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WATER MARKETS IN MEXICO: OPPORTUNITIES AND CONSTRAINTS

Robert R. Hearne and José L. Trava

ABSTRACT

In 1992, the Government of Mexico initiated a new national water law which decentralised water resources management and allowed the market transfer of water-use concessions between individual irrigators. These reforms were expected to improve water resources management through greater user participation in irrigation management, as well as to increase irrigators' incentives to improve water-use efficiency. At the time of its proposal the 1992 *Federal Water Law* was considered to the first step in the establishment of limited water markets. This paper addresses the opportunities and constraints to improved water resource use and allocation through the market incentives that result from transferable water-use permits. The paper reviews water allocation institutions in Mexico and provides case studies of water allocation and decision-making.

Introduction

Throughout the world the growing demand for potable water, irrigated agriculture, and environmental services is putting increasing pressure on finite supplies of freshwater resources. New methodologies and new systems for more efficient and equitable distribution of water between competing users are needed to meet this challenge. Traditionally, most countries have relied on centralised, state managed, command and control systems to ensure equitable distribution of water and provide subsidised water delivery services to farms and cities. But poor state management, increasing fiscal pressures on central governments, increasing concern about the environmental effects of large catchment and irrigation systems, and the continual growth of urban populations have led certain governments and agencies to rethink the role of government in water resources management. A new paradigm has emerged, characterised by decentralised management, user control of water delivery services, transferable water-use rights, and water markets (Easter and Hearne 1995, Rosegrant and Gazmuri 1994, Rosegrant and Binswanger 1994). To date, however, there has been relatively little empirical analysis of how this paradigm has functioned in practice.

In 1992, the Government of Mexico initiated a new national water law, which decentralised water resources management and allowed the market transfer of water-use concessions between individual irrigators. This new water law coincided with a series of policy reforms initiated in the late 1980s, and included:

- the privatisation of communal land holdings (*ejidos*);
- the transfer of the operation of canal systems to water user associations (WUAs);
- the revision of the role of the National Water Commission (CNA); and
- more liberal trade policies.

These reforms were expected to improve water resources management through greater user participation in irrigation management, as well as by increasing irrigators' incentives to use water more efficiently.

At the time of its proposal the 1992 *Federal Water Law* was considered to be the first step in the establishment of limited water markets in Mexico (Easter and Hearne 1995, Rosegrant and Gazmuri 1994). Mexico's system of transferable water-use concessions was compared to the system of water-use rights in Chile, where limited transactions have been shown to produce economic gains and to forestall the need to construct a new dam and reservoir (Hearne and Easter 1995 and 1997). Like Chile's 1981 *National Water Code*, Mexico's 1992 *Federal Water Law* maintains a central role for the CNA in the management of water resources and the regulation of transfers of water-use concessions. However, Mexico's long tradition of national control over water resources may have impeded the development of institutions, such as WUAs, that can facilitate the transfer of water.[1]

[1] The International Irrigation Management Institute (I.I.M.I.) is currently investigating the transfer of Mexico's Irrigation Districts to user management.

This paper addresses the opportunities and constraints to improved water resource use and allocation which arise from the creation of transferable water-use permits.

Section I presents the advantages to economic efficiency that result from the establishment of transferable water-use permits.

Section II reviews water allocation institutions in Mexico

Section III presents case studies of water allocation and decision-making which demonstrate how water allocation decisions are made in three regions.

Section IV concludes the paper with a summary and some policy recommendations.

I. Intersectoral and Intrasectoral Trade in Water-Use Rights

Intersectoral trade of water-use rights can be expected in a context where: i) urban areas are growing in population and income; ii) water-use is limited by both resource scarcity and by legally defined property rights; and iii) the value of water in non-urban sectors is relatively low. Income and population growth generate an increase in the urban demand for water. Alternatives to the acquisition of new supplies of water – such as desalinisation, wastewater re-use, and severe water conservation measures – are often very expensive. Hence, urban areas have strong incentives to purchase water rights from rural areas in order to secure water supplies at a reasonable cost.

