept that involves physical processes, policy issues, management practices, and community interaction. “Many factors are converging to cause citizens, scientists, resource managers, and government decision makers to look increasingly to watershed management as an approach for addressing a wide range of water related problems” (National Research Council 1999). These factors, which operate in varying degrees on both sides of the border, include:

- Decentralization of power from federal to state and local agencies in implementing water programs
- Increasing involvement of grassroots organizations and stakeholders in influencing watershed management practices

- Increasing awareness of the pressing need to address problems of water quality and quantity in the face of rapid urbanization
- Improvements in the science of watershed analysis
- Advancements in geospatial technologies such as geographic information systems (GIS) and remote sensing for data collection and spatial analysis

The rapid population growth in the U.S.-Mexican border region, with the concomitant increasing requirement of scarce water resources, demands that government agencies optimize the use of water. In its Fourth Report to the President and Congress of the United States, the Good Neighbor Environmental Board (GNEB) strongly recommends that the watershed become the unit of management for addressing water problems along the border (GNEB 2000). Unfortunately, the U.S.-Mexican political boundary does not coincide with the patterns of water flow resulting in drainage basins often being split into two international jurisdictions. In order to overcome this fragmentation, it is essential that the two nations coordinate their efforts to address water problems within the framework of those watersheds that lie astride the border. Doing so will lead to greater efficiencies in addressing water problems and thus benefit the economic development and environmental conditions in the border region.

History of International Watershed Management

Addressing shared water problems in a cooperative manner that recognizes the interaction of the physical and human aspects of a basin has been attempted in many other transborder watersheds. A large number of surface and groundwater basins are shared among two or more nations. The equitable management of these resources is an extremely difficult problem. A wealth of cases exist that can shed light on how international neighbors have worked to resolve issues over shared water resources.

Although an exhaustive review of international watershed management efforts and literature is clearly beyond the scope of this chapter, it is helpful to review briefly some of the more notable efforts that have been advanced within an international context.

Early work by White (1963) examined the spatial links that exist among and between water management technology, economic efficiency, and the social agency by which development is advanced within the Mekong Delta. Looking at international borders a bit closer to home, the work of the International Joint Commission (IJC) concerning U.S.-Canadian issues is worth exploring due to the insights it can provide in looking at issues along the U.S.-Mexican border to the south.

The 1909 Boundary Waters Treaty established IJC to assist the governments of the United States and Canada in addressing problems that arise over shared lake and river waters. At the time of the treaty's negotiation, the northern border waters of the United States were stressed by the disposal of waste products by the industrialized cities on the Great Lakes and other northern waterways. Canada, the United Kingdom, and the United States negotiated not from the common interest of preservation and protection of shared waters, but from different political and economic interests. Canada, because of its political and economic status, wanted parity with the United States and a treaty that would provide for a strong body to manage waters and settle disputes. The United States, on the other hand, wanted a much more flexible governing body and an agreement that left tributaries under the sovereignty of each country (Beach et al. 2000). The resulting treaty preserved the sovereignty of each nation over waters within its own territory. The treaty also attempted to establish an egalitarian status between the two nations by creating a joint commission with arbitration and investigation powers, and by requiring the approval of both countries of any actions that would hinder the natural flow of shared waters.

Much of the focus of the commission has been related to water quality issues. In 1972, the Great Lakes Water Quality Agreement (GLWQA) was established, and a comprehensive protocol on water quality was instituted in 1987. Both have increased the commission's powers. The protocol uses an ecosystem approach to water management, defines specific water quality parameters, and emphasizes the need for "lakewide" management plans to address pollution. An ecosystem approach integrates the physical and biological aspects of a water system with the social environment and advocates the integration of public participation within the decision-making

process, similar to a watershed approach (van Ast 2000). The GLWQA provides for this integration through Citizens Advisory Groups and other procedures that bring stakeholder input into the process.

Although the IJC has been criticized as being too weak to address sustainability, develop a true ecosystem approach, and sufficiently integrate public participation into the process, the model has been effectively providing a structure for cooperative management and dispute resolution. The IJC has been instrumental in adverting more than 130 disputes related to shared U.S.-Canadian waters (Beach et al. 2000). In fact, it has been so effective that the two governments expanded the commission's mandate in 1991 to include air quality issues between the two countries.

Another example of an integrated attempt to manage a trans-boundary watershed is the Mekong Committee. The Mekong Committee was formed in 1957 to help develop the irrigation and hydroelectric potential of what was, at that time, a largely natural river system. The Mekong flows through China, Myanmar, Thailand, Laos, Cambodia, and Vietnam. In this system, supply and the allocation of that supply are not the primary issues; it is the development of the system for riparians that is at stake.¹ Recognizing this, the United Nations set in motion a process that established the Committee for the Coordination of Investigations of the Lower Mekong, which included Thailand, Laos, Cambodia, and Vietnam. The committee's goal was the promotion and development of water resource projects in the basin. Each member country has equal representation, and committee members have the authority to speak for their respective nations.

International donors heavily fund the committee and its projects, and the United Nations has played a significant role in regional efforts. This has had both positive and negative impacts on the committee. Many concrete projects, such as hydrologic and meteorological monitoring stations, were constructed in the early years, as were extensive programs of data collection and mapping. These cooperative efforts continued despite regional conflicts and have been credited with helping ease political tensions among member countries (Elhance 1999; Beach et al. 2000). Large scale water management projects, however, have been difficult to implement because of the

inherent political and economic problems associated with this type of engineering undertaking. Additionally, the role riparians play in relation to donor nations has had an influence on the success of these projects (Elhance 1999). The manipulation of external funding and the top-down approach to the development of projects appears to have been detrimental to the commission's efforts. To address this, donors must allow more regional control and local input.

The success of the Mekong Committee, therefore, has not been in the construction of large development projects, since to date no projects have been built across the main stem of the river, although smaller projects have been built along tributaries. Its success lies in the continued capacity of member countries to work together in light of significant regional turmoil, and the ability to conduct scientific studies, share data, and work toward basin-wide cooperation. Additionally, the committee has been able to expand its role from pure project development to sustainability and environmental programs. This flexibility has also helped the Mekong Committee's success. In 1970, the committee created a 30-year plan for the development of the Mekong and in 1975 established a Joint Declaration of Principles, which set out the "reasonable and equitable use" of the basin. In 1995 the committee was reconstituted as the Mekong Commission.

Several insights that could be beneficial to the U.S.-Mexican border region can be drawn from these examples. Although differences exist in national interests, economic realities, and the levels of cooperation and public participation, the dynamics that are seen in other cross-border basins are also evident in this border region. These cases show that the ability to coordinate the collection of data, whether toward the remediation of pollution, development of river courses, or the management of limited supply, is helpful to all parties. Cooperation over scientific studies can, and often does, lead to greater capacity and willingness to continue joint efforts. Additionally, coordinated efforts have the potential to ease tensions related to water disputes and even other non-related matters. The ability of institutions to be flexible in their roles and grow appears to be integral to the success of these organizations. Therefore, integrative approaches that are responsive to public concerns and

address the physical and socio-economic aspects of basins with a local and a national character are necessary for effective transboundary management of water.

U.S.-Mexican Water Institutions and their Jurisdictions

The United States and Mexico base the management of their common water resources on an institutional structure whose origins go back to the signing of the Treaty of Guadalupe Hidalgo in 1848. For nearly 40 years, this treaty served as the only institutional framework to approach any potential conflicts over common boundaries and natural resources. The increasing importance of the boundary problems between the two countries, however, made necessary the eventual adoption of certain rules—including the Convention of 1889—and the creation of a binational body to monitor their observance. This organization, the International Boundary Commission (IBC), was created in 1889. The major events related to U.S.-Mexican water management are highlighted in Table 1.

During its early years of operation, IBC was engaged in boundary matters. In time, the increasing uses along the international rivers began to create conditions for potential conflicts to develop between their users on both sides of the border (Bustamante 1999). To solve this situation, the two governments signed the 1944 Treaty for Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, which provided guidelines to distribute the waters of the Colorado, Rio Grande, and Tijuana rivers. The treaty brought also a major modification in the institutional structure behind IBC that extended its capabilities as the implementer of the new rights and obligations assumed by each government. Accordingly, the name of the commission changed to the International Boundary and Water Commission (IBWC). Its functional organization has changed very little since.

The last 20 years have witnessed important transformations in the binational institutions. Two main forces are behind this trend. First is the growing concern about the environmental deterioration of the border region in the face of the demographic growth experienced by its communities over the past 40 years. Second is the demand from

different regional and local actors that they be permitted to participate in the decision-making processes surrounding the natural resources and environmental problems in their jurisdictions.² The rigid structure of operation at IBWC had begun to show its limitations to handle the new needs³ and it became clear a new institutional approach was in order. This began to take form with the 1983 signing of the binational Agreement for the Protection and Improvement of the Environment in the Border Area, known also as the La Paz Agreement. The accord included formal guidelines for the participation of a broad range of government levels in both countries through the design and implementation of transboundary environmental solutions by specific work groups. Important leading agencies at the federal level included the EPA, Secretaría de Desarrollo Urbano y Ecología (SEDUE), and Secretaría de Desarrollo Social (SEDESOL).

The first negotiations over the North American Free Trade Agreement (NAFTA) among Canada, the United States, and Mexico brought a growing concern for its potential environmental effects along the border. These pressures led to the release of the Integrated Border Environmental Plan (IBEP) in 1992 by the federal governments of the United States and Mexico. The plan aimed to strengthen enforcement of environmental laws and increase cooperative planning efforts. In the same year, GNEB was created to advise the president and Congress on environmental and infrastructure issues in the states bordering Mexico. This board has representatives from different governmental levels and private organizations. In spite of being practically unknown within federal circles, the board has submitted a number of recommendations to Border XXI groups and other border institutions, some of which have been implemented (Spalding 2000).

Table 1. Major Events in the Evolution of the U.S.-Mexican Water Management Institutions

Year	Event	Objectives
1848	Treaty of Guadalupe Hidalgo	Definition of the international boundary between the U.S. and Mexico
1889	Convention that created the International Boundary Commission (IBC)	Observance of the rules of the Boundary Treaties of 1848 and 1853, and the 1884 Convention in relation to the changes of course in the international rivers
1944	Treaty for "Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande" (IBWC)	Distribute the waters of the international rivers between the two countries and extend the functions of the commission for the application of the terms of the treaty
1983	Agreement for the Protection and Improvement of the Environment in the Border Area (La Paz Agreement)	Provide formal guidelines for the participation of a broad range of government levels in both countries, in the design and implementation of transboundary environmental solutions by specific work groups. Define the border region as the area lying 100 kilometers to the north and south of the international border line
1992	Release of the Integrated Environmental Plan for the U.S.-Mexico Border Area (IBEP)	Strengthen enforcement of environmental laws, increase cooperative planning, completion of expansion of wastewater treatment facilities, and development of a computer tracking system on the transboundary movement of hazardous wastes
1992	Creation of the Good Neighbor Environmental Board (GNEB)	Advise the President and Congress on environmental and infrastructure issues along the bordering states with Mexico
1993	Creation of the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADBank)	Assist communities on both sides of the border in coordinating and carrying out environmental infrastructure projects
1996	Release of the Border XXI program	Promote sustainable development in the border region by seeking a balance among social and economic factors and environmental protection in border communities and natural areas

Sources: Mumme; Spalding

The signing of NAFTA in 1993 closed another important chapter in the evolution of the U.S.-Mexican water management institutions. The passage of the trade agreement was accompanied by the creation of two institutions under principles similar to those of the IBEP: the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADBank). BECC was created to provide technical support to local and regional efforts to build infrastructure that improves U.S.-Mexican border environmental quality, and to certify projects for funding by the second of

the institutions to arise from the NAFTA debate, NADBank. NADBank was developed to be a completely binational and bilateral regional development bank that enjoys joint U.S. and Mexican representation and funding. NADBank's charge is to provide funding for projects certified by BECC and finance community adjustment and investment activities in response to the relocation of production and related functions as NAFTA is implemented. The North American Agreement on Environmental Cooperation (NAAEC) included the creation of the Commission for Environmental Cooperation (CEC), a group whose main objective is to enhance cooperation between the three countries to better conserve and improve the environment.

