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Interdependent Border Water Supply Issues: The Imperial and Mexicali Valleys

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Abstract

The meaning of the word "interdependence"—defined as the dependence that exists among elements of a population located in the same area—implies that in order for the elements of the population to exist optimally, there should exist a certain degree of understanding and cooperation among that population. Interdependence has been and will continue to be the essence of growth along the U.S.-Mexican border.

Throughout the border region between Mexico and the United States, interdependence has been present in many forms for more than 150 years. Some 13 million people share this enormous social and cultural richness, which makes them part of one of the most dynamic border regions in the world. Several factors have been at the crux of this interdependent behavior. Among them, and probably the most important, is the interdependence that exists on water issues. The Colorado River has been the main source of water for the Imperial and Mexicali Valleys. The impressive system regulating its flow provides more than 15 million acre-feet (MAF) of water per year, which serves more than 23 million people.

In 1944, the United States agreed via an international treaty to deliver 1.5MAF of water to Mexico each year. At that time the population of northern Baja California was about 43,000 and had a consumption rate of 3 million cubic meters (Mm^3) per year. Today the population of Mexicali alone is 928,572 and the town has a water consumption rate of $100Mm^3$ per year, not to mention the growing consumption of residents in Tijuana, Rosarito, and Tecate. Available data from 2000 indicates consumption of 386 liters per person per day in Mexicali.

This growing consumption is not exclusive to Baja California. In 1989, the Imperial Irrigation District (IID) signed an agreement to divert up to 106,000 acre-feet (af) per year of conserved agricultural water for urban uses. In 1998, IID signed another agreement to transfer 200,000af of conserved water to San Diego County. All this water is taken from agricultural users, and increasing competition for water between cities and agriculture is now readily apparent.

This increase in water consumption has benefited population growth and has allowed the incremental increase in consumption per inhabitant. The former is a product of the economic boom of the border region, while the latter is a product of the lack of consciousness regarding rational water use.

South of Morelos Dam, in Mexican territory, the Mexicali Valley has a huge hydraulic net of channels that gives life to the northern region of Baja California. Five levels of authorization are needed to deliver water to the 14,126 users there. Since 1992, the Ley Nacional del Agua (Mexico's Law of National Waters) and its regulations have established a new way of managing water and agricultural lands in Mexico. Under the law, Mexican irrigation districts of 5.8 million hectares in size were administered by their own users. In 1993, the Comisión Nacional del Agua (National Water Commission, in Spanish CNA) began the process of transferring the administration of irrigation districts in Baja California. The users formed 23 civil associations of agricultural producers called "modules." Since that time, water for agricultural purposes has been administered by these groups, similar to processes in the Imperial Valley.

On the U.S. side of the border, the Imperial Dam delivers water

to the All-American Canal (AAC) and the Gila Main Canal. From the Colorado River, the supply of water is transported to the valleys of Yuma, Gila, and Wellton-Mohawk in Arizona; Imperial and Coachella in California; San Luis Río Colorado in Sonora; and Mexicali in Baja California. All are located on an agricultural irrigation surface of more than a half-million hectares. The AAC is the main conduit for water to the region, which includes the agricultural valleys of Coachella and Imperial, California, where nine small cities, 142,000 people, and 250,000 hectares of agricultural lands are located.

Because the water volume assigned to Mexico was not enough to irrigate all the agricultural lands in Mexicali Valley, in 1955 the Mexican government established a program to drill wells. At the present time, 725 wells extract water from the aquifer below the valley. Imperial Valley does not use water from the aquifer, mainly because of its poor quality. In the past, this aquifer was recharged principally by infiltrations from the Colorado River, but currently it is recharged by infiltrations from the irrigation channels and the return of irrigation water. Infiltrations from the Colorado River play a much smaller role.

For Mexico, water from the aquifer is a reliable resource, which is why the Mexicali Valley aquifer represents an important source of available water in Baja California. For this reason, any actions that affect the volumes of recharge to the aquifer, such as the lining of the AAC and the decrease of the Colorado River watershed's natural runoff, directly impact the quality and quantity of available water.

There are also other bodies of water at risk. The Salton Sea today is the largest inland lake in California. Approximately 66% of the water that enters the Salton Sea every year comes from agricultural drainage, which has high saline concentrations. The salty water and high evaporation rates have elevated the saline concentration to 44,000 parts per million (ppm), with an incremental increase of 0.5 parts per thousand per year.

Organic loads in the water that enters the Salton Sea cause eutrophic conditions, which could be the main cause of fish mortality. Intense deterioration of environmental quality in the Salton Sea has caused events such as the deaths of hundreds of thousands of birds in the first four months of 1998. However, agricultural activities in the region, which contribute most of the water that enters the Salton

Sea via irrigation drainage, have an enormous economic impact in the region—annual revenue here is reported at $1.4 billion.

The U.S. Department of the Interior (USDI) conducted environmental feasibility and scientific studies in the preparation of a Draft Environmental Impact Statement/Environmental Impact Report (DEIS/EIR) on the Salton Sea in 2000. The DEIS/EIR identified the Salton Sea as an important part of a much bigger and more complex ecosystem that is intimately bound to the ecosystem of the Colorado River. It also includes the lower delta of the Colorado River and the Upper Gulf of California. Therefore, efforts to restore the Salton Sea should be connected to all the ecosystems in this group, and restoration of them all should be seen as one unit.

The deviation channel from Wellton-Mohawk to Santa Clara Sludge was part of the solution to the Colorado River salinity problem from 1961 to 1977. An annual average of 160Mm^3 of polluted water and 720,000 metric tons of salt discharged into the Santa Clara Sludge have been significant sources of contamination of land and water for more than 25 years.

In 1973, when International Boundary and Water Commission (IBWC) Minute 242 was signed, providing for the discharge of this polluted water, it represented a convenient exit for both the U.S. and Mexican governments. Their negotiations had been framed in a sense of good neighborliness within overall binational cooperation. Today, the perception of this agreement has changed. Both governments need to look for a new, creative, and good-neighborly agreement.

When the Hoover Dam opened in 1934, the natural flow of the Colorado River was changed, drastically impacting riparian ecosystems. Today, almost all countries in the world understand that sustainable development does not end at their borders and that the responsibility to conserve ecosystems is not just a national concern. The need to maintain a permanent flow in the Colorado River Delta is more urgent every day to guarantee the existence of the ecosystem and its hydrological relationship with wetlands in the natural river course, the Santa Clara Sludge, the upper Gulf of California, and the Salton Sea.

Paradoxically, the so-called "Law of the River" is not concerned with the river's health because the documents and agreements that

allow for the management of the Colorado River water do not account for any volume used by natural users. Furthermore, the states in the Colorado River's lower basin defined the conditions under which "surplus" water can be declared. This water eventually flows through the streambed of the Colorado River. There have been several transboundary effects, including reduced flood flow frequency, since these criteria have been identified. Most of them have occurred in the Colorado Delta, the aquifer of the Mexicali Valley, and the Gulf of California. Adopting a new approach for the allotment of these surplus waters would seem a reasonable solution, unless U.S. decision-makers forget the users in Mexican territory, the river itself, and the Colorado's lower basin.

Aspectos de la Interdependencia en el Abasto de Agua en la Frontera: Valles Imperial y Mexicali

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Resumen

El simple significado de la palabra interdependencia, definida como la dependencia que existe entre los elementos de una misma población, implica que, para alcanzar la interdependencia, debe existir un cierto grado de entendimiento y cooperación entre los miembros de esa población que la conforman. La esencia del crecimiento de la zona fronteriza México-E.U., ha ido más allá de este significado. Para esta región, la interdependencia ha estado presente en múltiples formas y sentidos, y de manera permanente en más de 150 años de convivencia binacional. Diez millones de personas, que comparten una gran riqueza social y cultural, que los ubica en el contexto internacional como una de las regiones fronterizas más dinámicas del mundo entero.

Varios factores han sido la esencia de este comportamiento. Entre

ellos, probablemente el de mayor importancia es la interdependencia en torno al agua. El Río Colorado ha constituido la principal fuente de abastecimiento de agua para el Valle Imperial y el Estado de Baja California. El impresionante sistema de regulación de su flujo hace posible controlar un volumen de 15 millones de pies acre anuales, para que pueda ser utilizado por 23 millones de personas.

En 1944, Estados Unidos pactó con México, entregar 1.5 millones de pies acre por año. En ese momento, la población de Mexicali que recibía agua del Río Colorado, únicamente era de 43 mil habitantes, con un consumo de 3 millones de m^3 anuales. Actualmente, la población en Mexicali es de 928,572 habitantes, con un consumo de agua de 100 Mm^3 al año. Sin embargo, ahora debemos considerar el consumo de las ciudades de Tijuana y Tecate, que con 121 Mm^3 por año, incrementan el caudal a 221 Mm^3. Datos disponibles indican que durante el año 2000, Mexicali reportó consumos de agua de 386 l/persona/día.

Este incremento en el consumo, no es exclusivo de Baja California. En 1989 el Distrito de Riego de Imperial (IID) firmó un acuerdo con el Distrito Metropolitano del Agua de Los Angeles (MWDLA por sus siglas en inglés), para comprar anualmente hasta 106,000 pies acres de agua agrícola para usos urbanos. En 1998 el IID firmó un acuerdo con Distrito Metropolitano del Agua de San Diego, en el que se transfieren 200,000 pies acres de agua anualmente a San Diego. Toda esta agua proviene de usuarios agrícolas, evidenciándose una fuerte competencia por el agua entre las ciudades y la agricultura.

Este aumento desmedido en el consumo ha sido potenciado tanto por el crecimiento de la población, como por el incremento en el consumo por habitante. El primero es producto del auge económico de la franja fronteriza. El segundo es producto de la falta de cultura y concientización sobre el uso racional del agua entre la población.

Presa Morelos, representa el elemento integrador del Valle de Mexicali. Es base de una enorme red de 2,500km de canales principales y laterales, que abastecen de agua a la agricultura y al 84 por ciento de la población de Baja California. Cinco niveles de autoridad se requieren para entregar el agua a 14,126 usuarios.

En 1992, la Comisión Nacional del Agua, en su reglamento estableció una nueva forma de administrar el agua y las tierras agrícolas en México. El objetivo a alcanzar era que los distritos de riego mexicanos, con 5.8 millones de hectáreas, fueran administrados por sus propios usuarios. Para 1993, la CNA inició en Baja California el proceso de transferencia de los distritos de Riego. Los usuarios formaron 23 asociaciones civiles de agricultores llamadas Módulos de Riego. Desde ese momento, el agua agrícola es administrada por sus usuarios, tal como en el Valle Imperial. El resultado de este cambio, aun es cuestionado por técnicos y académicos.