This intersectoral transaction would, in all probability, involve the sale of water-use rights by farmers. The farmer would benefit by selling his water right if its net present value (calculated as the expected value of the discounted marginal product of water over an infinite horizon) was less than the price offered by a buyer. The possibility of intersectoral allocation may increase the demand for water rights in the farmer's locality above the level determined by agriculture alone. In this case, the difference between the net present value of the water right in agriculture and the price that is determined by the supply and demand of water, would be an economic rent that would accrue to the farmer as owner of the property right.

Similarly, intrasectoral trading within agriculture can be expected in situations characterised by: unequal water endowments; evolving crop selection; and differences in the effectiveness of farm management. In South Asia, for example, water trade is common as a result of unequal access to groundwater. Even where surface water is available, purchases of groundwater may be frequent due to uncertainty of supply (Rosegrant and Binswanger 1994). Trade in water between neighbouring farmers would be expected whenever the difference between their marginal value of water in irrigation exceeds the costs of a trade. This might occur when higher valued crops are adopted by only some farmers, or when land quality is highly variable, or when farmers have different endowments of capital equipment and irrigation technology.

When water is transferred from a low valued use to a higher valued use in a market exchange, both parties are expected to benefit financially, and society gains in the form of higher valued output per unit of water inputs (Hearne and Easter 1995 and 1997). Furthermore, since the presence of water markets increases farmers' value of water, the incentive to use water more efficiently may reduce environmental degradation from waterlogging, salinity, and selenium (Dinar and Letey 1991). However, water-market transfers are often constrained by:

- the cost of constructing, operating, and modifying the infrastructure needed to redirect waterflows;
- the cost of gaining legal and bureaucratic approval for transactions of water-use rights from one user to another;
- the cost of finding willing buyers and sellers and negotiating a transaction; and
- the cost of registering and enforcing the transactions.

These transactions costs are generally considered to be the major constraint to active water markets. Efforts to reduce these transactions costs with investments include: i) water conveyance infrastructure; ii) public registries of water-use rights; and iii) effective WUAs to facilitate the transfer of water and increase the efficiency gains that are possible with water markets (Hearne and Easter 1995).

Recent Experience of Trade in Water and Water-Use Rights

There is a growing literature on efforts to include water markets and market incentives in water resources management. Most of this literature focuses on the western USA, where growing populations, water scarcity, and a mix of water allocation systems, generally based on prior appropriation, allow for well regulated market transfers (Brajer et al, 1989; Colby Saliba and Bush, 1987; Howe et al 1986). Recent innovations like the *California Water Bank* are also featured (McCaulay, 1991). More directly pertinent to the Mexican experience, Chang and Griffin (1992) analyse water allocation institutions and water markets in Texas and demonstrate that secure water-use rights and periodic market transfers have supported the growth in the value of agricultural production in the lower Río Grande Valley. Also, Rosen and Sexton (1993) analyse the transfer of water from the *Imperial Irrigation District* in southern California to the *Metropolitan Water District* of Southern California.

There are numerous examples of volumetric or quasi-volumetric trade in water occurring outside the USA. In a formal market in Alicante, Spain, farmers exchange scrip that entitle the bearer to period of time of canal flow (Maas and Anderson 1978). In South Asia, markets for groundwater supplement canal irrigation and provide a certain supply of water when canal flows are low (Shah 1993). Also, there are exchanges in canal water involving the modification of a turn in a *warabundi*[2] system (Renfro and Sparling 1986, Meizen-Dick 1994). Since these transactions are for certain specified flows, both the buyer and seller are fairly certain of the volume of water involved. In all of these cases, the sale of water is not permanent, and the seller can profit from the ability to trade in the short term while retaining the original water right.

[2] A *warabundi* is a formalised system of timed water delivery in the large canal systems in South Asia.