The last addition to the current institutional structure was the implementation of the Border XXI program in 1996. This program was a continuation of the IBEP and was considered by many to be more innovative and inclusive. It emphasized public involvement, decentralized environmental management through state and local capacity building, and a better level of communication among the different government levels and agencies involved (Spalding 2000). In the arena of border water resources, IBWC and its Mexican counterpart, Comisión Internacional de Límites y Aguas (CILA); the U.S. Department of the Interior (DOI); EPA; and Mexico's Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) participated.

BORDER TWIN CITIES AND CASE STUDIES

Forces and events on both sides of the U.S.-Mexican border have fostered human activities that have had significant impacts on environmental quality here. The entire border region has undergone dramatic economic development in the post-World War II era as a result of the major structural changes that occurred in the region's economy. Those changes were due to large-scale investment by the United States in the military-industrial sector in support of efforts in World War II (Hundley et al. 1993). More recently, a major period of industrialization and attendant population growth has occurred in border twin cities⁴ as a result of unilateral programs in Mexico and agreements between the United States and Mexico.

The Border Industrialization Program (BIP) and the Program of the Northern Border (in Spanish PRONAF) were established in the 1960s and 1970s by the federal government in Mexico to deal with the end of the Bracero⁵, or guest worker, Program and to increase general levels of border economic development (Dillman 1970a, 1970b, and 1976; Hoffman 1983). The goals of these programs were to increase employment in northern Mexico, offset the termination of the Bracero Program, and make major investments in the infrastructure of Mexico's northern border states. These programs allowed for the development of maquiladora plants⁶ (twin or maquila plants). Maquiladoras are assembly and manufacturing plants owned by foreign investors that employ Mexican labor to perform the assembly of finished goods (Hundley et al. 1993). The BIP was successful in attracting maquiladoras to the border region, and several border twin cities have seen dramatic increases in industrial growth as a result. The advent of NAFTA has increased these trends in urbanization and development.

As a result of the economic development and industrialization detailed above, the U.S.-Mexican border has experienced dramatic population growth in recent decades, and much of this growth has occurred in twin cities. The literature varies on how much of the total border population resides in these cities, but estimates are somewhere between 72% (EPA-SEDUE 1991) and 90% (Ham-Chande and Weeks 1992). With a vast majority of border population in these cities, most (but by no means all) of the problems and challenges associated with water resource management and resulting pollution occur in or near these urban centers.

Regional approaches to resource-quality issues and the conflicts involved are well documented in the geographic and resource management literature (Mitchell 1989 and 1990). They have also been advanced by the EPA in examining domestic and binational resource management issues (Gallant et al. 1989; EPA 1991 and 1993). Watershed approaches that offer the river basin or catchment as a spatial framework and context within which resource management issues may be addressed have been extremely useful in resolving water-based conflicts and advancing holistic management of basin-wide water resources (White 1963 and 1977; Downs 1991; Montgomery et al. 1995; Milich and Varady 1999).

Three different approaches to binational water resource planning have unfolded in three U.S.-Mexican border cities, specifically San Diego-Tijuana, Ambos Nogales, and El Paso-Ciudad Juárez. In the San Diego-Tijuana region, there are a range of innovative cross-border efforts that have been advanced by the U.S. and Mexican Consuls General representing this region, the San Diego Association of Governments (SANDAG), researchers working within regional universities, staff at BECC, and non-governmental stakeholders. Within the Ambos Nogales region, IBWC-CILA; EPA; the Sonora state water authority (CoAPAES in Spanish); the State of Arizona Department of Water Resources (ADWR); the City of Nogales, Arizona; and a range of private-sector consultants have cooperated over the last few years on a facilities planning process (FPP) that has advanced binational and regional efforts to develop water infrastructure. This chapter examines the interactions of these Ambos Nogales stakeholder groups in developing innovative mechanisms and models of cooperation. Lastly, the chapter describes a range of innovative efforts toward regional water resource management ongoing in the Paso del Norte region, which is comprised of Ciudad Juárez, Las Cruces, and El Paso. In the Paso del Norte region, these efforts include the interactions of the Paso del Norte Water Task Force, the New Mexico-Texas Water Commission, and other regional stakeholders to build a regional identity and advance opportunities to cooperate in water resource planning for the region. A range of management options in other regions are also examined in a manner consistent with important earlier work that has explored watershed approaches to contemporary water resource management challenges (Michel 2000; National Research Council 1999; and Wescoat 2000).

Specific questions of concern include: the manner by which these policy tools have developed, the range of issues that have been successfully addressed through these efforts, and the lessons that these water resource planning and management activities can offer along the U.S.-Mexican border. Of special interest are the key socio-cultural, political, and technical elements that have coalesced to allow these efforts to explore the particularly difficult water resource issues involved. What are the roles of different levels of government in these efforts? What are the roles of non-governmental organizations (NGOs) and members of the general public, and how can this public

participation be facilitated? How can the efforts advanced in the twin cities examined be modified and replicated across the border region?

The San Diego-Tijuana Region

The San Diego-Tijuana region⁷ is unique in many ways within the border context. While the highest levels of economic activity and demographic growth on each side of the border are found here, the most dramatic contrasts are also present in terms of economic, social, and cultural differences. The bordering sections of California and Baja California belong to a zone distinguished by two main types of weather: one extreme, desert-like climate toward the Sea of Cortez, and a warm, semi-arid climate along the Pacific Ocean. The rainy season occurs during the winter months and is characterized by low levels of precipitation—less than 10 inches annually. These conditions define a pattern of permanent water scarcity and make area rivers dry for most of the year. The Colorado River is the only reliable source in the region.

A representative feature of the San Diego-Tijuana region is the comparative dynamics of the population trends along the border. As Table 2 shows, the 1940s marked the beginning of a key period in the growth of the area. After the demographic boom that accompanied the flourishing of the military industry during and after World War II, the San Diego area has grown moderately as a result of both domestic and international in-migration.⁸ In comparison, as a result of the end of the Bracero Program, Tijuana experienced an influx of migrants who were attracted by the labor opportunities during the decades that followed. Currently, this city remains an attractive labor market in the face of higher unemployment levels in other regions of Mexico—a condition that continues to keep its growth rates among the highest in the country.

While both San Diego and Tijuana command comparatively high levels of development in their own national contexts, their economic asymmetries are quite large. This characteristic is clearly reflected in different aspects of transborder interactions, such as the consumer markets in the commerce and service sectors, and a significant segment of Tijuana’s economically active population (EAP) working in San Diego. Such differences also have important implications for the

financial capacity of the U.S. and Mexican governments to meet resource needs and approach specific issues in the region that are of mutual concern (including environmental problems).

Despite the obvious differences that exist in the region, recent years have witnessed an increase in the number of transborder initiatives to address common problems. These efforts have originated primarily from concerned groups of different backgrounds and have evolved into initiatives involving, in many cases, governmental agencies on both sides of the border. An innovative initiative came from SANDAG in the creation of the Committee for Binational Regional Opportunities (COBRO) in 1996. This group is an internal advisory committee that explores SANDAG’s role in binational U.S.-Mexican planning activities. A key characteristic of COBRO is its wide representation of different sectors on both sides of the border, including the participation of the Consuls General of the United States and Mexico (Brown and Mumme 2001). Related to COBRO are the Border Liaison Mechanism (BLM), a formal vehicle for binational cooperation, and the Border Water Council (BWC), which originated out of the need for transborder cooperation on regional water concerns.⁹

Table 2. Population Growth in Tijuana and San Diego, 1900–2000

Year	Tijuana	Annual Growth Rate (%) *	San Diego	Annual Growth Rate (%)
1900	242		18,000	
1930	11,000		210,000	
1940	22,000	10.0	289,000	3.8
1950	65,000	19.5	557,000	9.3
1960	166,000	15.5	1,033,000	8.5
1970	341,000	10.5	1,358,000	3.1
1980	462,000	3.5	1,862,000	3.7
1990	747,000	6.2	2,498,000	3.4
2000	1,125,200	5.1	2,896,900	1.6

* Each figure corresponds to the decade ending in the related year. Source: Weeks

One characteristic of the San Diego-Tijuana region relevant in the previous context is the Tijuana River Watershed (TRW). The implications here are numerous, as the watershed poses challenging circumstances in terms of transboundary coordination and planning efforts. To date, initiatives like the BWC have proved to be potential mechanisms to handle the region's common problems using approaches compatible with the watershed concept. On the other hand, Mexico's present decentralizing policies in relation to water management emphasize the organization of watershed councils, or *consejos de cuenca* in Spanish, at the regional level to address specific problems in each watershed. The experience gathered from these projects provides strong support for the possibility of a Binational Council functioning in this region (Brown and Mumme 2001).

Water Supply and Demand

In different ways, the water supply systems that operate in Tijuana and San Diego exemplify the structural differences that exist between the United States and Mexico. One primary distinction is the different characteristics of the water management institution. In the United States, individuals may appropriate water and the corresponding rights acknowledged by law independent of the rights-allocation system in use,¹⁰ whereas in Mexico, water is considered by law a property of the nation and the management of this resource is entirely state run.¹¹ Mexican federal law, however, does grant specific rights to municipalities to manage a number of public services, among them potable water and sewage systems.¹² Essentially, both San Diego and Tijuana are dependent on imported water from the Colorado River. San Diego also receives water from Northern California. In the San Diego area, water imports account for nearly 90% of the yearly supply (Table 3). The distribution of this water by use sector can be seen in Table 4. The San Diego County Water Authority (SDCWA),¹³ a public agency serving the region as a wholesale supplier of water for the local agencies, is the regional water manager. Local supplies account for nearly 12% of the available water. Among these, surface water is the most important and comes mainly from the reservoirs in the area, some of which are connected to the pipeline network of the SDCWA.¹⁴ The SDCWA is

composed of 23 member agencies that purchase water from the Southern California Metropolitan Water District (MWD) and are, in turn, responsible for potable water services in their jurisdictions. During the fiscal year ending in June 2001, the SDCWA served a population of nearly 2.8 million distributed over 920,000 acres. The city of San Diego is the largest recipient of water in the area, accounting for roughly 45% of the population serviced and 42% of the water supplied for municipal and industrial uses (San Diego County Water Authority 2001).

Although water reclamation represents a priority alternative to meet the needs of the municipal water districts in the area, on average less than 2% of the water available to the SDCWA comes from this source (San Diego County Water Authority 2001). This is due in large part to the high costs of water reclamation and the lack of a distribution infrastructure to convey the recycled water to potential users.

Table 3. San Diego Area Water Supply Sources, June 2001

Imported Sources-88%		
Colorado River	431,751.9af	73.0%
State Water Project	159,689.1af	27.0%
Total Imported MWD	591,441.0af	100%
Local Sources-12%		
Surface Water	51,384.6af	62.5%
Well Water	12,685.7af	15.4%
Recycled Water	12,693.0af	15.4%
Desalinated Groundwater	5,484.3af	6.7%
Total Local Water	82,247.6af	100%

Source: San Diego County Water Authority

Table 4. Water Uses in the San Diego Area 2001

User Type	Amount	Proportion
Residential	353,756af	54.7%
Industrial/commercial	126,021af	19.5%
Agricultural	107,227af	16.6%
Other	59,383af	9.2%
Total	646,387af	100.0%

Source: San Diego County Water Authority

In comparison to San Diego, Tijuana’s options to meet its present and future water needs appear to be much more restricted. The water imported from the Colorado River represents the only real and dependable possibility for the city.¹⁵ Currently, this source provides approximately 95% of its yearly supply, with the rest coming from local sources.¹⁶ The potable water and sewage services in Tijuana and Rosarito are the responsibility of the Comisión Estatal de Servicios Públicos de Tijuana (Commission of Public Services for Tijuana, in Spanish CESPT), a state agency that operates with an administrative board headed by the governor of Baja California and includes representatives of the public and private sectors. CESPT serves four water users in the cities of Tijuana and Rosarito: residential, industrial, commercial, and government. Table 5 shows the participation of each sector in total water consumption during 2001.