Los estanques sedimentadores de Presa Imperial, dan origen al Canal Todo Americano (AAC, por sus siglas en inglés), del cual se deriva agua al Canal Principal Gila y al propio cauce natural del Río Colorado. Desde este punto, se regula el abasto de agua a los valles de Yuma, Gila y Wellton Mohawk, en Arizona; Imperial y Coachella, California; San Luis, Sonora y Mexicali, Baja California. Todos ellos ubicados sobre una superficie de más de medio millón de hectáreas bajo riego agrícola; y además, abastece de agua a una población de 2.8 millones de habitantes. El AAC, es el principal conducto para distribuir el agua a toda la región, incluyendo los valles de Coachella e Imperial en California, esta última con nueve pequeñas ciudades con 142,000 habitantes y 500,000 acres de tierras agrícolas.

En 1955, el gobierno mexicano inició un programa para perforar pozos, pues el volumen asignado en el Tratado era insuficiente para regar la superficie agrícola. Actualmente, se cuenta con 725 pozos para extraer agua del acuífero. En Valle Imperial, el acuífero no es explotado, debido a la baja calidad del agua, pero sobretodo, porque no lo requieren. La recarga original del acuífero provenía fundamentalmente de las infiltraciones del Río Colorado. Actualmente, la recarga está directamente relacionada con infiltraciones de canales de riego, el retorno agrícola y las infiltraciones del Río Colorado y el AAC.

Para México, el acuífero representa la única fuente de agua segura, y tal vez más la parte más importante de disponibilidad de agua para Baja California. Por esta razón, cualquier acción que afecte su recarga, tal como el recubrimiento del AAC, y la disminución de los escurrimientos naturales del Río Colorado, impactan directamente sobre la calidad y cantidad del agua disponible.

Otros cuerpos de agua están en riesgo. La presencia del Salton Sea (mar Salton) es ancestral aunque su historia moderna inició a principios del siglo XX. Actualmente, el mar Salton constituye el cuerpo de agua interior más grande de California y sin embargo, este lago está a punto de morir. Aproximadamente el 66% de agua que cada año entra al mar Salton, proviene del drenaje agrícola de Valle Imperial, con alta concentración de sales. La concentración salina del agua en el mar Salton alcanza valores de 44 mil partes por millón, con un incremento anual de 0.5 partes por mil, propiciado por: el aporte de sales, la naturaleza endorreica de la cuenca y los altos índices de evaporación.

La causa más importante de mortalidad en peces podría ser la elevada carga orgánica que entra al mar Salton (provocando condiciones de eutrofismo), más que el aumento de la salinidad. El intenso deterioro de la calidad ambiental del mar Salton provocó que en 1992 miles de aves murieran. No obstante que las actividades agrícolas de la región contribuyan con la mayor cantidad de agua al mar Salton, provocan una derrama económica de más de $1.4 billones de dólares anuales. Sin embargo, esta situación no se ve reflejada en el desarrollo de la región, en ninguna de sus ciudades. Tal parece que la agricultura no le debe nada al Valle Imperial.

El Departamento del Interior de los Estados Unidos dirigió un estudio de impacto ambiental en el mar Salton, durante el año 2000, conocido como el Informe Borrador de Impacto Ambiental (“Draft Environmental Impact Statement/Environmental Impact Report”, o DEIS/EIR). El DEIS/EIR ya contempla al mar Salton como una parte importante de un más grande y complejo ecosistema del Río Colorado, que incluye al Delta, y el Alto Golfo de California. Esta recomendación del Gobierno, en sus esfuerzos de restauración del SS, debe considerar también al Delta, ya que ambas áreas están conectadas dentro de un mismo ecosistema, y por tanto, deben ser tratados como un único sistema.

El canal Wellton-Mohawk (WM) desde 1977 desvía agua salina hacia la Ciénega de Santa Clara, como parte de la solución al problema de salinidad del Río Colorado (1961–1977). El volumen promedio anual de esta agua contaminada, que ha descargado, durante más de 25 años, en la Ciénega de Santa Clara es de $60Mm^3$ lo cual implica que cada año 720,000 toneladas métricas de sales llegan al estero, constituyendo una importante fuente de contaminación del acuífero de Mexicali, y del suelo del Delta.

En 1973, cuando se firmó la minuta 242 de CILA, en la que se aprobaba descargar esta agua contaminada, se consideró como la forma más conveniente de dar salida a esta agua. Su negociación estuvo enmarcada en un sentido de buena voluntad, dentro de la cooperación bilateral. Hoy en día, la percepción de este acuerdo, ha cambiado totalmente. Por ello, ambos gobiernos requieren buscar instrumentos mixtos que combinen la buena voluntad, ingenio y creatividad, para hacer frente a este problema en un marco de buena vecindad, similar al que imperaba en 1973.

En 1934, cuando el Río Colorado fue controlado por la presa Hoover, el régimen natural del río cambió, impactando ecosistemas riparios de manera drástica. Actualmente, en casi todos los países del mundo, entienden que el desarrollo sustentable va más allá de sus fronteras y que la responsabilidad de conservar y hacer conservar esos ecosistemas, no es únicamente una responsabilidad nacional, sino de todos los que lo comparten. La necesidad de mantener un caudal perene en el Delta del Río Colorado que garantice la subsistencia del ecosistema y su relación hidrológica con los humedales naturales, en la vega del río, el Golfo de Santa Clara, la Laguna Salada, el Salton Sea y la cabecera del golfo de California, que cada día, es más apremiante.

Paradógicamente la llamada “Ley del Río” no considera la salud del Río. El compendio de documentos y acuerdos que permiten el manejo del agua del Río Colorado no considera el volumen de agua necesario para los usuarios naturales. Más aún, el U.S. Bureau of Reclamation, está proponiendo establecer un criterio para determinar las condiciones en las cuales los estados de la cuenca baja podrían hacer uso de los posibles caudales excedentes del Río. Esta agua eventualmente fluye a través del cauce natural del río. Se han cuantificado los efectos transfronterizos causados por la reducción de la frecuencia de este escurrimiento al establecer este criterio. La mayoría de los cuales serán sobre el Delta del Colorado, el acuífero del Valle de Mexicali y el Golfo de California. Adoptar un nuevo criterio para distribuir estos volúmenes excedentes, parecería razonable, a no ser porque en la distribución se han olvidado de los usuarios en el territorio mexicano y del río en si mismo, que también forma parte de la cuenca baja del Río Colorado.

Interdependence: 150 Years of Binational Coexistence

The meaning of the word "interdependence"—defined as the dependence that exists among elements of a population located in the same area—implies that for the benefit of all elements, there should exist a certain degree of understanding and cooperation within the population that is interdependent. Such an understanding makes it possible to guarantee the survival of all those who inhabit that region.

For the border region between Mexico and the United States, interdependence has been present in many ways during 150 years of binational coexistence. Throughout the history of the two countries the development dynamics and growth of their economies have been different, but intertwined. Without having been established in any document the traditions, customs, languages, nationalities, and countless other elements are nonetheless shared. This symbiotic coexistence between these two countries, which are so different in their essence, have become very similar.

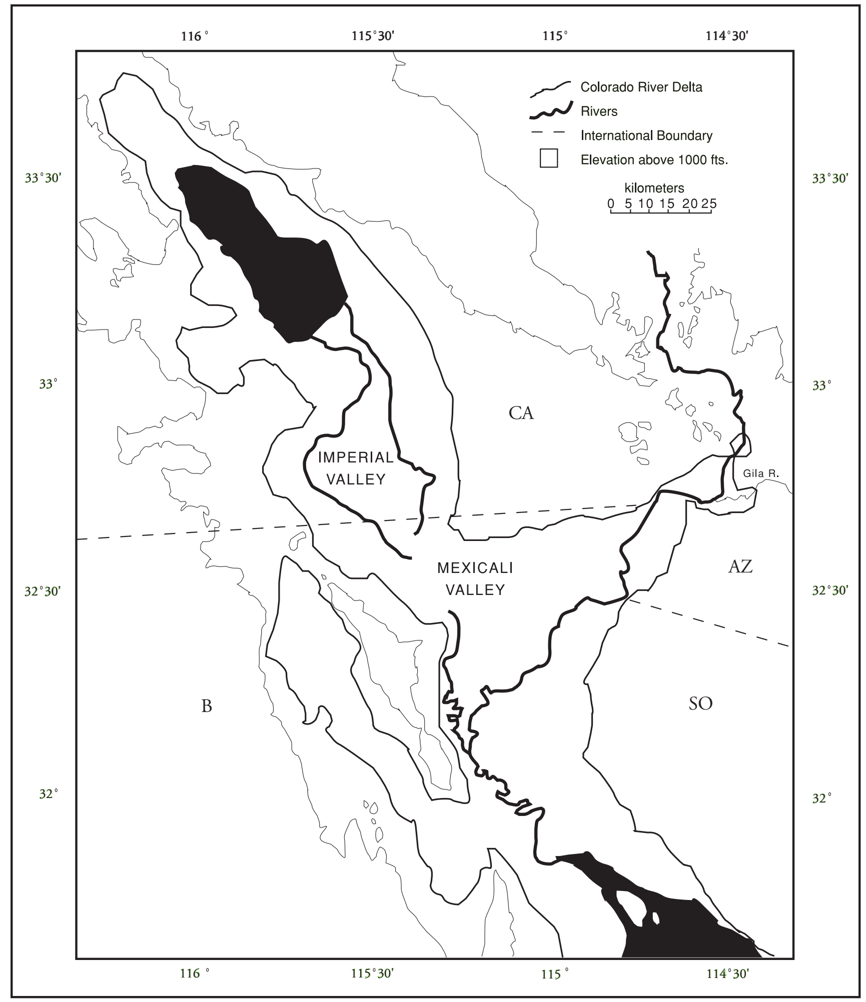
The U.S.-Mexican border, which extends 3,180 kilometers (km), is inhabited by 13 million people living in 35 Mexican municipalities and 25 U.S. counties. In this binational region, people share a great social and cultural richness that, in an international context, makes it one of the most dynamic border regions in the entire world. The rapid growth of border cities, starting in the 1950s, has caused enormous changes in these communities. People from every state in Mexico have migrated to this region in search of new opportunities.

Because of the region's semi-arid climate, interdependence of goods, services, and several other elements have not been as important as water. Water has made coexistence between the two countries more tense and their histories are plagued by needing to share it and, therefore, disputing rights to it.

For more than 100 years, the Colorado River has been the main water source for an important part of this binational region, which includes seven American states and two Mexican states. The economic development and social security of this region is based on water from the Colorado River (Román 1990). This water availability is possible not only due to the impressive system of regulation

and distribution of Colorado River water flow—including the construction of amazing engineering regulator and storage ponds and an enormous network of channels and aqueducts—but it is also due to a complex set of regulatory laws governing water rights and users (Román 1991a).