II. Water Institutions in Mexico

National Ownership of Water

National control of both land and water has been a key feature of the Mexican landscape since before Independence in 1821. Indeed, the Papal Bull of 1493 awarded both the land and water of most of the Western Hemisphere to the King and Queen of Spain. The land reforms which followed the 1910 Mexican Revolution were the apex of state control. Land was redistributed to the peasants in the form of State owned *ejidos*, and correspondingly, all water resources were nationalised. The national character of the current CNA can be explained by the importance that the farmers of the 1917 constitution placed on strengthening a national programme of land reform with irrigation development (Roemer 1994, Cummings and Nercessianz 1994). Likewise, the importance of national ownership of natural resources can be traced to the revolutionary response to foreign ownership of mineral and oil rights during the period of Porfirio Diaz's leadership, 1876 – 1911.

The 1917 Constitution, which is still in effect, stresses that the Nation is the original proprietor of land and water property, and that rights or concessions to use natural resources may be granted to private individuals. Furthermore, all private property is subject to appropriation by the Nation for reasons of conservation and improved distribution of wealth. The Mexican Nation's original propriety of natural resources is in many senses similar to 'eminent domain'.[3] However, the Nation's direct ownership of subsoil resources and water is emphasised directly in the 1917 Constitution, thus legally reinforcing national ownership of water as being distinct from 'eminent domain' (Roemer 1994).

Irrigation Development

Growing food production requirements, assistance to the new system of *ejidos*, and the desire of the national authorities to settle the extensive, unpopulated areas of northern Mexico, led to a significant national role in irrigation development. Before the 1910 revolution, the total area of irrigated land in Mexico was close to 700,000 ha. Currently, the figure is 6 million ha (*see Map 1*). More than half of this area, or 3.2 million ha, lies within 80 nationally developed irrigation districts, varying in size from 3,000 to 270,000 ha.[4] In virtually all of these districts, large parts of the newly irrigated land is reserved for the *ejidos*.

Since their creation, these irrigation systems have enjoyed generous government support, as part of the *ejido* system. Not only were the capital costs of irrigation construction never

[3] A right of government to take private property for public use by virtue of the superior dominion of the sovereign power over all lands within its jurisdiction

[4] A further 1.8 million ha is in smaller irrigation units of 50 to 200 ha., collectively or privately managed. Additionally, between 0.4 and 1.9 million ha of irrigated land is privately owned and developed.

recovered from farmers, but operations and maintenance expenses (O&M) were heavily subsidised (Cummings and Nercessianz 1994). Of course, irrigation development was only part of a pervasive system of government intervention in the agricultural sector. The government, and government supported parastatals, also guaranteed producer prices, subsidised fertiliser, agrochemicals and seed, supported farm credit and crop insurance, and controlled imports.

Most of the large irrigation systems were constructed during the period from the 1930s to the 1970s by the CNA's predecessors, the *National Irrigation Commission* and the *Ministry of Water Resources* (SRH). These institutions were mainly dedicated to the construction of irrigation systems. In the 1970s, the SRH reaffirmed central control of water with an extensive program of national water planning, culminating in the 1975 *National Water Plan.* Later, after the SRH merged with the *Ministry of Agriculture* to form *the Ministry of Agriculture and Water Resources* (SARH), the CNA was established in order to reinforce water policies and strategies (SEMARNAP, 1995). Later, CNA was included as a semi-autonomous part of the *Ministry of the Environment, Natural Resources, and Fish* (SEMARNAP, 1995).

In all of its forms, the CNA has maintained a dominant, central role in Mexican water resources management. And although it has accepted overall responsibility for the planning and management of water resources, the CNA has remained strongly orientated toward construction, irrigation development, and support for land reform (Cummings and Nercessianz 1994). Other subsectors have moved away from CNA's authority. Since 1980, the operation of potable water and sewage services have been the responsibility of state and municipal governments. However, CNA is responsible for delivering bulk water supplies to local potable water services.

The 1972 *Federal Water Law* continued to stress the federal government's ownership and control of water resources. Water was allocated to individual users through concessions[5] which were to last for 50 years. These concessions were awarded under a system of priorities, with domestic use receiving the top priority, followed first by agriculture and subsequently by all other users. Water-use concessions were not transferable and were restricted to both type of use and the land on which the water was used.