Table 5. Water Consumed by Sector in Tijuana and Rosarito, 2001*

Water Use	Consumption	Total (%)
Residential	49,305af	74.9
Industrial	6,900af	10.5
Commercial	6,596af	10.0
Government	2,992af	4.6
Total	65,793af	100.0

*Based on current water billed

Source: CESPT

The operation of CESPT requires coordination with two other agencies, the Comisión Estatal del Agua (State Water Commission, in Spanish CEA) and the Comisión de Servicios de Agua del Estado (State Commission of Water Services, in Spanish COSAE). The first is responsible for planning activities while the second operates as an intermediary in the purchase of water between the Comisión Nacional del Agua (National Water Commission, in Spanish CNA) and the State Commissions for Public Services throughout the state (Castro and Sánchez 2001). Water imported by Tijuana is part of an annual allotment of 162,000 acre-feet (af) from the Colorado River, assigned by CNA to meet the urban demands in the region.¹⁷ Approximately half of this quantity is delivered through the Colorado River-Tijuana Aqueduct (in Spanish ARCT) to Tecate and Tijuana.

One of the problems faced by most local and state agencies in Mexico relates to their financial difficulties in coping with the growing demand for their services. For potable water and sewage services, this is reflected in the inability to serve the regional population, which is particularly critical in Tijuana due to the high immigration rates. CESPT continues to search for more efficient ways of providing service. By December 2001, the proportions of population served with potable water and sewage in the city were approximately 88%¹⁸ and 76% respectively. Currently, CESPT cannot rely on alternative sources, such as treated wastewater, to supplement needs. Reclaimed water is not a viable option due to the low level of wastewater treatment¹⁹ and the lack of infrastructure for the distribution of this resource.

Unique Regional Challenges

The long-term solutions to meet the water demands in this region are a priority for the agencies in charge of its management. According to the available projections, the population of the region in 2020 will be 5.7 million, two-thirds of whom will be living in San Diego while the other third will be living in Tijuana (Weeks 1999). This is a 42% increase based on a projection of moderate rates of growth for both San Diego and Tijuana. This growth will generate a demand for water for which each side is preparing in different ways.

In San Diego, provisions are being negotiated through two agreements that would supply the region with up to 200,000af annually (San Diego County Water Authority 2001). The first is the Water Conservation and Transfer Agreement with the Authority of the Imperial Irrigation District (IID) for an initial term of 45 years beginning in 2002. The second is a "Water Exchange Agreement" between the SDCWA and the MWD, which would have allowed the transfer of the water from the IID to the SDCWA.²⁰ However, before a water transfer agreement like this could be finalized, a number of issues must be addressed. These issues include: the effects on water levels in the Salton Sea, the potential repercussions on air quality and fish and bird habitats, growth induction impacts in San Diego County resulting from additional water supplies, and the socio-economic influences in the Imperial Valley related to land fallowing.

In comparison to San Diego, the Tijuana area faces a much more restrictive situation in terms of its long-term water supply. Like other cities in the area, the water conveyed from the Colorado River in the Mexicali Valley forms the basis for the proposed alternatives to meet water demands over the next 15 years to 20 years. In this regard, a collaborative project between Mexico and the United States was initiated with the signing of Minute 301 of the IBWC in October 1999 to conduct a joint feasibility study for an aqueduct to transport water from the Colorado River to the San Diego-Tijuana region. The study was completed by the end of 2001, and upon evaluation of its results both governments will proceed accordingly.²¹

Water reuse is an essential part of the San Diego-Tijuana region's water future. SDCWA is in the process of preparing a Regional Facilities Master Plan that involves the analysis of a variety of alternative water sources, such as seawater desalination, groundwater recharge, the conveyance of additional water from the Colorado River, and the recycling of wastewater.²² Between 2002 and 2020 water recycling to tertiary levels in the county is expected to increase from 8.6 million gallons per day (MGD) to 121.3MGD, thus indicating a much greater reliance on reclaimed water in the future than is currently the case. Major recycling facilities in the southern half of the county are the City of San Diego North City Water Reclamation Plant, the Otay Water District Water Pollution

Control Facility, the Padre Dam Santee Basin Water Reclamation Facility, and the City of San Diego South Bay Water Reclamation Plant. These four facilities are expected to account for more than 50% of the tertiary treated water recycling capacity of San Diego County by 2020 (SDCWA 2002). Of special significance to the immediate border region is the South Bay Reclamation Plant, which is providing additional treatment capacity in the southern region of the City of San Diego, the Tijuana River Valley and the Otay Mesa area. This project lessens the southern part of the county's dependence on imported water supplies and will provide reclaimed water for markets in the Cities of San Diego, Imperial Beach, Chula Vista, and National City, and in the unincorporated areas of San Diego County.

As a result of natural drainage in the TRW (Figure 1), sewage flows from Mexico to the Tijuana River Estuary and the surf zone of the South Bay have been a problem for many years. In 1997, the International Wastewater Treatment Plant (IWTP) was completed to provide for advanced primary treatment of 25 million gallons of Tijuana sewage per day. The treated sewage is released through the South Bay Ocean Outfall, which was completed in 1999. The IWTP is intended to treat 50 million gallons of Tijuana sewage per day in conjunction with Tijuana's San Antonio de los Buenos treatment plant, which discharges treated sewage into the surf zone about four miles south of the border. Despite improvements in the treatment of Mexican sewage, pollution from cross-border sewage flows continues to be a problem in the Tijuana Estuary and adjacent beaches. One proposal to alleviate the situation is Bajagua, a controversial private wastewater treatment plant that would be built in Mexico and process between 50MGD and 75MGD of Tijuana's sewage. The water reclaimed through Bajagua would be available for industrial needs, public greenbelts, and groundwater recharge. Thus, it would help augment Tijuana's limited supplies from the TRW, the Colorado River, and the Guadalupe Valley. The controversy surrounding Bajagua relates largely to the privatization of wastewater, which continues to be a subject of intense debate.

Another interesting, but smaller-scale effort to reclaim water is EcoParque, a 15-acre project initiated in 1986 by El Colegio de la Frontera Norte (COLEF). The project is intended to represent a

model for the reuse of water in hillside urban areas. Given Tijuana's limited water supplies, topographic characteristics, location near the border, and its barren hillsides, there is a need to treat and reuse as much wastewater as possible to preserve precious water supplies, vegetate hillsides to reduce erosion and create green spaces, and reduce the flow of polluted waters into the United States. It remains to be seen if it is practical to extend the EcoParque model to other parts of Tijuana and the border region.

Figure 1. Hydrography of the Tijuana River Watershed



Source: Drafted by Carol Placchi, modified from IBWC and Pryde

Innovative Cross-border Efforts in the Region

Tijuana River Watershed Program

Universities and public agencies from both sides of the border have combined their efforts to help address environmental problems in the transborder TRW. The watershed covers 4,500 square kilometers—two-thirds of which is in Mexico—and has a wide range of

topography, climates, biological resources, land uses, and socio-political institutions (Wright et al. 1995). The TRW Program had its beginnings in 1994 when San Diego State University (SDSU) and COLEF signed a memorandum of understanding that laid out the guidelines for coordination between the two institutions in the development of a watershed GIS and its use for community outreach, education, and scientific research. Funding from the National Oceanic and Atmospheric Administration (NOAA), the Southwest Center for Environmental Research and Policy (SCERP), and other agencies has made possible the completion of more than a dozen projects, most of which have focused on water quality and quantity problems in the watershed.

Goat Canyon/Cañón de los Laureles Vulnerability Assessment

In 1998, the TRW was selected by the U.S. National Partnership for Reinventing Government and the U.S. Federal Geographic Data Committee as one of six pilot project areas in the United States to demonstrate the application of the National Spatial Data Infrastructure (NSDI) to solving community problems. The study area is Goat Canyon, or Cañón de los Laureles, a five square-mile canyon located just upstream from the Tijuana Estuary. Approximately 90% of the canyon is located in Mexico. Because of its physical and cultural characteristics, the canyon is a major source of the sediment that is rapidly encroaching on the estuary, which is a National Estuarine Research Reserve and one of the largest remaining functioning wetlands in Southern California. Like many other canyons in the area, Goat Canyon is subject to infrequent but intense precipitation events that lead to flash flooding and the loss of human lives, property, and natural habitats. The principal purpose of the project was to model the degree and geographic distribution of human vulnerability to flood hazards within the context of a binational, data-poor situation. Not unexpectedly, the sections of the canyon that were modeled as significant flood hazard areas were most likely to coincide with areas of low-income housing. This project demonstrates the difficulties of working in a transborder setting and what the paucity of human and physical data can overcome. This project relied on an effective binational data-sharing partnership struck among universities and federal and local agencies. In

addition, the project was assisted by technology transfer to some local partners in the private sector.

Flood Forecasting and Warning System for the Tijuana River Watershed

One of the outcomes of the TRW National Community Demonstration was a greater recognition of the fact that flooding is a serious threat to local communities. For this reason, some 13 institutions on both sides of the border have signed a declaration of intent to develop a flood forecasting system for the lower TRW. The participating agencies have agreed to:

- Participate in binational, interagency technical efforts to design a basin-wide flood monitoring system in support of the development of a flood forecasting model
- Seek opportunities to implement the monitoring program through binational, interagency partnerships
- Promote the development of a flood forecasting model and associated flood warning system for the TRW

The U.S. National Weather Service, the U.S. National Ocean Service, the County of San Diego Department of Public Works, and the City of Tijuana Protección Civil Estatal have led the way in moving the project along. In the first phase of the project, stream gages and precipitation recording stations were purchased and locations for the installation of this equipment were identified on the Cottonwood Creek, Alamar River, Campo Creek, and Tecate sections of the TRW. The equipment is scheduled for installation. The project will also involve an upgrading of the City of Tijuana's and County of San Diego's antennas to receive and transmit precipitation data to Protección Civil Estatal in the City of Tijuana and the Department of Flood Control in the County of San Diego.

Bight of the Californias Program

In 1995, the United States, Mexico, Canada, and more than 100 other nations adopted the Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-Based Activities. The GPA encourages countries to develop or strengthen programs to address land-based sources of pollution in the marine environment. To help implement the GPA, CEC has established two

pilot programs, one in the Gulf of Maine and the other in the Bight of the Californias. The Bight is formed by an eastward indentation of the coast that extends from Cabo Colonet, Baja California, northward to Point Conception, California. Within the Bight, a sub-region centered on the U.S.-Mexican border and extending from Ensenada, Baja California, to Encinitas, California, has been selected as the project area. This subregion includes a regional population of more than 4 million in the urban areas of San Diego, Chula Vista, Tijuana, and Ensenada. Rapid population growth and intense economic development are having major impacts on the nearshore marine environment in this binational region. The overall goal of this project is to establish the information and methodological bases for protecting the nearshore marine environment in the Bight from land-based sources of pollution. Specific objectives of the project are to:

- Identify the types of pollutants entering the U.S.-Mexican border section of the Bight
- Inventory marine water quality monitoring activities in the study area
- Identify data gaps
- Develop a watershed-level GIS database
- Develop an integrated terrestrial point-source pollution GIS database

The project is being accomplished through a collaboration among San Diego State University, Universidad Autónoma de Baja California, and the Southern California Coastal Water Research Project with funding from NOAA and SCERP. Technical input is provided by a binational technical advisory team comprised of representatives from local, regional, state, federal, and international government agencies. These organizations are engaged in various ways with water quality matters and thus are also potential beneficiaries of the project.