Figure 1. Study Area



Source: Modified from Cohen et al.

In 1849, the idea of taking advantage of the lands and the waters of the Colorado River Delta was proposed by a visionary man, Oliver M. Wozencraft. Today, the Imperial and Mexicali Valleys combined are one of the most important agricultural regions for the United States and Mexico and they will be the focus of this chapter.

Imperial Valley agricultural activities total more than $1.4 billion every year. A great part of the United States' wealth is generated in this region. However, when analyzing economic and social conditions of this region, that wealth is absent from many of the valley's communities.

In contrast, because of the Mexicali Valley's development and economic growth, this region is one of the most dynamic in the Mexican republic. At the present time, Baja California is the only Mexican state that has guaranteed access to water. The economic and social development realized during the last 60 years has been sustained mainly because of the availability of Colorado River water. Some 8.1% of the total volume available is transported to Baja California (Román 1990).

Problems caused by population growth in the borderlands include the emergence of new urban areas, insufficient urban water delivery infrastructure, and the lack of a legal framework that establishes priority uses for all consumption levels. The problem of water availability has increased significantly, not just in Mexico but in the United States as well. In the Southwestern region of the United States, the population is growing fast and commercial activity is developing quickly, but the benefits of services and the industrialization process cannot help water demand and consumption.

The urban region of the Colorado River Delta includes seven cities in the Imperial Valley and Mexicali, which are located 120 miles east of San Diego. The region has 1.2 million inhabitants, nearly 1 million acres of agricultural land, and receives a total water volume of 5.2 million acre-feet (MAF) per year.

Big cities outside the Imperial and Mexicali valleys criticize the enormous water volumes dedicated to agricultural uses there. Metropolitan water authorities from Los Angeles to San Diego are constantly working to find extra volumes of water for their giant populations. In Mexicali, a city with nearly 1 million inhabitants, the 2001 annual water consumption from the Colorado River as

reported by Comisión Estatal de Servicios Públicos de Mexicali (CESPM) exceeded 100Mm^3. That is 33 times more than allowed under the 1944 Water Treaty. But this is not the most serious problem, since today the diversion of Colorado River water for urban and industrial uses exceeds 221 million cubic feet per year—72.3 times more than the 1944 treaty allotted to Tijuana and Tecate.

This is one of the reasons border researchers are so concerned about demographic growth. Water demand in the Colorado River Basin increases every day, generating more and more wastewater, which is increasingly difficult to treat since the natural courses of the Colorado River and New River are so long. Evaporation, runoff from agriculture, and the build up of sediment are responsible for the Colorado River's high salinity, which is the major problem with the river today. The river's salt load increases progressively downstream and the greatest burden falls on the last downstream users—the Imperial and Mexicali Valleys.

Water planning errors on both sides of the border have resulted from city administrators' concerns only about how water is delivered to urban users. Planners forget about how their citizens are using water. There is no true culture of water conservation in the population and there will never be enough money to mitigate the deep thirst of a country that does not respect its most valuable resource.

The Imperial and Mexicali Valleys, located in the delta of the Colorado River, form part of this complex interdependency. This U.S.-Mexican border region is a good example of understanding and cooperation among a population that is interdependent on so many things, including water supplies. In the last 60 years, this border region has felt significant population growth and an intense pressure to transfer water from agricultural uses to urban centers. Issues that have played an important role in sharing water between both countries are analyzed here to highlight the need for interdependency to achieve economic and social development.

Colorado River Water: A Unique Resource for the Region

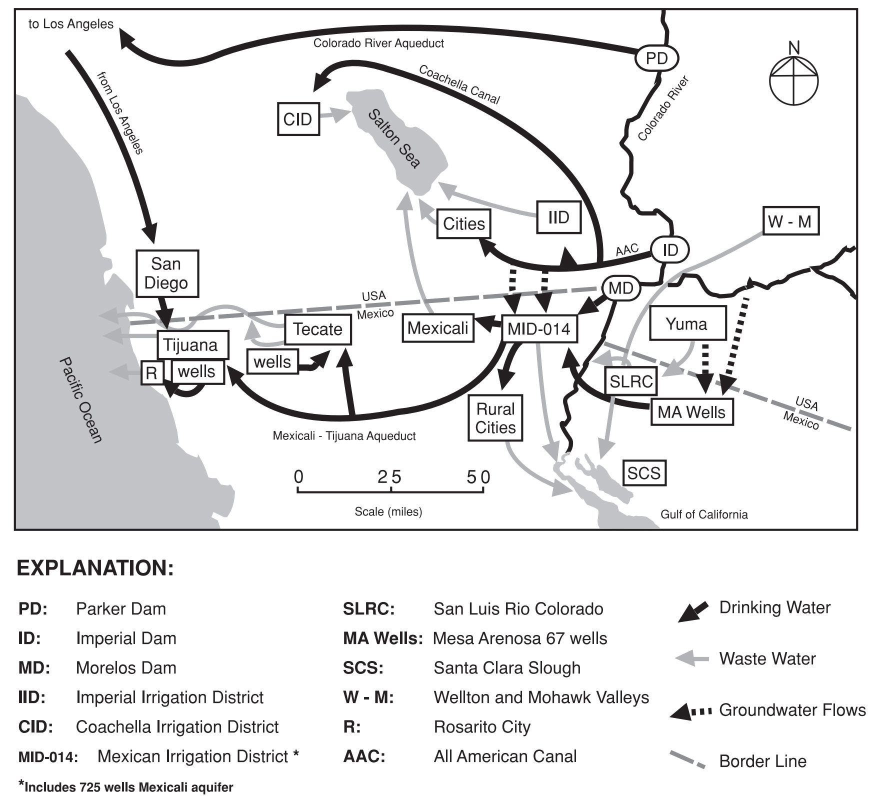
Although water is obtained from the Colorado River delta region, it is clear that the only source for a water supply is the actual Colorado River. From the total water distributed to the delta, more than 3.8Mm^3 per year are sent via the All-American Canal (AAC) to the Imperial and Coachella Valleys. For the main channel of Yuma, 2,000 cubic feet per second (cfs) are diverted to the valleys of Yuma, Gila, and Wellton-Mohawk, in Arizona. Via the natural course of the Colorado River, 1.3MAF flow to Mexico to irrigate the Mexicali Valley. At the delivery point, known as San Luis Río Colorado Valley, Mexico receives 200,000af (Comisión Nacional del Agua [National Water Commission, in Spanish, CNA] 2000),[1] of contaminated water (this volume was agreed to under the 1944 treaty) because it comes through the agricultural, urban, and industrial system drainage from Yuma, which is delivered through the south main drain of Yuma Valley (Román 2001b). To use this water on the Mexican side, it is necessary to combine it—in a place known as the "blender site"—with better quality water that comes from the Morelos Dam and the well system in the Mexicali Valley. Wastewater from the U.S. side has an annual average of 1,850 parts per million (ppm) of total dissolved solids, while water from Mexicali Valley has an annual average of 950ppm. The result of this mixed water is an average of 1,300ppm, 350ppm higher than the real Colorado River water has at this point.

Because the Colorado River water quota assigned to Mexico is insufficient to meet demand, producers in the Mexicali and San Luis Río Colorado need to obtain additional water by extracting it from wells that drill deep into the Mexicali Valley aquifer. Approximately 725 wells are located in the area. An average of 700Mm^3 are obtained in this way every year. The annual extraction of the battery of wells located in San Luis Río Colorado (International Boundary and Water Commission [IBWC] 1973) at the Mesa Arenosa, near the boundary with Yuma, is 197.4Mm^3. Aquifer recharge depends on returning water from the irrigation and infiltration processes back to the Colorado River. In this desert area, rain is practically non-existent; annual precipitation averages 65 millimeters (mm), and

completely dry years have been known to occur (Dowd 1956). The ratio of precipitation to evaporation is 1 to 40.

As shown in Figure 2, Colorado River water supports several cities in southern California, Arizona, northern Baja California, and Sonora. Water flow from the Colorado River is denoted by black arrows and wastewater is denoted by gray arrows. This schematic representation of water flows represents, in a simple way, the true complexity of water delivery and waste disposal.

Figure 2. Interdependencies of Colorado River Water Flows



Source: Authors

In 1944, when the water treaty was signed, the Mexican population that received water from the Colorado River was about 43,000, and they consumed only $3Mm^3$ per year. In 1970, the population that received Colorado River water grew to 310,940 and their annual consumption average increased to $12Mm^3$. This consumption included Mexicali and a significant part of Tecate's and Tijuana's demand.

In that time, the biggest problem for the Mexican side of the border was the fundamental lack of water delivery infrastructure. For this reason, the U.S. government supplied water to the municipality of Tijuana through the Colorado River-Los Angeles aqueduct with the understanding that the Mexican Government would solve the Tijuana water supply problem in the short-term.[2]

In 1976, construction of the Colorado River-Tijuana Aqueduct began. In 1982, the first water delivery operation was carried out, with a flow of 2.1 cubic meters per second (m^3/s) instead of the $4m^3/s$ projected total. For 1990, water consumption in Mexicali was $83Mm^3$ (CNA 2000) with an average daily consumption per inhabitant of 374 liters; that represented an additional volume of 102 liters per inhabitant when compared to the previous decade (Instituto Nacional de Estadística, Geografía e Informática [INEGI] 1991). For 2001, the Mexicali population, according to INEGI, was 928,572 inhabitants, and they had a water consumption rate of $100Mm^3$. In numerical terms, this represents 71.7-times more water consumed than in 1944, and 17.9-times more than in 1970.

This increase in water consumption has been encouraged to sustain Mexican population growth, as has the increase in the water consumption per inhabitant. The first is a consequence of the economic peak of the border region, which has a demographic growth rate of 2.4%—much bigger than the national annual average of 1.96% (INEGI 2000). The second is a consequence of lack of culture and consciousness among the population regarding water conservation.

Competing water demands between cities and agricultural lands is a significant problem that has not been appropriately addressed by the institutions responsible for water administration, or by the three levels of Mexican government. The argument is that the water volume consumed by the cities is minimal compared to water consumption by agriculture. This assertion, until now at least, is true, as the urban-to-agriculture consumption ratio is 1 to 9. However, during the last five years, water consumption by urban and municipal and industrial users has been increasing, putting the future availability of water at serious risk (Román 2001b).

In Baja California, the urban water allotment from the Colorado River has increased 56 times since 1944. This volume is the equivalent of the water needed to irrigate 2,986 hectares of wheat, 4,157 hectares of green onions, or 1,507 hectares of cotton. This problem is not exclusive to Baja California. This resource is shared with the rest of the residents of the Colorado River basin and the same phenomenon is now becoming evident in most of the southwest United States (Román 1990).