The construction, operation, and maintenance of irrigation infrastructure has always been a federal responsibility. Moreover, in contrast to the large, federally-sponsored reclamation and irrigation projects in the USA, irrigation projects in Mexico are considered to be single purpose projects with no financial contribution expected from other sectors or users. Consequently, financing for both the construction and maintenance of irrigation systems has been severely limited. Traditionally, both irrigators and the government contributed to O&M expenditures, yet these expenditures were generally inadequate. In the early 1960s, farmers' contribution to O&M expenditures accounted for over 60% of total outlays. Over time, however, both the government and the irrigators reduced their contributions. By the end of the 1980s, irrigators paid only 18% of O&M expenditures, and the government was not

[5] Although "concession" is the correct word to use in both English and Spanish, most people generally refer to these as *derechos* or *rights*.

willing or able to make up the difference (Roemer 1994, Cummings and Nercessianz 1994, Gorriz et al 1995). Consequent to the limited expenditures on O&M, canal systems in the irrigation districts fell into major disrepair, while water delivery became increasingly unresponsive to farmers' needs. Overall conveyance efficiency was reduced to 30% – about half the level achieved by irrigation systems in California and Arizona (Gorriz et al 1995).

The 1992 Mexican Federal Water Law

The 1992 Mexican *Federal Water Law* was intended to resolve these problems by imposing market based incentives on water resources management and by decentralising much of the management of Mexico's irrigation districts. The new law coincided with a new 1992 *Agrarian Law*, and with the 1993 *North American Free Trade Agreement* (NAFTA). The combined effect of these reforms is a sharp change in the incentives faced by farmers. Most importantly, the 1992 *Agrarian Law* allowed greater freedom for farmers in *ejidos* (or *ejiditarios*), to sell, rent, sharecrop, or mortgage their allocated parcels of land. This law in effect declared an end to the redistribution of land, while allowing *ejiditarios* the benefits of private property. Furthermore, the *Ministry of Agriculture* gradually began to eliminate subsidies on agricultural inputs and price supports for all commodities except maize and beans.[6]

Under the 1992 Mexican *Federal Water Law*, water remains national property. However, private transferable water-use concessions are granted to individuals, WUAs, and incorporated firms for a period of up 50 years. Although concessions are renewable, CNA has to approve the renewals. Water-use concessions are volumetric and based on consumptive use.[7] Within the Irrigation Districts, the CNA allocates concessions to WUAs organised at the level of irrigation units, or *módulos*, which in turn allocate concessions among the users according to their own procedures. The initial allocation of water-use concessions is based on historic levels of use. The federal government is further authorised to restrict water-use in order to: ration water during drought; prevent the over exploitation of an aquifer; preserve water quality; restore an ecosystem; and protect sources of potable water.

The concession title is granted by the CNA, and contains: the legal foundations for the grant; the name and home address of the concessionaire; the location for the extraction of water; the conceded volume of water; the initial projected use; the place for return waters discharge, with the necessary specifications of volume amount and quality; the duration of the concession; and the obligations and rights to which both the CNA and the users are committed.

In times of scarcity, the water required to meet volumetric water concessions is often not available. There is no system of prioritised volumetric rights as in most of the western United States, nor a tradition of proportional reduction as in Chile. However, the bylaws of each

[6] A further gradual elimination of all agricultural price supports has been agreed upon as part of the NAFTA agreement.

[7] In times of scarcity volumetric denomination of water rights is not applied.

irrigation district should specify a rationing system to distribute water when volumetric requirements cannot be met. When these bylaws are respected and enforced, growers have some security that a certain percentage of their water concession will be available.