San Diego Association of Governments and San Diego County Water Authority Work Toward a Border Water Council

In 1996, SANDAG formed COBRO to develop a binational policy framework and action plan for addressing a variety of problems in

the San Diego-Tijuana border region. For the past five years, COBRO has sponsored an annual conference on issues of major concern in the binational region. In recognition of the importance of water resources to the region, COBRO selected water as the topic of the first conference in 1997 (SANDAG 1997). Several recommendations came out of the conference, including suggestions to:

- Facilitate the exchange of information and technology on water-related issues
- Explore opportunities for binational participation in water transportation and storage projects
- Promote transborder water exchange and re-use
- Develop binational water conservation education and projects
- Develop plans to transfer water from one side of the border to the other in the event of an emergency
- Employ a watershed approach in addressing regional water problems

Under the auspices of the BLM, a Border Water Council (BWC) was established in 1997. Representatives of the SDCWA and CESPT are the co-chairs of the council. The BWC has moved toward the implementation of several of the recommendations of the 1997 workshop, but its major effort has been to encourage the exploration of options for the conveyance of water from the Mexicali and Imperial Valleys to San Diego and Tijuana. In recognition of the need to consider the county's bordering jurisdictions in matters of regional planning, the Board of Directors of SANDAG has made relations with its neighbors, especially Mexico, a high priority. To facilitate transborder approaches within SANDAG, a high-level position of Director of Binational Planning and Coordination and a Borders Policy Committee have been created. With this new organization, COBRO will send policy recommendations regarding binational matters to the Borders Committee, which then can elevate them to the full board (SANDAG 2002).

Regional Colorado River Conveyance Feasibility Study

Toward the goal of insuring adequate water supplies for the San Diego-Tijuana region, the State of California and the SDCWA provided funding for a study to explore potential routes for an aque-

duct from the Colorado River that could be shared by SDCWA and state agencies in California. The binational alignment options study, which is managed by a technical committee comprised of seven U.S. and Mexican agencies, is part of a larger regional facilities master planning effort being undertaken by SDCWA. The study of transborder options is based on the recognition that a conveyance facility may be more cost-effective if multiple agencies are involved and that SDCWA and Mexican agencies have a shared interest in evaluating the potential of a joint facility. Thus far, 10 binational alignment options have been identified in the study. This joint study is an excellent example of how agencies from the United States and Mexico can work together to determine the most effective way of meeting regional water needs. However, a number of issues will have to be resolved if the idea of a joint facility is to be pursued further, including:

- The use of the All-American Canal
- Security and reliability questions concerning the use of facilities outside each country's national territory
- Costs and methods of financing an international project
- The types of international agreements that will need to be put in place
- How to continue progress on the project with changes in administrations (Friehauf 2002)

Alamar River Corridor Study

San Diego State University, Arizona State University, and the City of Tijuana are examining alternatives for channelizing a portion of the Alamar River (Michel 2001). The study is being conducted as a part of the Borderlink Program coordinated by the Institute for Regional Studies of the Californias at San Diego State University. Borderlink is a highly successful program that involves university faculty and students from the United States and Mexico in collaborative projects on real world problems in the border region. The Alamar River is a segment of the TRW that extends from the U.S.-Mexican border downstream to the Tijuana River. The Alamar drainage, which includes Cottonwood Creek, Tecate Creek, and Campo Creek, provides approximately 50% of the flow of surface water in the TRW and is a major recharge area for the aquifer that underlies the lower

TRW basin. The principal finding of the project thus far is that the creation of a river park in the Alamar River corridor would provide a large number of benefits, including:

- Improved groundwater recharge to sustain or increase the supply of potable water for the City of Tijuana, which is rapidly out growing its supply of imported water
- Increased riparian habitats, which are home to a large number of threatened and endangered plant and animal species
- Expanded acreage given to open space and recreation in the City of Tijuana, which is well below international standards in the availability of green space per resident
- Improved water quality in the Lower Tijuana River Basin, an area characterized by ongoing problems with pollution in the groundwater aquifer, estuary, coastal beaches, and surf zone
- Restored natural hydrology of the lower Tijuana River basin to help reduce flooding, erosion, and sedimentation
- Reduced costs of providing flood control in an area subjected to serious flood events

This project demonstrates the value of integrating student education and applied research in addressing cross-border water resource problems.

AMBOS NOGALES REGION AND THE FACILITIES PLANNING PROCESS

The binational twin city of Ambos Nogales faces similar water resource management issues to those faced by San Diego-Tijuana and Paso del Norte regions. Preliminary population data from the 2000 census indicate that the current population in Ambos Nogales exceeds 200,000 (Instituto Nacional de Estadística, Geografía e Informática [INEGI] 2001). This number of people generates a growing need for water in the municipal and industrial sectors and creates a range of related water quality issues. Water resource management issues in Ambos Nogales include the provision of water supplies to sectors of society with competing needs; the provision of the needed infrastructure and “plumbing” to deliver water to major

sectors of Nogales, Sonora; the provision of adequate wastewater collection and treatment; proper management of groundwater and surface water interactions; and a range of water quality issues related to both groundwater and surface water resources. Figure 2, a map of the Upper Santa Cruz Basin within which Ambos Nogales lies, provides an overview of the spatial elements that exist in the Ambos Nogales region.

Unique Regional Challenges

Groundwater is the major source of water for the region, and wells in both the U.S. and Mexican portions of the basin affect groundwater availability and surface water flows in the river. Increasing urban groundwater extraction is impacting the long-standing agricultural use of groundwater in the basin and negatively impacting surface water flows in the river, which raises questions about sustainable use of groundwater for the future. Groundwater resources are frequently extracted at a much greater rate than that of groundwater recharge, making extensive extraction of groundwater, such as that found in the Ambos Nogales region, highly problematic.

In addition, the provision of drinking water is a particularly pervasive and immediate need in Nogales, Sonora, and this immediacy poses special challenges for regional approaches to water resource planning. The percentage of Nogales, Sonora, residents that have piped water or connections to sanitary sewers is estimated to be only 50% (Solís Garza 1999). Providing an enhanced delivery network, addressing major losses of water resources through leaks, and securing a raw water source with which to meet demand are three related and very important issues that face Nogales, Sonora. These needs have led to explorations of enhanced groundwater extraction in the areas upstream from the city near Mascarenas, Santa Barbara, and Parades (Barcenas 1999). As a first step to resolving these water supply issues, a major facilities planning process has been undertaken in the region. The effort is aimed at enhancing the wastewater collection and treatment facilities in the Ambos Nogales region and providing future supplies of potable water to Nogales, Sonora (Barcenas 1999; IBWC 1995).

Figure 2. Upper Santa Cruz Basin



Innovative Cross-border Efforts in the Region

The FPP that has been undertaken in the Ambos Nogales region is a binational planning effort that extends technical support to regional water resource planning agencies toward the goal of obtaining funds from EPA for the construction of needed wastewater management infrastructure (IBWC 1995). The FPP was formally established with the signing of Minute²³ 301 by IBWC and CILA. Within the FPP advanced under Minute 301, IBWC-CILA; CoAPAES; the ADWR; the City of Nogales, Arizona; and a range of private sector consultants have cooperated over the last several years on a regional water infrastructure effort. Both a technical working group and a policy group have developed various configurations of enhanced water resources infrastructure, and numerous options were explored (Barcenas 1999).

As a result of this process, an alternative was approved that provided for increased treatment capacity at the existing Nogales International Wastewater Treatment Plant (NIWTP), upgraded treatment processes, and replacement of outfall facilities (Camp Dresser & McKee 2000). Specifically, the treatment capacity at the international treatment plant will be increased from the present treatment capacity of 17.2MGD to 22MGD, an amount projected to meet the future demands of the sister cities. Wastewater treatment processes will be upgraded to increase nitrogen removal, thus allowing effluent treated in the plant to meet EPA and State of Arizona water quality regulations and also addressing water quality concerns advanced by members of the public downstream from the plant. Replacement of the outfall that brings sewage from the border to the plant will provide the additional transmission capacity needed to convey larger flows in the future and will also eliminate extraneous flows into the outfall due to infiltration of baseflow into the outfall (Camp Dresser & McKee 2000).

In addition, both wastewater treatment and potable water treatment facilities are to be built in Sonora. A small wastewater treatment plant (treating up to 5MGD) employing an advanced ponding system is to be built at Los Alisos in Nogales, Sonora, and a lift station will be built to convey wastewater to this new plant. Also, the existing wastewater collection network in Nogales, Sonora, will be

upgraded in an effort to reduce infiltration similar to that which poses problems with the outfall discussed above (EPA 2000). At the request of CoAPAES, a potable water component for Nogales, Sonora is being planned, which complicated the final design of the wastewater treatment plant and related funding issues. These complications were largely resolved in early 2001 and current plans are for approximately \$8.5 million from the Border Environmental Infrastructure Fund (BEIF) to support the potable water component of the project (Sprouse 2001; Wachtel 2001).

The discharge of treated effluent from the IWTP also has a major impact on surface water and groundwater dynamics within the downstream reaches of the river from approximately Rio Rico to Amado (Figure 3). The regular discharge of this effluent is the largest source of groundwater recharge in the region; over time, this effluent has become the largest contribution to regional groundwater balances. One particularly important facet of the facilities planning negotiations has been the desire on the part of ADWR and downstream riparians to negotiate some form of guarantee that adequate amounts of Mexican wastewater will be diverted over the long run to insure viable levels of recharge to groundwater aquifers. This guarantee is of primary importance to the possible formation of a groundwater replenishment district, which will be discussed in greater detail (Barcenas 1999), yet this idea of a guarantee solely reflects the perspectives of downstream riparians and agency staff in Arizona and the United States.

What of the Mexican perspective? In Mexico, both water and wastewater are state resources controlled by the federal government; consequently, it is important to ensure a Mexican perspective is part of the discourse on wastewater management in the Ambos Nogales region. According to the Mexican Constitution and la Ley de Aguas Nacionales, untreated and treated wastewater is a state-owned resource managed and controlled at the federal level. Furthermore, under Resolution 11 of IBWC-CILA Minute 277, which facilitated construction of NIWTP, wastewater treated at the Arizona, is still owned by Mexico, and Mexico plant in Nogales, retains recapture rights to treated effluent.

Based on discussions with top-level water resource leaders in Mexico, the wastewater generated in Nogales, Sonora, and treated at

Figure 3. Santa Cruz Basins Subregion



the NIWTP in Nogales, Arizona, is clearly seen as a potential resource that could contribute to meeting water resource demands in Nogales, Sonora (Herrera 2002). CILA sees a need for an integrated regional water resource perspective that includes management of regional groundwater resources and the possible inclusion of treated effluent in some manner of a conjunctive use scenario (Herrera 2002). Mexican officials wish to retain control of the potential use of Mexican effluent, and this has been a considerable barrier to making much progress on negotiating a flow guarantee for Mexican effluent as part of discussions toward a regional groundwater replenishment district.

Two efforts have developed in conjunction with the Santa Cruz Active Management Area (SCAMA) staff that are of relevance to the water resource management issues in the reaches of the river below Ambos Nogales: the SCAMA Groundwater Users Advisory Council (GUAC) and the SCAMA Settlement Group.²⁴ GUAC is an official governmental effort whereby private citizens who are active users of groundwater resources regularly meet with SCAMA staff to discuss groundwater uses in the region and various means to manage these resources more effectively. Specific topics on which the council have focused include the status of water rights adjudication in the region, awards of ADWR grants to study groundwater resources, results of the Statewide Safe Yield Task Force, adjustment of pumping fees for groundwater users, and the status of a SCAMA surface water model (GUAC 1999). Of particular note is the extremely open manner by which these meetings are conducted. Not only are members of the council and SCAMA staff welcome to actively participate, interested members of the general public are also welcome to attend and contribute to the discussions. If openness and participation are deemed positive contributions to regional approaches to water resource management on the border, the efforts of this council provide a valuable lesson learned for future efforts in other regions along the border.

Related to GUAC is a less formal effort known as the SCAMA Settlement Group. This group is composed of private citizens who own water rights within SCAMA, attorneys representing the legal interests of large water rights holders in the region, and various staff members at ADWR. The goal of the Settlement Group is to work

toward resolution of water rights adjudication in SCAMA outside the ongoing legal process that has made little progress to date (Settlement Group 1999). Of special note is the extremely participatory manner by which the Settlement Group functions, a fact that is not surprising given the membership of the group and the open manner by which SCAMA staff conduct business.