The U.S. Supreme Court set the water allocation for the seven U.S. states that are members of the Colorado River basin in 1964 (Román 1990). However, residents of California's big cities protested against the volume of water assigned to agriculture. Now, the cities of San Diego, Las Vegas, Tucson, and Phoenix are also very interested in acquiring water rights from the Imperial Valley via water for sale from agricultural users. In 1989, the Metropolitan Water District of Southern California (MWD) and the Imperial Irrigation District (IID) signed a water conservation agreement enabling MWD to divert up to 106,000af per year of conserved agricultural water through MWD's Colorado River aqueduct (Pitt 2000). In 1998, a new agreement between IID and the San Diego County Water Authority would have allowed the transfer of as much as 200,000af of conserved water from agricultural users to the authority.

Proposals for water purchases are quite varied. Some of them include acquisition of agricultural lands with water rights, equipment for wastewater treatment, and water rights for lands no longer cultivated. Las Vegas, Los Angeles, and San Diego are carrying out impressive purchases of land and water rights for $12 per acre-foot for resale at $500 per acre-foot. In the 1990s, an investment group from Las Vegas purchased 40,000 acres of land in the Imperial Valley and then tried to sell or lease the water rights to San Diego, only to find out they could not do so legally without the approval of IID. Today, nearly 10 years later, a new possibility exists: San Diego still needs water and a new aqueduct is required. An international aqueduct has been proposed as a private-sector concept.

Several years ago, the state of California began using water that had been allotted to, but unused by, Arizona and Nevada. However, these states now are demanding that they get that water back. The U.S. Bureau of Reclamation (USBR) required a strategic plan from California detailing how it would reduce its Colorado River water use by 2015. This plan is known as the CA Plan, or the California 4.4 Plan. In order to reduce its consumption and simultaneously establish the interim Surplus Criteria for the handling of surpluses of Colorado River water, California assured all users that within 15 years, the water would be regulated and that the states would receive their water quota from the Colorado River.[3]

Urban Water Consumption and Cost of Delivery

A priority of the Mexican government is providing drinkable water and sewer systems to urban centers. In 1999, the Mexican population was 97.3 million, and 87.4% of it had water services inside their houses. This population grew at an annual rate of 1.96%, which, although smaller than the growth rate during the 1990s (INEGI 2000),[4] has caused increases in demand that are difficult to satisfy due to the unequal distribution of the users' economic conditions. For this and other reasons, water acquires a growing economic value every day in areas of shortage and decreases in value in those areas where it is readily available (CNA 1999).

According to INEGI, in 1995 the daily average consumption per family was 1,706 liters. In 2000, water consumption decreased to 1,603 liters per family per day, which is slightly below quantities reported for Mexicali in 2000, when the reported consumption was 1,738 liters per day.[5] In Tijuana, consumption was 903 liters per family per day. In some areas of northern Mexico, solutions to water delivery have been limited. Financing and environmental costs of new projects have risen drastically, surpassing government investment possibilities. Table 1 presents information from CNA on water volume deliveries to CESPM[6] for urban and industrial uses from

1993 to 2000. In 1993, the allocated volume to Mexicali was 82Mm^3—but, the city used over 6Mm^3 more than they were allotted. Total consumption has gradually increased every year because of demographic growth.

Table 1. Baja California Peninsula Water Volume Deliveries to CESPM in Million Cubic Meters from 1993 to 2001

Year	Used	Allocated	Difference
1993	88.065	82	6.065
1994	90.285	82	8.285
1995	91.094	82	9.094
1996	93.111	82	11.111
1997	96.220	82	14.220
1998	94.355	82	12.355
1999	96.060	82	14.060
2000	99.000	82	17.000
2001	101.000	82	19.000
Total	849.190	738	111.190

Source: CESPM

In order to solve this problem of over-assigned water volume it is necessary to develop a plan that gives incentives for water conservation, taking into account water availability. In some cities, like Tijuana, increased rates for water delivery represent a viable alternative to the government conserving water. This collected money is the main source of revenues for service providers. An appropriate policy tariff, correctly applied, would allow the agencies to recover their investment costs. It would also enable them to invest more resources in infrastructure, improve and expand the services provided, and enable agencies to finance a wastewater treatment plant.

The development of new projects has been impacted by some marginal social sectors that do not have a real capacity to pay for water services. This impedes revenue increases and growth. In many cases the government has avoided granting subsidies—yet another factor that limits growth and provokes excessive water use.

In Mexico, two types of rates exist. Measured service offers a price according to water volume consumed, which is quantified through a flow meter. Fixed quota rates require the same amount be paid year-round, independent of the water volume consumed. Rates are determined by a state-government conducted socio-economic and financial study of the geographic area. These tariffs reflect the marginal structure of extraction costs and distribution, as well as economic efficiency, financial sustainability, social justice, and good service.

In 2000, various water rates were analyzed in several Mexican states. The goal was to determine real behavior of water prices with an annualized inflation index from 1999 of 12.3%. This means the water service prices were maintained during 2000 with a price similar to 1999. The rates should increase in the same proportion to inflation registered during that year. CNA (2001) pointed out that from 1996 to 2000, Mexicali inhabitants every year paid an average of 8% of their wages for water service, versus 14.3% paid in the rest of the country.

In 2000, INEGI reported that 96% of the Mexicali population had water delivery service. This represents a total of 172,937 domiciliary water services (DWS), of which 160,746 were residential services, 11,672 were commercial services, and 519 were industrial. This DWS data does not correspond with the number of electricity inlets installed in Mexicali in the same year, which INEGI reported as 249,698. It is hard to justify the difference of 76,761 DWS, if it is assumed that a demand for water also exists in each home that requested electricity service. Data from CESPM indicates that in 2000 in each of the DWS in Mexicali, 578.2m^3 (1.58 cubic meters per day) were received. According to the density population index of 4.18 that INEGI reports for every home in Mexicali, this breaks down to 386 liters per person per day.[7]

Hydraulic Infrastructure in the Binational Region

Hydraulic Network Infrastructure in the Mexicali Valley

Construction of the José María Morelos Dam was completed on November 8, 1950. This dam is the hydraulic infrastructure that receives the Mexican quota of Colorado River water and where the enormous net of channels in the Mexicali Valley is born, giving life to the whole northern region of Baja California.

Five levels of authority manage the water on the Mexican side of the delta.[8] It allows the operation of a 2,552km-long network of channels with the participation of the 14,126 users that comprise Irrigation District 014, Colorado River. Because of its 207,935 hectares of water rights, a great diversity of crops (more than 100 species) and high level of productivity, this irrigation district is considered the third most important in Mexico. The 470km-long main channels maintain flows of 50m^3 per second and an absolute maximum value of 159.6m^3 per second. From the network of main channels, 328km are concrete lined and 142km are not protected. Some 2,082km of the network is comprised of secondary channels, 93% of which are lined. It also has 6,443 water flow measurement structures within the irrigation modules.

The 1,492km network of open drains is made up of 422km-long main drains and 1,070km-long secondary drains. The open drainage network is insufficient for controlling soil salinity and drainage water. Consequently, these agricultural drainage waters are controlled by 1,288 hydraulic structures. The artificial drainage network in the Mexicali Valley is hardly 722km. Although some technicians who have researched the situation claim that soils in the Mexicali Valley do not require artificial drainage, a great many of them require the installation of artificial drainage systems due to the shallowness of the well water level. The road drainage network is 2,422km long, 1,378km of which are paved.

Hydraulic Network Infrastructure of the Imperial Irrigation District

The Imperial Dam is the most important hydraulic infrastructure in the Colorado River delta region. The Imperial Dam, through the framework of the AAC, the Gila Main Canal, and the natural course of the Colorado River, regulates the water supply of the Arizona valleys of Yuma, Gila, and Wellton-Mohawk; the Imperial and Coachella valleys in California; the San Luis Valley in Sonora; and the Mexicali Valley in Baja California. All of them are located on a surface of more than 500,000 hectares, which have agricultural irrigation. The Imperial Dam also supplies water to a population of 2.8 million inhabitants. The IID, founded in July 1911, is operated by a civil user association.

IID network channels are 2,573km in length, including main and lateral channels. Also, there are 2,336km of drains captured by an immense network of pipes of nearly 50,000km that forms the system of artificial tile drainage. This system covers 93% of the cultivation surface of the Imperial Valley.

For the IID, there is a fundamental need for an artificial drainage system, mainly because most of its agricultural lands are situated below sea level and flows of internal drainage cause shallow well-water levels and salinated soils. This situation is made worse by surplus water that comes from urban and agricultural uses from the Imperial Valley's cities and from Mexicali through the New River and El Alamo Canal, which frequently divert waters from agricultural irrigation and water drainage.

The All-American Canal

The AAC is the main conduit for delivering water and energy to the region that includes the agricultural valleys of Coachella and Imperial, where nine small cities with 142,000 inhabitants and 500,000 acres of agricultural lands are located. For operational purposes, the AAC is divided into three large branches that include East Highline Canal, Central Main Canal, and Westside Main Canal. They feed all irrigation areas by gravity. More than 3Mm^3 of water are managed in the Imperial Valley every year. This channel has a

total length of 132km. Its width varies from 46m to 61m, and its depth varies from 2.1m to 6.1m; its topographical gradient presents a difference of 53.3m. Over its course it moves more than 3.8Mm^3 of water at a rate of 488.3m^3 per second. This channel also diverts water toward Arizona's Yuma Valley at a rate of 56.6m^3 per second and toward California's Coachella Valley at 70.7m^3 per second.

Besides being the main vein of water supply, the AAC is important because of the water volume filtered to the aquifer. The AAC crosses the Yuma Sand Dunes for 38km. This geologic formation has characteristically high permeability because of the sandy-textured soils and surpasses the basic infiltration speed of 7.6 centimeters per hour, which is the technically recommended maximum level for gravity irrigation methods in agricultural uses (Román 1990). Under normal operation, AAC requires a permanent water volume because it delivers water to cities and agriculture. This situation and the electricity generation at five generating stations located along AAC forces IID authorities to maintain a constant hydraulic load, which supports turbine operation and water delivery services for agricultural lands and communities. In the dunes area, most of the filtered water flows underground naturally toward the south and becomes a very important part of the water recharge of the Mexicali Valley aquifer.

In December 1988, IID and MWD authorities signed an agreement for the sale of 123Mm^3 for \$28 per acre-foot for a 55-year period, with the option to renew the agreement (Román 1991a). The water volume sold was determined in light of expected water savings that would be achieved via the concrete lining of most of its irrigation channels and the lining of AAC over 38km of its course.