The Water Law requires the CNA to create a *Public Registry of Water Rights* (REPDA) listing all concession holders. This allows the CNA to control the assigned volumes, as well as to record the information needed to grant future concessions. The REPDA also serves the task of certifying public and juridical acts of registration, extension, suspension, termination and transmission of water rights, as well as of permits for sewage waters utilisation. This registration of water-use concessions allows any individual access to information on the allocation of water. Ideally, it guarantees and gives legal validity to registered concessions, it facilitates water resources planning and programming, and it is a readily available instrument for water users who may want to defend their rights during conflicts.

The Water Law also creates a system of water fees to be paid by the owner of the concession according to the intended use of the water. This water fee is assessed for both water extracted and for the quantity and quality of discharges. These water fees are designed to support the activities of the CNA. However, the fee for irrigation water has been zero.[8] If water fees are not paid for three consecutive years, the CNA can declare that the water is not being used and rescind the concession. Municipal and state government authorities responsible for potable water and sewage services are required to pay fees for water delivery and wastewater discharges.

Although the registration of water-use rights should increase the security of water delivery, individuals who register their rights are subject to the water-use fee. Given the difficulty of monitoring extraction of water, especially from groundwater sources, the registration of concessions has therefore been slow. According to the CNA's 1994 annual report, the total number of water users identified as having some 'right' to water volumes was 206,500, while the number of registered users was only 26,375. The volume of registered water as a percentage of total identified water-use is shown in Table 1.

Table 1:	**Registration of Water-Use Concessions**
Use of Water	**Registered Volumes as % of Total Volumes**
Irrigation	55%
Urban	65%
Industrial	30%
Hydropower	90%
Sewage	50%.

8 With the transfer of canal management to WUAs, irrigators have been required to pay a fee for management, operation, and maintenance. Part of this fee is allocated to the CNA for the operation of head works, main canals and drainage networks.

Irrigation System Management

The 1992 *Federal Water Law* stipulates that the responsibility for management of Irrigation Districts should be vested in the users.[9] Primary catchment and main delivery canals remain under the control of the CNA. The law also stipulates the conditions under which the transfer of management of irrigation systems to users will occur. Furthermore, CNA procedures for the transfer of water have also been adopted. The large irrigation districts are initially divided up into *módulos*. The size and shape of these *módulos* is determined by CNA officials, and based on the existing irrigation infrastructure, community needs, economies of scale (Gorriz et al 1995). Irrigators who wish to form a WUA are required to establish a not-for-profit organisation, or *asociación civil*. Each WUA is governed by a General Assembly and Executive Council, although the structure and organisation of these groups is often complicated by the presence of both *ejiditarios* and small private farmers in the same system. Because of this complication, many different representation systems have been established in different *módulos*.[10]

Together with the Executive Council of the *módulo* and the local CNA engineer controlling the Irrigation District's storage system and head works, the Irrigation District's Hydraulic Committee plays an important role in the determination of each farmer's water delivery schedule and crop selection. The Hydraulic Committee is, according to law, comprised of representatives of all the WUAs in the district. However, local CNA engineers and agricultural extension officers may also sit on the hydraulic committee. In each district, the availability of irrigation water is estimated by the CNA at the beginning of the cropping season. This information is made available to farmers who are then required to submit a cropping plan to the WUA. Based on farmers' cropping plans, the WUA submits an irrigation plan to the district's Hydraulic Committee and to the CNA, which attempts to minimise conveyance losses by delivering water in bulk under a co-ordinated schedule.

Most irrigation districts use a rotation system to deliver water according to a prearranged schedule. These systems were initially designed in the 1940s and 1950s to irrigate grains. A number of WUAs have introduced an alternative 'arranged demand system' which allows farmers to place daily requests for irrigation water.[11] However, this requires not only investments in canal infrastructure and gates, but also changes in farmers' irrigation techniques.

As long as the terms of the concession are not changed, transfers of water require only the notification of the Public Registry of Water Rights. In the event that a transfer of a concession affects a third party, authorisation is required from the CNA. Transfers of a concession outside the district requires the approval of the general assembly of the WUA, as well as authorisation from the CNA. The benefits of a transfer of water outside of the district are

9 As of the end of 1994, 76% of the irrigated area in Mexico's irrigation districts have been fully or partially transferred to user control.