An anecdote involving the activities of the Settlement Group demonstrates this openness and provides insight into how discussions concerning complex water resource management can be advanced. During late 1999 and early 2000, the group worked with ADWR staff to develop and implement a pilot project whereby water rights holders would be surveyed to gather data on land ownership and various facets of water rights. The first step in this project was the delineation of the study area, and ADWR staff presented a sophisticated, computer-generated map outlining what they thought was a reasonable area. Immediately, local water rights holders commented on several problems with this area, including areas with limited water uses that may not be worth the time and energy to survey, and other locations where an uninvited visit from ADWR staff could actually pose a risk to the staff involved. To the credit of ADWR staff, this local knowledge was actively welcomed into the debate. After more discussion, the study area was modified to take into account the hydrologic science that ADWR staff brought to the table, as well as the valuable local knowledge that ranchers and other water rights holders possessed. Given the political climate of rural Southern Arizona, considerable tensions exist among water rights holders and ADWR staff, and the cooperation evident in this meeting is a much needed ingredient in implementing this project. To date, all the surface and groundwater rights that exist in SCAMA have been documented, and this information has been provided to all water rights holders and claimants. Currently, ADWR staff are working to verify and qualify the water rights that have been asserted and also the amount of "wet water" that may actually be available for use in the SCAMA area. The goal of this work, which may be completed by 2003, is to reconcile the total water rights in the area with the amount of wet water, and then move toward some form of management strategy that would acknowledge the regional shortage of wet water relative to water rights in an equitable manner

(Barcnas 2002).

In addition to the water quantity issues SCAMA efforts are addressing, water quality of the treated effluent discharged by the NIWTP is also of importance. Monitoring of effluent quality and surface flows downstream from the plant has revealed elevated levels of ammonia and nitrates (Friends of the Santa Cruz River 1999). These levels raise water quality concerns that have been voiced to EPA staff involved in the upgrade of the plants (Valentine 1999). The IBWC, as the primary operator the NIWTP, has failed to meet National Pollution Discharge Elimination System Standards, and these water quality concerns have been a good part of the impetus for enhancements to the rigor of the treatment processes at the plant (Holub 1999).

A contributing factor to the establishment of the SCAMA in 1994 is its location directly on the U.S.-Mexican border. "...[T]he legislature recognized the international nature of water management issues facing the Upper Santa Cruz Basin ... and the desire of the water-using community to participate in local water resource management and binational coordination efforts" (ADWR 1999). As noted above, one of the most difficult binational challenges facing SCAMA is how to reconcile the confluence of issues related to the treatment of binational wastewater in the Ambos Nogales region with the role of discharged treated effluent in regional water balances. This challenge is well-suited to regional approaches. Results of field work on this issue not only verify this proposition but also uncover an interesting and innovative means to handle the issues related to treating binational wastewater in Ambos Nogales.

Given the increasing rates of groundwater extraction occurring in the region and the daily generation of millions of gallons of treated effluent, what prospects exist for acknowledging the hydrologic connectivity of surface water and groundwater in the Ambos Nogales region? Various regional water resource experts have advanced the idea of a binational regional groundwater replenishment district as a means to reconcile the needs of various interest groups and water users across the border within a regional framework that acknowledges regional links, surface water and groundwater interactions, and the value of regional and local knowledge (Holub 1999; Barcnas 1999; GUAC 1999). Many variations on this theme have

been advanced, although the specific details of them are outside the scope of this chapter. However, a discussion of the basic concepts involved in this type of management regime is valuable to see how a regional approach may fit the relevant issues.

Presently, approximately 10MGD of wastewater generated in Nogales, Sonora, are diverted to NIWTP in the United States. At the plant, these flows and approximately 2.5MGD of wastewater from Nogales, Arizona, are treated and discharged into the Santa Cruz River. The cost to Mexico for treatment is approximately \$300,000 per year, and this amount is paid by CILA. The NIWTP was built with U.S. federal money and has been managed and jointly owned by IBWC and the City of Nogales for many years.

As mentioned previously, the wastewater generated in Mexico is owned by the Mexican government. As wastewater, it lacks immediate value. However, once treated to various levels, this wastewater can have value as reclaimed water for a variety of uses. Once the wastewater crosses the border, enters the plant on the U.S. side, and is treated and discharged into the river, this treated effluent becomes an appropriable water resource within the State of Arizona (Barcnas 1999). Broad recognition exists in the region that the appropriable nature of this effluent poses a potential conflict with Mexico's right of recapture, as discussed above, and discussions to resolve this conflict have been ongoing for several years.

The aforementioned dynamic takes on more than academic importance when the impact of the treated effluent on downstream surface and groundwater balances is addressed. The treated effluent is the largest input of water supply into these water balances and has great importance to the riparian condition in downstream reaches and as a source of groundwater recharge to downstream aquifers. The reliability of the input of wastewater into this water balance is also of importance to IBWC-CILA, EPA, and BECC. All the plans for expanding wastewater management infrastructure in the Ambos Nogales region require that minimum inflows of effluent arrive at the plant to justify its build-out and ensure efficient and effective plant operation.

Implicit in this situation is the need, on behalf of Arizona riparians and ADWR, for some form of guaranteed minimum flows of wastewater to be generated by Mexico. The conditions by which this

guarantee are arranged from the pre-conditions for a binational groundwater replenishment and management district. One scenario advanced in the past is that some entity (perhaps the City of Nogales) assume the \$300,000 per year cost of operation and maintenance that Mexico is paying and provide additional funds to buy or lease the rights to the wastewater involved, in exchange for a guarantee of certain minimum flows to the plant. A variation of this theme would see some U.S. entity provide treated potable water in exchange for the flow guarantee, perhaps at a 3:1 effluent to potable water credit rate (Barcnas 1999). This minimum flow guarantee would then be transferred into some variation of an assured water supply that the ADWR would accept as a valid source of supply for future management options. The actual discharged effluent would continue to enter the hydrologic system of this portion of the basin as a source of groundwater recharge, which could then be appropriated by some form of water right or leased water right by downstream users. These rights would be distributed via some form of market mechanism, and proceeds from the market transactions would fund the operation of the district and financial transfers to Mexico.

In order to create this type of a district and establish the Santa Cruz Water Management Authority, the State of Arizona Senate Bill 1410 was introduced (Arizona State Legislature 2002). ADWR and SCAMA staff questioned the ability of the authority to generate revenues for projects, the manner by which a flow guarantee with Mexico could be effected, and the overall management of the authority. These issues and a lack of overall detail prevented the legislation's being voted out of committee. Plans are to reintroduce the bill in future legislative sessions, with SCAMA and ADWR staff taking a more active role, which may help address some of the concerns that made the first bill problematic (Barcnas 2002).

Although this arrangement of water flows, ownership, and potential terms of exchange is quite complex, some form of an "Ambos Nogales Binational Groundwater Replenishment and Management District," has considerable potential to meet regional water resource management needs well into the future planning horizon. Such a district could also be viewed as a form of regional water resource management tool similar to watershed councils, or *consejos de cuen-*

cas, which are advanced in Mexico's national water law by CNA (CNA 1992 and 1997). Implementing these tools would incorporate the value of local and regional knowledge into a spatial framework consistent with that of the Upper Santa Cruz Basin.

The above framework offers promise for innovation in binational water resource management, but it comes with several barriers. The principal barrier is the hesitance of the large federal and international agencies involved in water resource management to openly and actively engage the public and regional players in border water resource management (Barcnas 1999; dos Santos 1999; Holub 1999). The centralized manner by which IBWC-CILA and CNA have traditionally undertaken their responsibilities may pose a barrier to this type of regional cooperation. As noted in the 1944 Water Treaty, IBWC-CILA have the pre-eminent right and responsibility to direct binational water resource management and planning, and past experiences have shown a reluctance on the part of IBWC-CILA to surrender this political primacy. In addition, Mexico's water law established CNA as the Mexican agency with absolute authority for management of federal water resources (CNA 1992 and 1997). It is clear that these institutions must be at the table for a replenishment district to emerge, and to date, this participation and willingness to work with regional stakeholders has not been as evident as may be necessary for this to occur.

At the state and regional levels, issues of management and control are also potential barriers. Were a replenishment district to emerge, who would manage and control the district, ADWR headquarters in Phoenix, or the regional staff of the SCAMA? Historical management of the ADWR would argue for the former, while the degree of regional expertise and perspective needed to manage such a district would argue for the latter. This issue of management would need to be resolved for the needed support within the legislature and executive branches of government to materialize. Lastly, a lack of experience in managing traditional surface waters exists within the active management area (AMA) framework, which evolved primarily to manage groundwater resources.

How might these barriers be removed or lessened? At the federal level, participation of the Counsels General that serve the Ambos Nogales region through the BLM may be helpful in facilitating the

willingness of CILA and CNA to explore such a district. In addition, the recent tendency of IBWC-CILA to employ a more participatory and open management style would increase the likelihood that the proper links between IBWC-CILA leadership and regional stakeholders would emerge. Ambos Nogales is a smaller urban region than larger twin cities and it has a greater sense of community and a desire to cooperate regionally. This quality is also helpful in generating the needed intra-regional dimensions that a successful effort would require. Long-term communication and lobbying with key people at the state and national level will also increase the likelihood that these individuals will be willing to help the establishment of a replenishment district move forward (Holub 1999).

What insights can be drawn from the facilities planning process in Ambos Nogales that may be of use in other regions along the border? The potential for a binational recharge district clearly acknowledges the hydrologic connectivity of ground and surface waters. It also recognizes the importance of the connectivity in the dynamics of water uses on both sides of the border. These cross-border dynamics clearly exist in other border twin cities, and management efforts in other twin cities may benefit from actively and clearly acknowledging these dynamics. The successes of the SCAMA Groundwater Users Advisory Group and Settlement Group demonstrate the value of local and regional knowledge as well as the open exchange of information that facilitates public participation. This access and openness of operation can be considered a lesson learned that may benefit other efforts toward regional management of water resources along the border. IBWC-CILA and others involved in the facilities planning process made a sincere effort to involve open public participation in the later stages of their projects, but such an inclusion may have been of greater value if the public would have been more actively involved earlier in the process.

PASO DEL NORTE REGION

Regional Overview

The Paso del Norte region is defined by limited rainfall, scarce water resources, and its position at the junction of three states and an international boundary. Like many other twin city areas it is characterized by burgeoning growth, vast expanses of land, limited economic resources, and isolation from other population centers. The Paso del Norte region sits at the intersection of New Mexico, Texas, and Chihuahua, where the Rio Grande/Río Bravo shifts from a transboundary river to a boundary river. When defined by water issues, the Paso del Norte begins at Elephant Butte Dam in New Mexico and ends at the twin towns of Ft. Quitman, Texas, and Cajoncitos, Chihuahua. The region's geography is determined by a series of isolated mountain ranges—the Franklin Mountains in Texas, the Organ Mountains in New Mexico, and the Sierra de Juárez in Mexico—and a wide basin through which the Rio Grande flows. The area is semi-arid, receives an average 8.5 inches of rainfall annually, has approximately 64 inches of net annual evaporation, and is at the northernmost end of the Chihuahua Desert ecosystem. Regional elevation is approximately 4,000 feet and temperatures can range from 47°C (117°F) on summer days to below freezing on winter nights. The most dramatic temperature changes are found in the winter, where daytime and nighttime temperatures can shift as much as 4°C (40°F), causing atmospheric inversions that dramatically affect air quality.

The principal cities in the region are Las Cruces, New Mexico; El Paso, Texas; and Ciudad Juárez, Chihuahua, which had a combined official population of 2,073,100 in 2000, although other estimates are higher, as noted in Table 6. Although the combined population of the San Diego-Tijuana region is greater, the international urban area formed by El Paso-Ciudad Juárez is the largest community directly on the U.S.-Mexican border. That population is generally young, predominately Hispanic, and relatively poor. The region has experienced rapid population growth since the 1950s, and at current rates of growth—approximately 3% per year—the regional population will double by 2024. All of these factors impact how regional

institutions approach the challenge of increased demand and limited supply.