The Alamo Canal

The course that today is known as the Alamo Canal is a natural channel formed by the large water volume that comes from the Colorado River. Due to its strategic location and important route, this canal was essential to the development of the Imperial Valley. It travels 67km in the northern part of Mexicali Valley and 60km into Imperial Valley until it reaches the Salton Sea. Because of the lack of economic resources that made driving water to Imperial Valley impossible, the Alamo Canal was used to transport water (Huntley 1966).

Originally, half of the water in the Alamo Canal was assigned to irrigate lands in Mexicali Valley and the other half was assigned to the Imperial Valley. This situation was not welcome by the Imperial Valley producers because they felt dependant on the water coming from Mexico. As soon as construction of AAC was finished, the growers' position changed. In 1940 the first water deliveries began, and by 1942, the Alamo Canal had stopped delivering water to Imperial Valley farmers. This was negotiated and resolved for the first time by the 1944 water treaty.

Today, the Alamo Canal has become one of the three main channels of the Mexican Irrigation District, which is known as Canal Principal Reforma. Its initial route, near Morelos Dam, has been transformed the most; however, some sections of the old branch still receive water that Mexicali Irrigation District technicians put on its course, mainly in order to recharge the aquifer when surplus water volumes are present in the Colorado River.

Because the water taken from the Alamo River is not used, a detailed registration of its volume does not exist, with the exception of that registered at the border crossing with the United States 11.3km east of Calexico, California. At this point, IID technicians have placed a stream gauging station that permanently measures the water flow crossing the border. Registered flows correspond to direct filtrations of AAC and waters of agricultural drainage from the Mexican side. Registered flows are not significant, as is pointed out in the registrations from 1946 to 1998 that Comisión Internacional de Límites y Aguas (CILA) provided in its annual bulletin. Runoff values vary from 50 liters per second to 100 liters per second, which, from the point of view of agricultural irrigation flows, is considered irrelevant.

Water from Wells

The original, historic delta's formation process, principally its sedimentary filling, was carried out by two fundamental activities: depositing of marine silts, caused by the Gulf of California coming from its southern flank, and depositing of silts of a continental origin, carried by the Colorado River (Van Der Kamp 1973). The Imperial Valley's formation is the most exposed ancient formation attributed to the historic delta of marine origin, and it confirms the incursion of the Gulf. The Upper Cenozoic deltaic sediments and non-marine sandstones and clays that appear in the northern and western portions of the basin confirms the continental contribution of the Colorado River. During the middle Pliocene, possibly during a period in which the sea level was lower, the Colorado River built its delta and thus created the crest located in Yuma city, the Cerro Prieto Volcano, and the Cocopah Hills (U.S. Department of the Interior [USDI] 2000). This crest formed a barrier that split the Salton Trough into two sections: one to the South of the delta, in close contact with the Gulf of California, and another to the North, from the depositional and topographical point of view, to the Salton Basin. The latter is occupied in its central part by the Salton Sea (Muffler and Doe 1968). The historic delta was characterized by Colorado River discharge through ephemeral drainage channels that were quickly filled with sediments, which created a new course downstream from the deltaic cone. In most cases, there was a lateral ramification that finished at the Gulf of California. Occasionally, the river forked toward the northwest and flowed toward the Salton Basin, depositing clays and sands in deltaic and lacustrine phases (USDI 2000).

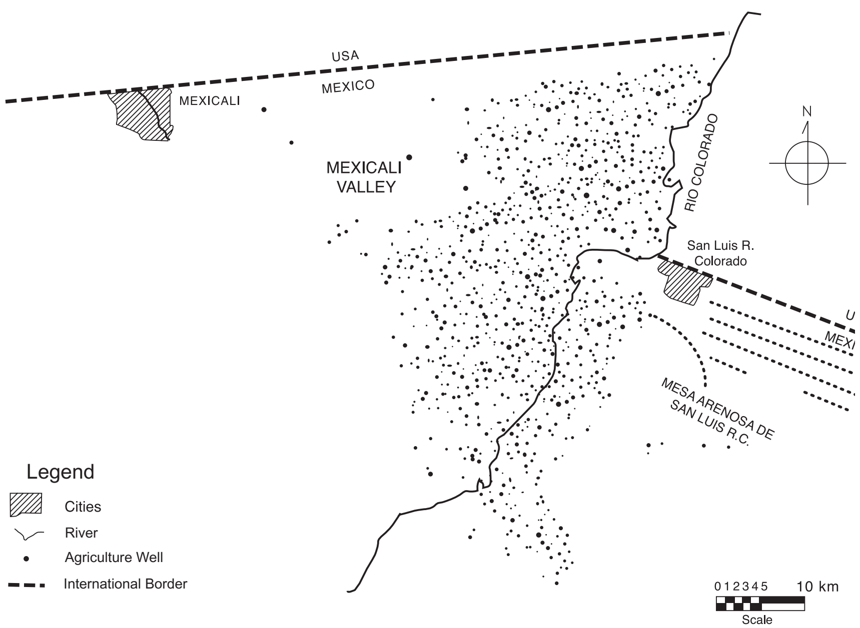
Sedimentary filling was saturated with Colorado River water and marine origin water, forming an aquifer body that in the central part of Mexicali Valley is more than 5km thick. Regional flow in the aquifer shows two main directions. One goes northeast of the Mexicali Valley into the entrance of the Colorado River, to the Trough, and then moves toward the Gulf of California in a southwesterly direction. In the other direction, it flows from the northern border of the crest of the delta, heading southwest to the Cucapah Hills, then rotates to the northwest toward the basin of the Salton Sea.

Geohydrological studies have estimated that original aquifer recharge came from Colorado River infiltration. At the present time, recharge is directly related to infiltration from irrigation channels, return of irrigation water, and infiltration from the Colorado River.

In Mexicali Valley, three fronts of horizontal underground recharge can be identified. The first one comes from AAC infiltration, the second comes from the Arizona-Sonora border toward the San Luis sandy table; and the third comes along the bed of the Colorado River on the border between Arizona and Baja California.

The delta's depositional process was influenced directly by the chemical water quality. Colorado River water created an aquifer with low saline concentrations. Nevertheless, the gradual decrease in water volume and quality of the recharge has increased the water's salt concentration. For that reason, it is possible to find wells with salt concentrations between 800ppm and 2,200ppm. The beginning of the 1930s witnessed the first well drillings to obtain additional aquifer water for agricultural purposes; however, that ended in 1955 when Mexicali irrigation district authorities "froze" users at 207,935 producers, the same number there are today (Figure 3).

Figure 3. Location of Agriculture Water Wells in Mexicali Valley



Source: Modified from Ramírez-Hernández

Because the water volume assigned to Mexico in the 1944 Water Treaty is limited to $74Mm^3$ (1.5MAF) it was necessary to establish a program of well drilling that enabled the granting of water to those users. This amount of water is only enough to irrigate 136,400 hectares, pending the granting of water to 69,335 hectares. Those growers, at present time, form part of the wells area. The actual number of wells is 725, of which 468 were built by the federal government; the rest were built by private producers.

Imperial Valley aquifer water is not used for two reasons. First, the low quality makes it unsuitable for agricultural uses. Second, the growers receive enough Colorado River water for their half-million acres of agricultural land. Therefore, aquifer water in this region is the only reliable contributor to water volume,[9] which is why the Mexicali Valley aquifer is the most important source of local water available to Baja California. Consequently, any actions that affect aquifer recharge water volumes, such as the lining of AAC or a decrease in Colorado River natural runoff, will directly impact the availability of water to the region.

Managing Water Resources

Agricultural Water Management in the Imperial Valley

The IID encompasses nearly 500,000 acres of agricultural land—the largest land use dedicated to agriculture in the United States. When it was first developed into farmland, agricultural land exploitation was not easy. Lack of water infrastructure was one of the most important problems to solve. Soil salinization problems due to a phreatic low level made developing the Imperial Valley into an agricultural area harder. But with the help of Mexican laborers, hundreds of canals were constructed and in July 1911, IID began to operate an enormous irrigation district. Today, in spite of all kinds of technology, water delivery is not efficient. More than 50% of the irrigated land is used to forage crops, mainly alfalfa, which need a large amount of water to grow. Irrigation practices that control the amount of salt in the soil are not widespread. Because Colorado River water is available at any time, agricultural lands are cultivated year round, which means that depending on vegetative cycle crop, one surface can be used several times. This contrasts significantly with Mexicali Valley farmers, who can use land only once each year. Since almost all lands in the Imperial Valley are below sea level, 92% of the total irrigated land requires tile drainage to avoid saline problems. All agricultural drainage is directed to the Salton Sea, which at 27 meters below sea level receives water that varies in quality.

The Imperial Valley population rate has increased dramatically. In 2000 it was 142,361, having increased at a rate of 30.2% since 1990. When compared to California as a whole, the population has risen 13.6% (U.S. Census Bureau 2000).[10] Notably, in 1940, the decade the 1944 treaty was signed, the Imperial Valley had a population of just 59,740, which was only 17,000 more people than Mexicali (U.S. Census Bureau 2001).[11]

Management of the Mexican Quota: The Irrigation Modules

Legal issues surrounding the availability and assignment of water rights are complex and different in each country. While the Mexican Constitution settles everything related to land and water in a single article, in the United States, each state handles and administers these resources independently. Article 27 of the Mexican Constitution assigns lands and waters to the federal government because this property is inside the limits of the national territory, and the Republic is entitled to transmit the domain of lands and waters directly to people as private property.

Because the topic of water rights has grown in importance in Mexico, in December 1992 the Congress of the Union published the Ley Nacional del Agua (Law of National Waters, or LNW), and in January 1994, its regulation was published (CNA 1999). Until that moment, no legal instrument existed in Mexico to allow private users to hold their water as property, since it was the government that decided on the forms of use and assignment of water rights.

The LNW settles in Articles 13 and 14 a new form of management for water and agricultural lands in Mexico. *Consejos de cuencas* (watershed councils) were formed at the national level in 1992. The objective was that Mexican irrigation districts with 5.8 million hectares would be administered by their own users because it was too expensive

manage them (Cortéz and Whiteford 1999).

In 1993, CNA began the process of transferring administration of the Colorado River rights in Baja California to Irrigation District 014 users, establishing the first three irrigation modules (CNA 2000).[12] An irrigation module is a parcel of land constituted as a civil association of agricultural producers located in a specific area. Growers give their water and land rights to the director of their association, who administers the available resources to his partners' benefit. In Mexico, water rights are assigned directly to each producer.

The water volume of each water right depends on the total water availability as determined by the irrigation district. In the Mexicali Valley in 1944, water rights were granted to each farmer at a volume of 19,576m^3 per hectare (15.87af). At present, due to demographic growth, the water rights have been reduced to 10,700m^3 per hectare (8.35af).

This water volume of 10,700m^3, in real terms, is not sufficient because water demand for each crop varies. For example, perennial crops, such as alfalfa and asparagus, demand a high water volume while crops on short vegetative cycles demand less. An additional issue that affects water availability is that according Mexican law and local regulations of the irrigation district, each water right can only be used once per year, independent of the water demand of the crop (Román 2001b).

Civil associations formed by groups of agricultural users were called irrigation modules (CNA 2000). They, in turn, are supervised by a Modules Coordinator[13] called the Society of Limited Responsibility (SLR), which is an administrative structure named by the governor of the state to oversee and evaluate the operation of the modules. This supervision also includes technical support of the Irrigation District of the CNA.

For crop irrigation, the director of each irrigation module presents to CNA, SLR, and the Irrigation District a breakdown of the module users' water needs. The water volume is assigned depending on the cultivation, distance of the land from the points of hydrometric control, and their programmed demand. For 1998, average water volume per hectare was 10,300m^3, yet in 1950, farmers were allotted an average of 12,290m^3. This drastic decrease in water availability was caused by the increase in irrigated surfaces as much as by the decrease in the water volume available. Table 2 shows the relation of total irrigated area, the number of users, and allocated water volume per year for each irrigation module during year 2000.

Table 2. Governance of the Baja California Peninsula

Irrigation Module	Land Surface (ha)	Users	Allocated Water Volume (million cubic meters)
1	11,000	762	100.099
2	6,498	474	55.448
3	9,335	582	95.950
4	13,040	869	95.884
5	9,965	594	99.238
6	5,836	430	59.975
7	12,676	751	71.337
8	10,151	833	101.159
9A	9,080	631	76.275
9B	9,569	622	73.410
10	13,265	968	158.396
11	9,324	584	112.236
12	9,683	646	116.558
13	7,351	576	87.711
14	8,363	524	101.056
15	9,935	605	119.591
16	6,686	700	80.482
17	8,949	644	106.172
18	7,891	650	95.197
19	8,946	629	107.717
20	6,388	528	76.894
21	5,578	494	83.293
22	4,985	405	61.122
Total	204,494	14,501	2,135.200

Source: CNA

Handling the transfer of the administration of the irrigation district to the modules raises the possibility of changing the policy of traditional water assignment, also known as the water volumetric delivery. Delivering water criteria through the volumetric delivery method assures that each module receives a volume that corresponds to 10,700m^3 per hectare for each water right registered in the module

during 2000.

Water is delivered to the hydrometric control point of each module. The module's technicians then take charge of their internal water distribution and each user quantifies and controls the water received on their parcels. The water savings obtained from each irrigation module is reported to the module headquarters and this savings is counted as water volume in favor of that user. When users take more water than their water rights, they are subject to an additional charge. This new way to deliver water creates incentives for saving water, as well as a water market that could be sold in the same module, other modules, or for urban and industrial uses.

Agricultural Water Use Efficiency

Of the total water available in both valleys, most of it is used for agriculture. Some 90% of the water in Mexicali and 98% of the water in the Imperial Valley is used for agricultural purposes. Unfortunately, efficiency of water use in both cases is very low—only 50% in Mexicali and 55% in Imperial Valley. In spite of high-tech agricultural developments in the Imperial Valley, agricultural use of water is the main cause of increasing soil salinity. Sprinkler irrigation systems are the most-often recommended solutions, however in most cases, these systems are used only in the first stage of cultivation. After that, gravity watering is used in an open furrow mode.

In the Mexicali Valley, gravity irrigation systems are used most often despite the variety of irrigation systems available. Only vegetable cultivation uses sprinkler and drip irrigation systems, and they do so over a minimal surface area. In both valleys the cost of water is lower than the other costs of the productive process, including seeds, fertilizers, machinery, and equipment. Cost, use, and value of water differ significantly across the border (Table 3).

Water in the Imperial Valley is priced at $12 per acre-foot, which is equivalent to $0.01 per cubic meter. In Mexicali, water is sold by 24-hour rates. Farmers pay $6.35 Mexican pesos for every liter per second delivered during 24 hours, a total of 86.4m^3 per day. The cost of this water translates into 7.3 centavos, or about $0.007 per cubic meter.

Table 3. Cost, Use, and Value of Water

	Imperial Valley	Mexicali Valley
Cost ($/m^3)	0.01	0.01
Cultivated Land (thousand hectares)	202.50	208.00
Water Need (Mm^3)	3.07	2.55
Revenues (million US$)	1400.00	4.25
Production Coefficient ($/m^3)	0.45	0.16

Source: Authors

The Mexicali Valley has 207,935 hectares under cultivation each year. To farm this land, 2.55 billion cubic meters of water is needed. The total revenue produced with this volume of water is $425 million per year, which leads to a productivity coefficient of $0.16 per cubic meter used. Although Imperial Valley farmers cultivate less land—only 202,500 hectares—they use significantly more water, an annual total of 3.065 billion cubic meters, and have higher revenues per year, at $1.4 billion. As a result, Imperial Valley's productivity coefficient is $0.45 per cubic meter used.

When comparing the cost of water to the revenues generated, it is clear that water appreciates substantially in value based on its rate of return. Water profitability in the Imperial Valley is 45 times the cost of water because a farmer is able to generate $0.45 for every $0.01 spent per cubic meter. Although less extreme than in the Imperial Valley, water profitability in Mexicali is also high at 22 times the cost of water. Mexicali farmers generate revenues of $0.16 for every $0.007 spent per cubic meter of water. Thus the ratio of water productivity of Imperial County to Mexicali is $0.45 to $0.16 or 2.8:1 for each cubic meter.

Under these circumstances, it is clear that agricultural water use in this region, when compared with domestic and industrial uses, has an extremely low index of economic productivity. Agricultural water uses that report the lowest yields and/or low water use efficiencies should be abandoned in favor of more profitable uses. Crops with high water demand, like alfalfa and asparagus, also must be regulated.

Interdependencies Between Water Use and the Environment

Salton Sea: A Dead Sea?

Today, the Salton Sea is the biggest inland lake in California, extending 360 square miles at an elevation of 228 feet below sea level. The maximum depth of sea is 51 feet but the average depth is 31 feet (Cohen, Morrison, and Glenn 1999). Approximately 75% to 80% of the 1.35MAF of water that enters into the Salton Sea is drainage water coming from the IID. Much of the agricultural water that empties into the sea, including tail drainage system water, has high saline concentrations (Pitt 2000). It has been estimated that average surface water drainage inflow to the Salton Sea is approximately two-thirds tail water and one-third drainage water (Amrhein 2001). The very nature of the basin, taken together with high evaporation rates, have increased salt concentrations to 44,000ppm. In the absence of restoration efforts, salinity will continue to increase gradually over time.

In addition, agricultural wastewater and the water that comes from the city of Mexicali has a higher-than-normal load of organic matter, boron, and selenium, among other heavy metals (Pitt 2000). Some 35% of the total water that enters into the Salton Sea comes from the New River, one-third of which originates in Mexicali.

Investigators have identified the organic load of the water that enters the Salton Sea as the cause of the eutrophic conditions that result in fish mortality even more so than increased salinity. This intense deterioration of environmental quality of the Salton Sea has, since 1992, caused the death of hundreds of thousands of birds. In fact, during the first four months of 1998 17,000 birds of 70 different species died (Cohen et al. 1999).

Researchers have considered solutions to the problem of growing environmental deterioration and the massive death of fish and birds for more than 30 years. The problem has even attracted the attention of the federal and state governments, which have dedicated more than $20 million to studying and defining the problems at the Salton Sea during the last several years.

Although this investment seems substantial, in reality it is quite insignificant compared with the enormous income earned through agricultural activities in the Imperial Valley. And, the magnitude of the problem has not been sufficiently evaluated. The Salton Sea Restoration Project only focuses on stabilizing the water level at 232 feet below sea level and reducing salinity to 40,000ppm. The Salton Sea is a valuable natural ecosystem that cannot be ignored. It provides a habitat to more than 380 bird species, three endangered species (the desert pupfish, the Yuma clapper rail, and the California brown pelican), and gives refuge to migratory birds on the Pacific route (Pitt 2000). As a recreational area for fishing, hunting, bird observation, photography, and other activities, more than 250,000 peopled visited the area between 1997 and 1998 (USDI 2000). However, agricultural activities, from which water drainage contributes most of the water that enters the Salton Sea, generate more than $1.4 billion in annual revenue and provide work to one in three employees in the area (Pitt 2000).

The U.S. Department of the Interior, working in partnership with the Salton Sea Authority and many other federal, state, tribal, local, and academic entities, conducted environmental feasibility and scientific studies in the preparation of a Draft Environmental Impact Statement/Environmental Impact Report (DEIS/EIR) on the Salton Sea. In the DEIS/EIR, it is already a given that the Salton Sea is an important part of a much larger and more complex ecosystem and that it is intimately bound to the ecosystem of the Colorado River, which includes the delta of the Colorado River and upper Gulf of California. Therefore, the Salton Sea restoration efforts should be connected to all those ecosystems and their restoration should be seen as one unit. The objective of the DEIS/EIR is to maintain a sustainable, long-term balance, conserving the Salton Sea as a holder of agricultural wastewater but looking to improve ecological conditions and provide a safe refuge for birds and fish, as well as an area for recreational use. In short, the goal is to maintain equilibrium among economic activities, the natural ecosystem, and recreational activities. At this moment, that is a difficult objective to reach.

Nevertheless, achieving this balance would require a study of the relationships between components of the ecosystem and the most critical factors (salinity, loads of organic matter, water level, infestations, etc.) in these relationships. This would involve carrying out an enormous research effort, obtaining financial support, and redefining goals and objectives in the understanding of the ecosystem. The formation of a scientific subcommittee for the creation of a strategic scientific plan with objectives for the short-, medium-, and long-term undoubtedly constitutes the most important achievement in the restoration of the Salton Sea, as is provided for in the DEIS/EIR.

It is interesting to consider that the U.S. government recognizes the importance of carrying out intensive studies on the Salton Sea as part of the ecosystem of the Colorado River (USDI 2000). But at the same time, in the Environmental Impact Statement for the Colorado River Interim Surplus Criteria, the United States refuses to take any responsibility for the impact to the environment in Mexican territory due to the interruption of flows of fresh water in the low portion of the delta region and the discharge of polluted waters to the Santa Clara Slough (USBR 2000). In both cases, these fresh water flows are an important part of the sustainability of this enormous binational region and the ecosystem itself.