Table 6. Historic and Projected Population of El Paso and Doña Ana Counties and Ciudad Juárez

Year	El Paso County	Doña Ana County	Ciudad Juárez	Regional Total
1950	194,968	35,688	131,308	361,964
1960	314,070	55,509	276,995	646,574
1970	337,471	65,633	424,135	827,239
1980	479,899	94,051	567,365	1,141,315
1990	591,610	135,510	798,499	1,525,619
2000	745,000	174,700	1,521,500	2,441,200
2010	940,000	204,767	2,250,000	3,394,767

Sources: City of El Paso, Department of Planning, Research and Development; 1990 U.S. Census; 1990 Mexican Census; and Ciudad Juárez Planning Department

An international treaty and a state compact form the regulatory framework for this portion of the watershed. The Convention of 1906 between the United States and Mexico distributes the waters of the Rio Grande in the upper stretch. The Rio Grande Compact of 1924 then divides the waters in the upper stretch of the river not already allocated to Mexico between Colorado, New Mexico, and Texas. Under this framework, river allocations were based on a complicated formula that considered population, irrigated lands, and average annual flow at the time of the allocation, with some projections into the future. Surface waters are allocated primarily for irrigation use, and none are set aside in the legal framework for instream flows. The Mexican allocation from these waters is 60,000af annually, which is delivered at the American Diversion Dam in El Paso, Texas, and managed by the Valle de Juárez Distrito de Riego 009. In a full-water year, southern New Mexico is allocated 494,979af, which is managed by Elephant Butte Irrigation District (EBID), and 376,862af are allotted to El Paso County Water Improvement District #1 (EPWID#1) (Bureau of Reclamation 2001). When the river was apportioned, the number of irrigated acres and population was much less than at present, and recent

growth has shown that this allocation scheme does not reflect current needs. Although the entire stretch of the river has never been adjudicated, Brown and Ingram (1987) contend that the river is fully committed and most likely over-appropriated. Groundwater basins are also shared among states and the two countries. There is no treaty that regulates the use of aquifers between the countries.

Water is managed by a complex set of laws and institutions that include irrigation districts, state agencies, federal agencies, and international commissions, as detailed in Table 7. Many of these have overlapping jurisdictions. IBWC-CILA management and apportionment of border waters has historically represented a workable model of binational cooperation (House 1982). At the federal and state level in each country, water management is rooted in different legal traditions throughout the basin. In Mexico, water is the property of the federal government, while in the United States different state laws govern water. In New Mexico, water is owned by the state, and the right of prior appropriation conveys both surface and groundwater. In Texas, surface water is owned by the state, and groundwater is placed under common law that conveys it as a property right. At the federal level, surface water in Mexico is managed by CNA and in the United States by the Bureau of Reclamation (USBR). At the state level, it is managed by the Junta Central de Agua y Saneamiento, Chihuahua (JCAS), the New Mexico Office of the State Engineer (OSE), and the Texas Commission on Environmental Quality (TCEQ). At the local level it is managed by a number of utilities and irrigation districts.

Since the Paso del Norte region falls within the 100km zone designated by the environmental side agreements to NAFTA, planning for public water and wastewater infrastructure is influenced considerably by BECC purview. The certification process established by the BECC-NADBank system has the potential to influence the way water and wastewater projects in the border region are designed, funded, and implemented (Brown 1998), since projects seeking certification must address the sustainability of the project as it pertains to both physical and economic resources. Additionally, the certification process requires significant public input and transparency, which, historically, has not been common in the border region.

Table 7. Water Management Institutions

Agency Level	Name
International	Comisión Internacional de Límites y Aguas (CILA)
	International Boundary and Water Commission (IBWC)
Federal	Comisión Nacional de Agua (CNA)
	United States Bureau of Reclamation (BOR)
Tri-State	Rio Grande Compact Commission
State	New Mexico Office of the State Engineer (OSE)
	Texas Commission on Environmental Quality (TCEQ)
	Junta Central de Agua y Saneamiento, Chihuahua (JCAS)
Local	City of Las Cruces Water Resources Department
	El Paso Water Utilities (EPWU)
	Junta Municipal de Agua y Saneamiento, Ciudad Juárez (JMAS)
	Small Municipal Suppliers
	Elephant Butte Irrigation District (EBID)
	El Paso County Water Improvement District Number One (EPCWID)
	Valle de Juárez Distrito de Riego #009

Water Supply and Use

The Rio Grande and a number of aquifers supply water in the region. Table 8 provides specific information on water sources, use, and management institutions. The Rio Grande is the only renewable regional water source. All waters in this stretch originate in the United States and are the result of snowmelt from the Colorado Rocky Mountains, limited rainfall, and agricultural and municipal discharges into the river. Figure 4 provides a map of the basin. On this stem of the river two major reservoirs manage flow: Elephant Butte is a storage reservoir and Caballo is a regulating reservoir. Elephant Butte is approximately 125 miles north of El Paso and Caballo is about 25 miles south of Elephant Butte; both are operated by USBR. The average combined annual release over the life of the project has been 790,000af to United States irrigators. Rio Grande waters provide irrigation supply for approximately 178,000 acres of land in EBID and EPWID#1, 25,000 acres in the Juárez Valley, and 18,000 acres in Hudspeth County, which is managed by the Hudspeth County Reclamation District (HCRD). Hudspeth irrigation waters are composed primarily of drainage waters. The river is dry most years from Ft. Quitman-Cajoncitos until the Río Conchos enters the main stem near Big Bend National Park.

Table 8. Water Sources, Use, and Management Institution

Jurisdiction	Las Cruces, Doña Ana County, New Mexico		El Paso City & County, Texas		Ciudad Juárez, Chihuahua	
Use	Municipal-Industrial	Agricultural	Municipal-Industrial	Agricultural	Municipal-Industrial	Agricultural
Source	Groundwater	Surface water & Groundwater	Surface water & Groundwater	Surface water	Groundwater	Surface water & Groundwater
Amount	Las Cruces: 93% Mesilla Bolson	87% Rio Grande	44% Hueco Bolson	100% Rio Grande	100% Hueco Bolson	34% Rio Bravo 33% Hueco 33% wastewater return flow from M&I (2000) ²
	7% Jornada del Muerto	13% Mesilla (2000) ¹	18% Mesilla Bolson			
			38% Rio Grande			
Annual Water Use	Las Cruces: 20,680af	545,435af (2000) ¹	41.6 billion gallons	264,127af (2000) ¹	150 million cubic meters	173,500 af (2000) ²
	246gpc/d (2000) ¹		159gpc/d (2000) ²		330 l/h/d (2000) ³	
Management Institution	Water Resources Department	Elephant Butte Irrigation District	El Paso County Water Utilities	El Paso County Water Improvement District #1	Junta Municipal de Agua y Saneamiento	Valle de Juarez Distrito de Riego 009
Ownership	Surface water & Groundwater: State, NM State Engineers		Surface water: State, TCEQ Groundwater: Landowner		Groundwater: Nation – Landowner can drill subject	
					Surface water: Nation, CNA	

¹Paso del Norte Water Task Force, ²El Paso Water Utilities, ³Luis Mario Gutierrez

Groundwater has provided the majority of the municipal and industrial supplies since the region was settled. The primary sources of groundwater are the Hueco and Mesilla Bolsons, and the Rio Grande Alluvium. These span the international border and are used for both municipal and agricultural purposes. For a full description of the structure, water quality, and available supply of these aquifers, see *Transboundary Aquifers of the El Paso/Ciudad Juárez/Las Cruces Region* (Texas Water Development Board and New Mexico Water Resources Research Institute 1997). Traditionally, municipal water was extracted from the bolsons—as was agricultural water during times of drought—while the river was maintained for agriculture since it is legally and historically allocated to the growing of crops. All three communities are reliant on these aquifers for the majority of municipal and industrial water. Until recently, groundwater was an inexpensive, dependable source of water. The Mesilla Bolson is

the principal source of groundwater for southern Doña Ana County, and a limited source for El Paso. It also has the potential to provide water for Ciudad Juárez; however, the exact amount and quality of that water is unknown. The Mesilla Bolson is a stream-related aquifer whose health is tied to the health of the Rio Grande. The extent to which regional development of the river will impact this basin still needs to be determined. The Hueco Bolson is the only current source of municipal water for Ciudad Juárez and a primary source for El Paso. It is a fossil aquifer that is being mined. The Rio Grande Alluvium is shallow, approximately 200 feet deep, and water from this alluvium is generally of poor quality (Lyndon B. Johnson School of Public Affairs 1999).

One of the primary regional water concerns is the municipal water supply. As municipal and industrial demand has increased, groundwater basins are becoming contaminated or depleted (Hetrick 1989; Sharp 1998). Due to increasing salinity and declining groundwater levels, serious shortages are expected in the near future. Estimates are that at El Paso's historic rates of withdrawal, potable water in the Hueco Bolson will be exhausted by the year 2025 (El Paso Water Utilities Public Service Board 2001). Pumping in the Ciudad Juárez portion of the Hueco Bolson, where there is less fresh water available overall, is almost double that of El Paso pumping. Ciudad Juárez is expected to experience a major deficit in the Hueco by 2004 (Gutierrez 2000). Water providers, therefore, have been forced to look for means to extend the limited reserves in the bolson, use surface water, and seek alternative supplies. Although Ciudad Juárez and Las Cruces are still dependent on groundwater, El Paso is using the Rio Grande to meet demand during the irrigation season. Ciudad Juárez is investigating the transfer of its 60,000af allotment of surface water from agricultural to municipal uses; however, these waters would be subject to seasonal availability and would require the alteration of the existing legal framework that allocates surface water to irrigators. Additionally, Ciudad Juárez is looking at use of the Mesilla Bolson to supplement municipal supplies through a project that is anticipated to cost \$30 million and yield 25,567af annually (Gutierrez 2000).

Figure 4. Hydrography of the Rio Grande/Río Bravo Watershed



Source: Drafted by Carol Placchi, modified from U.S. State

Unique Regional Challenges

Finite water resources have combined with a rapidly expanding population to help define the regional water situation. Regional water problems are therefore closely linked to rapid population growth. Estimates are that the regional population will double in 21 years, with most of this growth in the urban areas of Ciudad Juárez. Growth has combined with high levels of poverty to create a situation where water distribution has not kept up with water demand. Under current use and allocation scenarios water demand is outstripping available supplies. The agriculture sector uses approximately 78% of the total water in the region while growing demand lies in the urban sector. Use among the urban sectors is also disproportionate, with Ciudad Juárez having the lowest per capita use at less than 100 gallons per capita per day (gpc/d) and Las Cruces having the highest at more than 240gpc/d. As well, the U.S. allocation is approximately 90% to 93% of available surface waters.

These allocation structures and growth patterns have impacted El Paso, Ciudad Juárez, and Las Cruces individually, and increased competition between sectors, communities, states, and nations. They have had an effect on how these communities relate to each other and surrounding areas. Communities surrounding El Paso fear that the city will look their way for additional groundwater as water supplies in the Hueco Bolson become harder and more expensive to access. This is a not entirely unfounded as El Paso's Public Service Board has purchased a 25,000-acre ranch approximately 150 miles south of the city as a contingent groundwater supply. They have done the same with several large tracts in New Mexico for their water rights. And, competition for Rio Grande water has increased significantly as growing urban areas face serious shortages of groundwater and look to the river for replacement and new supplies. Rising environmental concerns have also focused on a need for water to be allocated for instream flows. The treaties and the Rio Grande Compact did not provide water for instream flows or for the preservation of species. In 1994, the Rio Grande Silvery Minnow, whose habitat is in northern New Mexico, was declared an endangered species. This surface water allocation to agriculture has created friction over water distribution between use sectors (Bath 1986; Hetrick

1989; House 1982; Paule 1996). Although increased competition, to this point, has not resulted in an alteration of the allocation framework, small-scale transfers of water from agriculture to municipal use have been achieved through the leasing of water rights. Finally, because of asymmetry in growth and allocation, Mexican urban areas are experiencing pressure on water resources at a faster rate than U.S. communities; however, the potential for using agriculture waters to address municipal-industrial concerns is highest in the U.S. portion of the Paso del Norte.