Wellton-Mohawk and the Santa Clara Slough

Wellton-Mohawk (WM) is a deviation channel that was built for the USBR as part of the solution to the Colorado River salinity problem, which was first discussed between Mexico and the United States between 1961 and 1977.[14] The delivery water was established on June 23, 1977. The volume diverted to the Santa Clara Slough has averaged 160Mm^3 (130,000af) of polluted water annually (Luecke 1999). This has been an important factor in the contamination of the region's land and water for the last 25 years. The presence of this drain water, which has saline measurements of between 3,800ppm and 5,200ppm, enlarged the coastal wetland of the Santa Clara Slough, which covers 20,000 hectares (50,000 acres). Currently, it is a natural refuge for the largest population of Yuma clapper rail and desert pupfish.

Before 1973, there was no direct water contribution from the Colorado River and brackish water was not present in the Santa Clara Slough. In fact, the only tributaries that fed this topographical trough were the artesian wells and agricultural water drainage that comes from Riíto, Sonora. The surface of the Santa Clara Slough was only about 500 acres.

Depositing this waste water in the Santa Clara Slough was an excellent and "temporary" solution for both sides of the border until the Yuma Desalting Plant entered the picture. The plant was finally constructed in 1992 but it has never really operated because, among other reasons, it would have to file a declaration of environmental impact. It spills an average of 560,000 metric tons of salt into the Santa Clara Slough annually[15] (Burnett et al. 1997), and also contributes other pollutants such as insecticides, herbicides, and fertilizers that have never been quantified.

Nevertheless, several researchers (including Cohen, Galindo, and Campoy) studying the binational border have pointed out that this brine has been beneficial for the development of the Santa Clara Slough. The level of contamination in this wastewater is higher than the contamination found in the original water poured onto this site in the past from the original tributaries.

In its time, the Wellton-Mohawk deviation channel was a convenient exit for both governments and its negotiation was framed in a sense of good neighborliness within overall bilateral cooperation. However, 25 years later, and after the millions of tons of salt discharged in the area, Mexico now has the right to demand that, before discharge into the slough, these waters be treated independently from the water Mexico receives from the 1944 treaty. Clearly, this "temporary" solution settled back in 1973 should reconsider the depositing of these fossil waters in Mexican territory.

Colorado River Delta: The Forgotten User

The Lower Colorado River Compact, signed at Santa Fe in 1922, marked the beginning of the deterioration of the natural hydrological system of the Colorado River. Although the construction of Hoover Dam was completed in 1934 and construction of Glen Canyon Dam at the end of 1960, some argue that the real beginning of Colorado River Delta deterioration was in 1909, when Laguna Dam, near the Imperial Valley, was completed. They also say the irrigation of Imperial Valley agricultural lands was another factor in

the lower delta's deterioration. However, impacts to the lower delta from these diversions were not significant because after this, Colorado River water was still running to the Mexican side of the border and its natural flows reached the Gulf of California.

In the Lower Colorado River Compact, six of the seven states in the hydrological basin agreed to distribute the water of the river, and they did so without regard for environmental sustainability. With the completion of the Hoover Dam in 1934, the natural conditions of the river were altered, drastically impacting the riparian ecosystems. Today, there are 10 major dams along the river with a total storage capacity that controls flow by nearly four times the river's natural annual flow, thereby creating a situation of total dependence for downstream users (Román 1990).

The concept of the natural user emerged in the United States after the ecological accident at the Cuyahoga River in 1967 (Cuyahoga River Remedial Action Plan Coordinating Committee 1992) when the river caught fire because it had been polluted with so many flammable substances. This marked the beginning of the development of an environmental conscience in the United States. Some might argue that this environmental conscience began earlier (see *Silent Spring* by Rachel Carson). However, the Cuyahoga River's accident gave the United States the opportunity to create true environmental institutions like the U.S. Environmental Protection Agency (EPA) and true environmental policies like the National Environmental Policy Act (NEPA).

In developing countries like Mexico, concern for the environment and sustainable development of ecosystems came later. The first international efforts began in 1983 with the La Paz Agreement, the Integrated Border Environmental Plan in 1992, and continued through the Border XXI program. In March 1993 a proposal to declare the upper gulf and lower delta a biosphere reserve was presented to the Government of Mexico by a group of non-governmental organizations. Due to the extraordinary biological and cultural importance of these ecosystems and the increased international pressure to protect the endemic vaquita porpoise and totaba, the Mexican government declared this region a Biosphere Reserve in June 1993 (Brusca et al. 2001).

At almost the same time, the LNW and the General Law of

Ecological Balance and Protection to the Environment were created. These documents recognize that a minimum flow of surface water is necessary to maintain an ecological balance.

The combination of demographic and economic growth in the Lower Colorado River Delta, in addition to a complete absence of an environmental conscience, required the planners take into account environmental concerns as an essential part of the whole system. As a result, the Colorado Delta "natural user" suffered enormous pressure. During the twentieth century, on the delta's Mexican side, Colorado River water flows were decreased by 75%. Between 1896 and 1921, the annual average flow of Colorado River water to the lower delta in Mexico was 16.7MAF (20.7 billion cubic meters). From 1984 to 1999, however, the annual average was reduced to 4.2MAF (5.2 billion cubic meters) (Luecke 1999).

Consequences that resulted from this greatly reduced flow include morphology changes in the natural course of the river, decreases in silt transport, polluted silts, soil erosion, and high salinity in soil and water. Overall, these changes have adversely affected the lower delta and altered its ecosystem. Furthermore, the decrease in fresh water volume to the lower delta and the conversion of land to agricultural uses have diminished the wetlands to 5% of their original area. Although the estuary in the lower delta has not been taken over by agriculture, it has been adversely affected by the lack of fresh water.

Non-native species and invaders have reduced the population of native species. For example, the poplars, shallows, and willows have been supplanted by the salt cedar, the cachanilla, and the chamizo (USDI 2000). The different sources of water filling the lower delta carry a variety of contaminants that are toxic to wildlife and humans. There is no program in place that systematically monitors for a variety of pesticides on the lower delta. In the 1970s, levels of DDE, the most persistent metabolite of DDT, in clams from the Mexicali Valley were as high as 11ppm (wet weight); in the mid-1980s the amount was less than 0.2ppm. Selenium levels 1.8 times to 14.2 times higher than the EPA's criterion of 5 micrograms per liter have been reported in lower delta waters and sediments. Several studies have indicated the presence of DDE and selenium in low concentrations in the lower delta's riparian system and at greater levels higher in the food chain, especially when periodic adequate flushing from the Colorado River does not take place (Brusca et al. 2001).

Nevertheless, a century of development has not been able to kill the lower delta's ecosystem. As is true with the Salton Sea, the lower delta continues to be a refuge for migratory birds along the Pacific flyway during winter. It includes an estuarine environment that stimulates the development of marine fauna, including various species of shrimp, the totaba, and the vaquita porpoise in the Upper Gulf of California. The lower delta also includes important riparian areas along the waterways of the Colorado River—from the border to the lower delta these waterways include the Rio Hardy wetlands at their fork with the Colorado River, the intertidal wetlands, and the Santa Clara Slough (Luecke 1999).

For the past 15 years, various U.S. federal agencies and several state governments on the Upper Colorado River basin have begun to implement conservation measures for the natural habitat and endangered species by assuring a permanent flow from the Colorado River. In 1994, a plan was proposed with the overall aim of lessening the adverse impact the controlled flow of the river has on endangered species. In 1996, fresh water was released from the Glen Canyon Dam to redistribute silt and sand in the Grand Canyon and to reestablish sandy areas at recreational sites along the river.

These concrete restorative actions of the upper and lower basin clearly reflect the power of the Endangered Species Act and the threat of litigation. Although it is clear that the impact on the lower delta is a product of the regulation and diversions of the flow of the river, it has not been the object of the same concern as the Salton Sea has been. Until very recently, it has been considered a completely separate ecosystem from the Salton Sea. As a result, restoration programs have not included the lower delta in their plans.

According to Luecke and colleagues (1999), if Mexico demanded an increased quota from the Colorado River, it would create friction between users from the United States and Mexico.[16] Instead of demanding more water, they recommend that lower delta rescue efforts concentrate on the protection of existent, but not regulated, flows. They also mention that recovery of the short-term lower delta could be reached if the flows registered in recent years continued.

The surplus flows of the last years are currently being assigned to the users in the United States without considering Mexico (Luecke 1999). The regulation of surplus water among United States users will lead to a drastic reduction in surplus flows to Mexico. It is clear that competition for Colorado River water will be more intense for the short and medium term.

Restoration and conservation of the natural habitat of the Lower Colorado River Delta and Upper Gulf of California is an unresolved subject even today. However, countries all over the world are beginning to understand that sustainable development does not end at their borders and that the responsibility to conserve ecosystems is not just a national concern.

It should be understood that a permanent flow to the lower delta is vital to guarantee the survival of the wetlands, the natural river course, the Santa Clara Slough, and the Upper Gulf of California ecosystems. Preliminary findings suggest that the riparian corridor requires 260,000af every four years to regenerate trees. To create a perennial flow of water, 50,000af per year is required. This total 115,000af on an annualized basis is less than one-twelfth of Mexico's annual appropriation of Colorado River water (Varaday et al. 2001).

If there is no consensus about the water volume necessary to restore the lower delta, the quality required is even more complex to define. Quality must be measured in multiple ways. Salinity, microbial contamination, chemical pollution, and pH levels all influence the marine and estuarine organisms. The Mexican government faces three quality-related challenges: rising levels of water salinity, high concentrations of nutrients from agricultural drainage, and contamination from heavy metals, especially selenium[17] (Varaday et al. 2001).

Brusca and collaborators (2001) affirm that the only way water can be allocated to meet the environmental needs of the lower delta will be at the expense of agriculture on both sides of the U.S.-Mexican border. The first step toward this is making users of Colorado River water recognize the lower delta as a tenth user.

Interim Surplus Water Criteria

Management of Colorado River water is governed by a wide and complex group of documents and agreements that are collectively known as "Law of the River." Handling the main watercourses of the Colorado River's lower basin is the responsibility of the secretary of the USDI, which acts through the USBR.

The Upper and Lower Colorado River Basin States Water Compact, signed in 1922, divided 15MAF per year between the Upper and Lower Basins and seven U.S. states.[18] Average flow of the river was estimated based on data from 1910 to 1920, which was one of the wettest decades. Averaged out over many decades, the mean flow of the river is close to 13.2MAF per year. In 1944, when the Water Treaty was signed with Mexico to guarantee 1.5MAF of Colorado River water per year, it included the two Mexican states of Baja California and Sonora. It is clear that with the demographic, agricultural, and industrial growth of the lower basin states, the volume of 7.5MAF that was assigned in 1929 is no longer sufficient.