Watershed-based planning and management would seem to be an optimal approach for the region since it provides a defined physical space and is thought to optimize the supply for human and ecosystem use (National Research Council 1999). Water resource planning in the region, however, is not held in any single authority, and no comprehensive plan exists for the area. Water planning is segmented by jurisdictions. All of the major jurisdictions currently have, or are in the process of generating, water plans, as noted in Table 9. Although the different planning mechanisms address similar aspects, such as population, land use, water supply, and water demand projections, how they deal with these issues varies. A review of the documents shows that population projections, land use, water use estimates, and even planning horizons are different for the various plans. Additionally, the assumptions and necessities inherent to irrigators and municipalities help to make many of these plans incompatible.

Innovative Cross-border Efforts

Several innovative efforts to address regional water concerns have arisen in the last two decades. The New Mexico-Texas Water Commission (NMTWC) is one such endeavor. The commission was formed in 1991 out of the agreement that settled a long, bitter, and expensive lawsuit between Texas and New Mexico over Texas' use of New Mexico groundwater. El Paso sued for the right to drill wells in the nearby Mesilla Bolson and pump that water over the New Mexico state line for municipal use. Out of this litigation came the commission, which was established to examine methods to plan cooperatively for surface water use between Texas and New Mexico. The parties agreed that instead of looking to Doña Ana County groundwater for

additional resources, El Paso would continue to broaden its options by looking to surface water allocations already made to Texas irrigators. Parties to the commission therefore work together to investigate the use of Rio Grande waters for municipalities. The commission has proposed the El Paso-Las Cruces Sustainable Water Project to achieve that goal. The project is a series of canal improvements, surface water treatment plants, distribution systems, and aquifer storage and recovery infrastructure. Environmental impacts have already been examined and the project sponsors, El Paso Water Utilities, and IBWC, are seeking the necessary permits.

NMTWC is unique in that it is a quasi-official cross-border water management effort. Its mission and the stakeholders involved, however, are clearly defined and structured by the settlement agreement, thus making it difficult for other parties and alternative concepts of water allocation, management, and planning to emerge. Until recently, the effort did not include environmental interests, but it changed because of continued pressure. As a result, the commission formed the Paso del Norte Watershed Council to provide input on mitigation and other environmental issues associated with the Sustainable Water Project. The environmental impact process also brought public input into the project as a requirement of an Environmental Impact Assessment.

Because of the history of the commission, Mexico is not included in either the commission or the subsequent Sustainable Water Project. Although there is recognition and discussion among members that effective planning cannot occur without Mexico at the table, at this time, NMTWC is still a New Mexico-Texas entity. Another point to be considered is that while the commission has been successful to date in project planning, it has not necessarily made relations between El Paso and Doña Ana County more relaxed, nor has it eliminated tensions between irrigators and utilities or lessened the regional tendency toward litigation. Part of the City of El Paso's long-term plan for contingency supplies involves the above-mentioned New Mexico tracts purchased for their water rights. Lawsuits are threatened as El Paso looks for ways to transfer water from those lands to Texas for municipal use.

Table 9. Paso del Norte Water Planning Efforts

Plan Name	Entity & Area Covered	Significant Aspects
Plan Maestro de Ciudad Ju rez	Junta Municipal de Agua y Saneamiento Ciudad Ju rez	Assessment of potable water services and supply, water reuse, transfer of agricultural waters to municipal uses Plan to 2020
Do a Ana County Regional Water Plan	New Mexico State University, EBID, Las Cruces Water Resources Department, Do a Ana County Do a Ana County	Water demand and use, surface and ground water supplies, no projections of future water sources Plan to 2035
Regional Water Plan — in progress	Lower Rio Grande Water Users Organization Portion of Sierra County & Do a Ana County	Water rights, surface and ground water aspects, water supply and demand, water quality and conservation issues Plan to 2040
Las Cruces Water and Wastewater System Master Plan	Las Cruces Water Resources Department Las Cruces	Municipal and irrigation water demand and supplies, continue to rely on groundwater for municipal uses Plan to 2015
Far West Texas Regional Water Plan	Far West Texas Planning Group, Texas Water Development Board 7 west Texas counties	Mandated under Texas Senate Bill 1, all regions have a plan, water supply and demand, no transfer of water rights, addresses drought of record conditions Plan to 2050
El Paso-Las Cruces Sustainable Water Project	New Mexico-Texas Water Commission El Paso & Las Cruces	Year round drinking supply through surface water treatment plants for municipal use, and aquifer storage and recovery systems
Tri-regional Planning Group	Junta Municipal de Agua y Saneamiento, Las Cruces Water Resources Department & NM regional Water Users, El Paso Water Utilities Ju rez, El Paso, Las Cruces	Surface water treatment plant for Mexico allocation and some additional waters for US

Source: Authors

Several other efforts to bring about regional water planning and management in the region have sprung from universities, private foundations, and NGOs. The concept of the university as an honest broker for regional dialogue is fairly well-established in the border

region and has been effective in achieving results in other areas. One of the first efforts in the Paso del Norte region was the University of Texas at El Paso's Binational Water Project (BWP), supported by the Ford Foundation. This project began in 1990 as an attempt to bring together water planners and policymakers from both sides of the border to share information, gain understanding, and establish a long-term dialogue. The BWP worked from the premise that community-based dialogue, local transborder networks, and data and information sharing were crucial to achieve regional planning and management of resources. The success of the BWP was its ability to provide an initial space for dialogue that would lead to the understanding of stakeholder concerns and needs, although very few concrete results arose from this endeavor.

Perhaps the most innovative and successful cross-border effort related to regional environmental issues is the Paso del Norte Air Quality Task Force (PdNAQTF), which was initially supported by the Environmental Defense Fund (now, Environmental Defense). The task force emerged in 1993 due to community concerns over unhealthy levels of PM₁₀, ozone, and carbon monoxide in the Paso del Norte region. The PdNAQTF is a "ground up" initiative that includes both governmental and non-governmental interests at all levels. The motivation behind this effort was the acknowledgment that air was shared in an "airshed" and thus could only be managed effectively if all parties worked together regardless of jurisdictional boundaries. The ultimate goal of the PdNAQTF is the development of an air quality district that would operate across boundaries to reduce regional pollution. Immediate goals, however, were the development and implementation of doable, applied projects that would have a direct impact on regional quality of life. In 1996, the Joint Advisory Committee on Air Quality Improvement for the El Paso-Ciudad Juárez-Doña Ana County Air Quality Management Basin was formed by the establishment of Appendix I to Annex V of the La Paz Agreement. The Joint Advisory Committee signifies federal-level recognition on the parts of the United States and Mexico as to the importance of joint management of air resources in the region, and paves the way for a regional air quality district. The Task Force continues to work toward the creation of that district.

The success of the PdNAQTF provides a model for other cross-

border environmental efforts. The PdNAQTF was successful in part because of a bottom-up approach that focused on community-level tangible results without losing sight of larger management goals. It is an inclusive binational group involving local, state, and federal agencies, as well as non-governmental health and environmental stakeholders. Additionally, it chose and implemented projects that had an impact on regional air quality and demonstrated, with the implementation and success of these projects, that jurisdictions could work together toward common goals. The PdNAQTF provided leadership and focus for regional efforts related to air quality, and it integrated governmental, non-governmental, academic, and regulatory concerns over air pollution on a level playing field.

However, the success of the PdNAQTF cannot necessarily be transferred to regional water issues. Attempts at cross-border water planning and management have been less favorable. Elemental differences exist between air and water both in the management and ownership of the resource, as well as in the resource itself. Air is not the finite resource that water is. Water, unlike air, has a well-defined historical structure of controls, management practices, and ownership patterns that are difficult to alter. Finally, there is a long history in the region of water conflict, primarily in the form of litigation. Nonetheless, innovative efforts currently are underway in the region that deserve recognition.

One such effort is the Paso del Norte Water Task Force (PdNWTF). Although many of the goals are similar to those put forth by the BWP, there are differences in approach. The PdNWTF attempts to promote sharing information and understanding among participants in order to avoid duplication among members, and to encourage coordination in individual planning and management efforts. The members of the PdNWTF are a small group of binational stakeholders that primarily includes municipal, irrigation, and private water interests, the assumption being that a small core group is necessary for meaningful results. An academic-scientific Support Team assists the task force.

The PdNWTF was convened by IBWC in 1999 and initiated by the Houston Advanced Research Center with support from the Hewlett Foundation. It had initial success in a series of dialogues where members visited each other's facilities to gain an in-depth

understanding of management and planning operations and concerns. The most important product of these visits and related efforts was the publication of a comprehensive report on regional water resource issues, *Water Planning in the Paso del Norte: Toward Regional Cooperation*. At present the PdNWTF Support Team has proposed a series of projects that attempt to provide tangible results to address specific regional water concerns. These include:

- An investigation of municipal-agricultural joint projects, with California as an example
- A regional water plan
- An assessment of regional water markets
- Expansion of a regional computerized seamless water resource map of the Paso del Norte region toward a GIS database that can be used by all parties

The implementation of these projects has the potential to further regional dialogue related to water. PdNWTF efforts, however, need to be expanded to include the public in this dialogue if it is to be meaningful in the long term.

Two areas where transborder collaboration has been most effective are the domain of research and NGO-based environmental and cultural efforts. A good example of cooperative research efforts is the Transboundary Aquifer Assessment Program, which is a collaborative regional study supported by IBWC-CILA. This project builds on 1997's *Transboundary Aquifers and Binational Groundwater Data Base Report—City of El Paso-Ciudad Juárez Area*. This report was the culmination of a multi-year, multi-agency effort that included IBWC-CILA, JCAS, EPA, Texas Water Development Board, and New Mexico Water Resources Research Institute. It collected data on groundwater hydrology, historic water levels, pumping trends, water quality, and current and future extraction estimates. It provided data and GIS-based maps for dissemination to all parties and the public. It did not, however, make a detailed analysis of the findings nor did it provide recommendations as to future groundwater management options. The official, State Department-level of this project made both the effort and the report important to collaborative regional efforts.

The Rio Grande/Río Bravo Basin Coalition is an NGO-based

environmental organization that grew out of university efforts in 1994 to bring together individuals and organizations from throughout the basin to share information and develop long-lasting networks. These coordinated efforts grew until the coalition was officially registered as a non-profit in 1996. The coalition currently has a board of directors, more than 50 NGO member organizations, and two co-directors who represent the United States, Mexico, and the Pueblo nations. It is committed to multi-cultural, multi-national efforts that unite the basin and promote sustainability and environmental health. It operates through the building of networks that operate at the local levels and across the watershed, the promotion of social and cultural diversity, and the creation of dialogues through a democratic process. This approach has worked well. The coalition currently has a paid staff, maintains an informative electronic listserv and website, and sponsors numerous events to raise environmental and cultural awareness about the basin and its inhabitants. The democratic, binational, basin-wide approach of the Rio Grande/Río Bravo Basin Coalition was difficult to mold initially, but has proven to be a successful model for dialogue between non-governmental entities.

The constraints to regional planning and management continue to be large. These include different legal systems that regulate water, historical use and ownership patterns, the litigious nature of water conflict between Texas and New Mexico, rural-urban and municipal-agricultural tensions, and rapid regional growth that requires both short-term actions and long-term decisions. However, the efforts outlined above show the potential for locally driven projects to build toward coordinated regional planning and management. These efforts provide several lessons.

Although the above efforts demonstrate that it is easier and more effective to cooperate on engineering and scientifically-based projects and studies, they also indicate that as the dialogue builds, larger and more sensitive technical concerns can be addressed. Often the collection of data provides a non-threatening avenue to cooperation concerning the very difficult issues surrounding regional water management. The sharing of information and building of formal and informal dialogues is an important step toward coordinated regional efforts. However, the decision on who participates, or more right-

ly stated, the exclusion of parties to that dialogue, is a concern. Many of the current efforts recognize, or are beginning to recognize, the need for regionally-based solutions that include all stakeholders. Often, however, the public and environmental voices continue to be excluded or are minor players in regional water discussions. Additionally, regional efforts are still highly fragmented around jurisdictions and are hampered by the existing legal structure that allocates water in the region. Although it is evident that litigation has not solved the problems in the region and that cooperative solutions save time and money in the long-term, litigation continues to have a large presence in the region.