This Colorado River water over-assignment has created a crisis. For decades, California has dipped freely into the Colorado River to the tune of approximately 5.2MAF annually. This was allowed because California was the first state to have a water distribution system. In recent years, however, three significant events greatly altered California's favorable position. First, under a 1963 decision of the U.S. Supreme Court, California's entitlement was set at 4.4MAF annually. Second, Arizona is approaching its full entitlement because of the completion in the late 1980s of the first phase of the massive Central Arizona Water Project (Eugene 2000). Third, Nevada reached its allotment in 2000.

This situation was the main reason the USBR was obligated to implement diverse actions of technical and political character—among them the Colorado River Interim Surplus Criteria strategy.[19] This strategy consists of criteria under which surplus water volume in the lower basin of Colorado River could be declared during the next 15-year period (USBR 2000). Interim surplus criteria (ISC) are used annually to determine the conditions under which USDI may declare the availability of "surplus" water for use within the states of Arizona, California, and Nevada.

The Long Range Operating Criteria (LROC) for the Colorado River define a normal year as one in which annual pumping and release from Lake Mead is sufficient to satisfy the 7.5MAF of consumptive use in accordance with the decree. A surplus year is defined as a year in which water in quantities greater than normal (7.5MAF) is available for pumping or release from Lake Mead. USDI is authorized to determine the conditions upon which such water may be made available. The USDI must comply with and carry out the provisions of the Colorado River Compact of 1992, the Colorado River Storage Project Act of 1956, the Boulder Canyon Project of 1928, and the 1944 Water Treaty. Article 10(a) of the 1944 treaty states that Mexico is entitled to an annual allotment of 1.5MAF of Colorado River Water. Under Article 10(b) Mexico may schedule up to an additional 200,000af when a surplus of water exists in the Colorado River in excess of the amount necessary to supply the United States. As a result of current operating experience, particularly during recent years when there has been an increase in demand for surplus water, the USDI has determined that there is a definite need for specific surplus criteria. The ISC could help implement the specific provisions.

Thinking in purely U.S. terms, it seems reasonable to adopt a new approach for assigning surplus water in order to allocate more water to its U.S. users. Mexico, however, also a member of the lower basin of the Colorado River and a consumer of Colorado River water, should be taken into account. The U.S. government is concerned only with complying with the 1944 treaty and argues that this ISC does not affect the water volume that should be delivered to Mexico.

In the United States, this kind of decision must be supported by an Environmental Impact Statement (EIS), which must include a public comment period open to anyone around the world. Several Mexican organizations, including public universities like the Universidad Autónoma de Baja California, sent letters to the committee pointing out the disadvantages of reducing the flow of water to the Gulf of California. There were two arguments. First, this surplus flow is used to recharge the Mexicali aquifer and dilute its salinity, which affects the economic activities in Baja California and Sonora, who are the eighth and ninth users. Second, an ecological flow along the Colorado River from the border to the lower delta is

necessary to support the marine ecosystem of the Gulf of California, the tenth user. The EIS of the Colorado River Interim Surplus Criteria outlines the potential transboundary effects of reduced flood flow frequency in section 3.16.5.3.

According to the EIS there are positive and negative effects of excess flows to Mexico. On the positive side, the excess flows to Mexico produce lower salinity in the Colorado River. This reduced salinity cancels the adverse effect of the seepage from farm irrigation, groundwater, and drainage recharge. On the negative side, however, increased flow carries sediments that are deposited in the river channel. Furthermore, the increased groundwater level damages crops, which subsequently lowers yields.

The effects of reduced frequencies of excess flows include the following:

- Mexico will not be able to use excess water to recharge and dilute the aquifer, which supplies more than 700 agricultural and urban wells. Currently, salts are leached from farmland on the left bank of the river. This lack of water recharge would induce a draw-down of the piezometric level of the aquifer and consequently lead to an increase in the salinity of its waters.
- ISC and the proposed CA Plan—including lining of the AAC and Coachella Canal—further complicates matters. This would result in the recovery of 67.7MAF per year from the AAC and 26MAF per year from the Coachella Canal. At present, the 67.7MAF per year infiltrates to aquifers in the Mexicali Valley and is used in agriculture, delivered through deep wells.

Conclusions

Development activities for more than 150 years along the enormous borderland that Mexico and the United States share has given rise to a great interdependence among both communities. Their advanced political maturity has created initiatives designed exclusively for this region, where a complex mix of hydrological basins, entry points, and deserts have turned the binational coexistence phenomenon into something more than simple, everyday activities. The Mexicali and

Imperial Valleys are good examples of this interdependence. Colorado River water is shared between two nations and nine states, and recently both countries have been begun giving attention to a tenth user, the ecosystem.

Several issues have been discussed in this chapter, some of which are being solved, others of which have been identified and quantified. Still others must be recognized as binational problems, including the:

- Residual waters that flow through natural courses end as deposits in the Salton Sea and the Santa Clara Sludge
- Intrinsic hydrodynamic relationship between the Mexicali aquifer and the All-American Canal
- Need for an ecological flow along the Colorado River from the international border to the lower delta and to the Gulf of California
- Need for extra flow to maintain the salinity levels in the Salton Sea to guarantee the ecosystem's preservation
- Growing water demand from agriculture, urban, and industrial sectors creating a situation of over-allocation of water among users of the Lower Basin of the Colorado River
- Tension between agriculture and urban users
- Need for a definite and unilateral Colorado River interim surplus criteria

Today in both countries the perception of borderland problems has come into a wider focus than it was 100 years ago. Its origins, effects, and impacts must be analyzed with an integrated vision and with equal consideration of political, ecological, social, and economic issues. Sustainable development is not conceived of only in a friendly environment where geography is considered a unique ecosystem, where the benefits of biodiversity are appreciated, and where borderlines are not distinguished, because all are linked to each other.

Mexico and the United States have learned that reasoning and respect among neighbors is the only way to develop solutions. In December 2000, the first diplomatic agreement, IBWC Minute 306, was signed to demonstrate the intent of both countries to protect

the Colorado River Delta ecosystem. Since 1889, IBWC-CILA has played an important role in creating these agreements and they are the government office responsible of promoting amendments to the 1944 treaty.

Endnotes

1 To use these waters, Mexico's government must mix them in a place known as the "licuadora" (blender) with water from the wells and the Colorado River because the level of salinity of the water that arrives in Mexico is 1,850ppm.

2 At that time, the construction of an aqueduct that supplied Tijuana from the City of Mexicali was not considered, given the magnitude of the investment and work—since the natural barrier of the Sierra of Juárez, a topographical difference of more than 1065m in height, was in the way.

3 The complex over-assignment of water to Los Angeles created serious confrontations between USBR and users. The implementation of a policy for the interim approach to handling surpluses of water from the Colorado River and the CA Plan meant that the parties would not have to revisit this issue for at least 15 years.

4 The average annual rate of growth in Mexico decreased from 3.25% in the 1990s to 1.96% for the year 2000.

5 This value is determined by taking annual total assignments delivered to the city and dividing them by the total number of domiciliary services registered. A crowded index is considered 4.18 members per family.

6 In 1980, the Secretary of Agriculture and Hydraulic Resources, with the intent of planning the water demand in Baja California and the volumes that would be assigned to each city of the state, decided Tijuana would receive 88Mm^3 per year. However, the consumptions reported for 2000 were 117Mm^3 per year, delivered via the Colorado River-Tijuana aqueduct. Mexicali was assigned 82Mm^3 per year, Tecate 16Mm^3 per year, and San Luis 13Mm^3 per year. The San Luis Sonora Sandy Table, or Mesa Arenosa de San Luis, assignment was based on the extraction of 64 deep wells.

7 In May 2001, at a meeting held by the Commission of Hydraulic Resources of the Senate of the Republic, CESPM

announced that the consumption of water per person in 2000 had been 424 liters per day. However, CNA Subsector Agua Potable y Saneamiento reported water consumptions per person per day varied between 392.3 liters in 1996 and 351.3 liters in 2000 in Mexicali.

[8] When water initially arrives in Mexican territory, the IBWC gives the water to CILA; CILA delivers it to CNA; CNA delivers it to the Mexicali Irrigation District, then the district delivers the water to each Irrigation Module.

[9] In a personal communication, Michael Cohen of the Pacific Institute said that the only reliable supply is the water allocation of 1.5MAF from the 1944 treaty because nobody knows the groundwater recharge rate.

[10] Although percent change is more than double for the Imperial Valley than for the whole of California, the distribution of the ages within the population is approximately the same.

[11] In a 60-year period the population was almost three times more.

[12] Colorado River Irrigation District 014 is comprised of 23 irrigation modules or *módulos de riego.* Each module may have a different area, number of partners, type of crops, and soils.

[13] This administrative figure appears later on in the creation of the modules because problems arose in handling them. The main argument in favor of CNA configuring this administrator is that the modules did not have any administrative experience. In January 2002, due to serious administrative problems, CNA abolished Modulate 13, the authorization to operate the hydraulic net. This module is now operated by technical personnel of Irrigation District 014.

[14] IBWC Minute 242 establishes that the United States will con–tribute the funds for Mexico to build the channel deviation for fossil waters coming from the confined aquifer in the Wellton and Mohawk Valleys. The starting point takes them from Morelos Dam to the Santa Clara Sludge.

[15] According Earl Burnett and collaborators, the Santa Clara Sludge has received, through a bypass drain, an average flow of 195 cubic feet per second with an average quality of 2,942ppm of total dissolved solids from 1977 to 1993. This results in 1,546 tons per day, or 560,000 tons per year deposited into the sludge.

[16] They argue that the water consumption of states in the Colorado River's Lower Basin is increasing competition for the water. California already uses more than its assigned quota and Nevada is next to reach its quota. Mexico will see its underground water reduced with the lining of the All-American Canal.

[17] These three challenges were pointed out by Saúl Alvarez Borrego, a researcher from the Universidad Autónoma de Baja California during the symposium and workshop "... to the Sea of Cortes: Nature, Water, Culture, and Livelihood in the Lower Colorado River Basin and Delta," held in Riverside, California, September 29 to October 2, 2000.

[18] State allotments of Colorado River Water, based on the Water Compact and in million acre-feet per year, was: California, 4.4; Colorado, 3.86; Arizona, 2.85; Utah, 1.71; Wyoming, 1.04; New Mexico, 0.838 and Nevada, 0.3.

[19] This strategy arises as an alternative solution to a difficult problem, because it is impossible to tell residents of this populous and powerful community that because there is not enough water for everyone, no one will receive any of it. This strategy is only a palliative that grants to USBR authorities a 15-year term to solve the problem of water consumption in California's big cities.

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