CONCLUSIONS

Given the in-depth examinations of three twin cities that lie within three important border river basins, what general trends or lessons learned can be drawn from these case studies to provide insight in other regions on the border? These case studies have examined the utility of employing a watershed perspective to explore a complex array of water resource management challenges in border basins that include issues of water supply, wastewater treatment and management, flood control, and general water quality control and management. Watershed-based approaches and institutional organizations have provided valuable insight and acted as management frameworks that have been useful in all the basins employed. These include efforts like San Diego-Tijuana's Border Water Council, which has a fairly formal connection to existing governmental institutions like IBWC-CILA, SANDAG, and the San Diego County Water Authority. Conversely, less-formal efforts, including those in the Santa Cruz Active Management Area in Arizona, which are based on public input and participation, and the Paso del Norte Water Task Force and Paso del Norte Watershed Council, which also share similar structures and qualities, have been effective. In general, these types of watershed-based efforts have an important role to play in innovations toward improved water resource management along the U.S.-Mexican border.

What of more specific lessons that may have utility in other border regions? Looking at the federal levels of governments responsi-

ble for foreign relations on an international basis, several efforts are worth reviewing and exploring for their usefulness along the border. The Border Liaison Mechanism (BLM) that was so important in the formation of the Border Water Council in San Diego clearly has a role to play in bringing agency officials at all levels of government on both sides of the border together in a dialogue on water resource issues. One unanswered question that remains is: To what degree can this effort be applied in other regions?

BECC has also played an important role in fostering a greater level of public participation through its public participation mandate and by presenting a formal process through which this participation must be advanced to gain BECC certification. This process has also been partially responsible for a rather dramatic change in the manner by which IBWC-CILA conducts water resource planning and engineering works along the border. Both have worked harder to actively and openly include public input into their operations, and this is a welcome change from the past practices of these important agencies. Although BECC, IBWC, and CILA have received a fair amount of criticism that these efforts have not yet been enhanced, there is clearly a welcome change in how these agencies do business that is consistent with, if not openly supportive of, watershed-based initiatives along the border.

Examining the local and regional level of interaction along the border, it is clear an even wider array of innovations may be useful in a broader context. The San Diego-Tijuana region has seen numerous important research efforts advanced through partnerships between regional universities, local water and public works utilities, and state and government agencies, and these efforts highlight the role of partnerships across levels of governments and across the border. Perhaps one of the most successful outcomes in this region is the binational aqueduct planning process that came from the pioneering work of the Border Water Council. This effort also reinforces the importance of working across levels of government and across the border, and is an important and exciting development to follow. An unanswered research question to be examined in the future is: To what degree (and how) can the efforts of the Counsels General, the Border Water Council, an active association of governments such as SANDAG and regional water utilities be borrowed by

other regions to foster innovation on other cross-border water resource problems?

The Santa Cruz Active Management Area in Arizona also offers valuable lessons on how regionally grounded approaches that have active public participation and input can make progress on difficult water resource management challenges. Through this type of approach, stakeholders in the region have made progress on a water rights adjudication that saw considerable barriers over a long period of time in a traditional legal and litigation-based framework. Related to this is the potential development of some form of binational groundwater replenishment district that would take into account hydrologic connectivity of groundwater and surface water resources across the international border, and the complex manner by which wastewater and raw water supplies may need to be managed together. Future research should track these developments to determine how successful they may become and what lessons can be extracted and ported to other basins.

Looking to the Paso del Norte region, there are different configurations of institutions asking somewhat similar questions. Water supply challenges in this region involve conjunctive management of groundwater and surface waters, and a range of institutional innovations presently wrestle with the challenge of how to provide an adequate water supply to an actively growing region with dwindling groundwater resources and competing demands for finite, yet renewable, surface water resources. The model of a “task force” that brings regional stakeholders and experts together has been successful in the region. The Paso del Norte Air Quality Task Force has been successful in advancing a meaningful dialogue on air quality management issues, and the Paso del Norte Water Task Force has advanced similar discussions toward regional management of water resources. We have also seen innovations emerge from a protracted legal process in a manner similar to the situation in the Santa Cruz Active Management Area in Arizona. The New Mexico-Texas Water Commission brings together the large agricultural irrigation districts of the region with water utilities and university researchers for a discussion of regional water resource management, and the Paso del Norte Watershed Council specifically advances important dialogue on related environmental issues. Although not all these efforts

employ a strict watershed-based perspective, all benefit from explicitly regional approaches likely to be useful elsewhere.

The role of university-based research is an important theme in many efforts across the three regions. This investigation has illustrated the value of universities in participating in cooperative efforts across the border, and in some cases, university involvement is a key element in getting stakeholders to communicate across institutional and international borders. University-based research can also answer important applied scientific questions that, in turn, can help in the development of a regionally focused sustainability science approach, as advanced by Kates et al. (2001). Such a science-based perspective is connected to regional political agendas for development activities and is also connected to regional nature-society relationships—connections that are especially important in developing regions like the U.S.-Mexican borderlands (Kates et al. 2001). Related to this ability is the perception in many cases that universities can provide an unbiased perspective to complex problems that is useful in moving past the institutional and regional gridlock that often accompanies water resource challenges along the border.

These case studies have dealt with a wide range of water resource challenges in several regions of varying scales and configurations. Watershed-based efforts have clearly aided in helping answer many difficult questions, although many questions either remain unanswered or developed out of this initial inquiry. Even so, insights gained from this work have some small but important utility in future investigations of shared water resource management and other areas of collaboration along the U.S.-Mexican border.

ENDNOTES

¹ The term “riparian” refers to the banks of a river, stream, water way, or other body of water, as well as to plant and animal communities along such waters. Social scientists have also used the term to refer to human political jurisdictions that occupy the banks and drainage areas of these waters.

² In Mexico, important changes took place in the water institutions during this period. The first step was taken in the Federal Water Law of 1972, with the recognition of water’s urban uses as the first priority over the traditionally favored agricultural uses.

The National Water Law (Ley de Aguas Nacionales) of 1992 reflected, in turn, important environmental and sustainability considerations and emphasized a more active participation of the private sector and the communities affected. The constitutional modifications of 1983 that supported the transfer of the management responsibilities behind the urban water services to the state and local governments around the country (Castro 2001) are also worth mentioning.

³ IBWC has frequently been criticized for being too technical in its orientation and for its top-down structure, which does not allow any public participation in the commission's areas of jurisdiction (Mumme 1993; Spalding 1999).

⁴ "Twin cities" are interrelated urban areas spatially contiguous to each other on both sides of the international border. "Boundary cities have become so functionally intertwined that their futures are inextricably bound, whether the two national governments are able or unable to devise formal procedures for addressing border related problems" (Ham-Chande and Weeks 1992).

⁵ The Bracero Program was a guest worker program that formalized the flow of Mexican workers migrating north during World War II to fill the need for labor in the United States that resulted from large numbers of working-age American males entering the armed forces. The Bracero Program ended in the early 1960s, resulting in large numbers of Mexican workers being repatriated to Mexico.

⁶ Maquiladora, or in-bond, plants are foreign-owned assembly plants that initially used lower-priced Mexican labor to assemble goods from imported components (Herzog 1990). Yet, NAFTA has allowed these plants to be full-scale production facilities (Koci-Pavlovic 1994). In-bond refers to the lack of access to Mexico's domestic markets for the components involved (Dillman 1976). Maquiladora is a name reflecting the Spanish word *maquila*, the portion of flour retained by the miller as payment for grinding a client's grain (Herzog 1990).

⁷ For analysis purposes, the San Diego-Tijuana region is usually defined as comprising San Diego County and the municipality of Tijuana. Its core is the urban conglomerate formed by the cities

of San Diego and Tijuana, together with a number of adjacent communities on the U.S. side of the border. In the case of water and environmental issues, the municipality of Rosarito is also considered (Ganster and Sánchez 1999).

⁸ The 1990s witnessed dramatic changes in the growth of San Diego as an effect of the recession that hit the economy. This was due primarily to the disappearance of the defense industry in the area and the corresponding out-migration.

⁹ Since its creation in 1998, BWC's activities have encompassed a wide range of objectives, among them, the enhancement of cross-border cooperation in delicate environmental issues through the use of a watershed approach.

¹⁰ To assign water property rights, California uses the "reasonable and beneficial use" system, which is a combination of the appropriator's beneficial use of the water and the riparian landowner's reasonable use of the water (Dzurik 1990).

¹¹ The property rights of the resource fall entirely on the state. Individuals can only have access to temporary concessions.

¹² Article 115 of the Mexican Constitution bestows on state governments the ultimate decision to decentralize services to the municipalities. In the case of the potable water and sewage services, most state governments have kept the responsibility of the service at the local levels, pointing to the low-levels of operational efficiency shown by the municipal agencies.

¹³ The Public Authority represents the usual and more extended form of governmental intervention for the management of public services in countries of Anglo Saxon origin. Its structure mixes elements of private enterprise nature, giving them the appearance of hybrid organizations (Mitchel 1992).

¹⁴ The major seller of imported water for the SDCWA is the Southern California Metropolitan Water District (MWD), a Los Angeles-based regional agency that serves various counties in the state. Colorado River water is transported from Lake Havasu to a reservoir in Riverside County (Lake Matthews) via the 242-mile Colorado River Aqueduct. Water from Northern California is transported to the south from the delta of the Sacramento and San Joaquin Rivers via the 444-mile California Aqueduct. The water from both is blended at Lake Skinner and then sent to the

San Diego area by means of the two aqueduct systems operated by the SDCWA.

¹⁵ Water from the Colorado reaches Tijuana through the Colorado River-Tijuana Aqueduct (in Spanish ARCT), a 118-mile pipeline connecting Irrigation District No. 14 in the Mexicali Valley with the El Florido treatment plant in the Tijuana area.

¹⁶ These are usually a number of wells located in the Tijuana River and Alamar River beds within the urban zone. A third source, the Abelardo L. Rodríguez Dam located in the southeast part of the city, supplements the available supply only in periods of unusual heavy rain.

¹⁷ Another 51,000af are assigned from the underground reservoirs in the state.

¹⁸ Based on the number of connections for residential service in December 2001 (CESPT 2000-2001).

¹⁹ The Tijuana area is served by two wastewater treatment facilities: the International Wastewater Treatment Plant on the U.S. side, and the San Antonio de los Buenos treatment plant operated by CESPT. In the first case, the treatment level of the plant has not been upgraded yet to the secondary level, as accorded by the two countries in IBWC-CILA Minute 283. The San Antonio plant has exceeded its capacity by about 12%, and its rehabilitation is pending (CNA 2000).

²⁰ This agreement with the MWD will permit the delivery of those 200,000af via the Colorado River Aqueduct.

²¹ Currently there is already a proposal submitted by a consortium of private firms to construct a binational aqueduct, but so far there is no commitment on the part of either side to review or promote the project.

²² Although the use of recycled wastewater in the San Diego area goes back to the 1960s, with the experience of the Padre Dam Municipal Water district, its consolidation on a larger scale has followed an uneven path. First, no regional coordination existed among the local water agencies until the SDCWA took the lead and developed the San Diego Area Water Reclamation Program in coordination with the area's agencies. A second obstacle faced by the proponents of reclaimed water was the initial opposition by

some agencies and water districts. This opposition was a reaction to negative public perceptions about the use of recycled water beyond the usual irrigation application (i.e. the toilet-to-tap concept).

²³ IBWC-CILA Minutes are formal agreements signed by senior staff of IBWC and CILA, who are also official representatives of the U.S. Department of State and Mexico's Secretaría de Relaciones Exteriores. These Minutes act as treaty mechanisms toward resolution of specific boundary and water resource problems along the border and carry the full weight of international law.

²⁴ Active Management Areas (AMA) were established under terms of the 1980 Arizona Groundwater Management Code as subregions within which groundwater resources were experiencing major overdraft. Specific management goals were developed for each AMA, with the overall goal being a 100-year assured water supply for areas relying heavily on groundwater resources (ADWR 1998 and 1999). The Santa Cruz Active Management Area is located adjacent to the U.S.-Mexican border, hence it is functionally linked to the Ambos Nogales region.

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