10 Conversation with Sam Johnson IIMI, March 1996.

11 A recent World Bank Study concluded that arranged demand systems can be more efficient than a rigidly scheduled rotational system. (World Bank 1993)

reserved for the district, not for the water user. (The effects of this will be discussed later in the paper.)

Summary of Water Institutions In Mexico

Mexico's 1992 *Federal Water Law* provides the necessary legal basis for water-market transactions. Its inception corresponds with a period of dramatic change in Mexico's agricultural sector. The law also allows the federal government to play a continued dominant role in the regulation of water-use, especially during periods of water scarcity. Thus a shift to decentralised water resources management, and the use of market forces to determine the allocation of water, may be constrained by a continuation of the federal government's and the CNA's traditional preference toward centralised control.

III. Case Studies

During a 1996 visit to Mexico City and northern Mexico, government officers, researchers, NGOs, irrigators, and CNA officials were interviewed in order to assess the current progress of decentralisation and water transactions. Case studies in northern Mexico were chosen because of the insights they were expected to provide. After the visits, data on market transactions was collected from CNA sources. Unfortunately, northern Mexico was entering the third year of a drought during this period. Thus, these case studies present water resources management during a period of cyclical water scarcity.

A. *The Río San Juan – Monterrey Area*

In a 1952 agreement, water from the Río San Juan, which originates in Nuevo Leon and flows north through the Marte R. Gomez Dam in Tamaulipas, was allocated to irrigate 76,951 ha in the Lower San Juan Irrigation District #026 in the Río Bravo area of Tamaulipas, near the US border (see Map 2). This is a coastal, semi-arid area with maximum temperatures reaching 35 degrees Celsius, average annual rainfall of 370 mm, and annual evaporation of 2,031 mm. The district adjoins a string of small, industrial, border cities centring on Reynosa, with a 1990 population of 265,000 inhabitants.

In this district, 13,231 ha belong to the 'social' sector of 1,407 *ejiditarios* and 63,720 ha belong to 3,535 private owners. The average *ejido* plot is 9.40 ha, whereas private farms have an average size of 18.02 ha. Traditionally, the major crops in this district are: i) maize, with 50% of cultivated area; ii) sorghum, with 20% of cultivated land; and iii) cotton, with 30% of cropped area. With water from the Marte R. Gomez Dam (storage capacity – 932 million cubic metres (MOM)), some additional water from the Río Bravo/Río Grande, and a canal network of over 1100 km, this district has had a fairly secure water supply.

In 1993, management of the irrigation district was transferred to 13 WUAs. These *módulos* range from 1,974 hectares to 9,269 hectares. Water fees to recover the costs of operation and maintenance of the canal system range from US$ 17.90/ha/season to US$ 31.45/ha/season, with expected delivery of 3.5 thousand cubic metre (TCM) per hectare. Estimated cost recovery during the 1994-95 irrigation season was 87%. This figure fell to less than 50% during the 1995-96 due to water shortages.

The district's relative security of water supply was drastically reduced when the 1952 agreement on the use of the Río San Juan was modified with the construction of the El Cuchillo Dam in Nuevo Leon. This new project (the dam has been completed but never filled) resulted from an agreement which was signed on May 1990 "in order to satisfy urban and industrial water demands of the city of Monterrey, State of Nuevo Leon, and to preserve those for multiple uses at Irrigation District #026 in the State of Tamaulipas". The dam, which has a storage capacity of 1,300 MCM, will also supply irrigation water to the small Irrigation District #031 – Las Lajas. The city of Monterrey is an important industrial centre with a growing population of over 3,000,000. 50% of this population are recent immigrants.

The agreement, which was signed by representatives of the Federal Government as well as the Governors of Nuevo Leon and Tamaulipas, further stipulates that the 60% of the water that is to be diverted from El Cuchillo is to be replaced by treated wastewater. This wastewater will flow from Monterrey, via the Río Pesqueria, to Marte R. Gomez Dam, and thence to the irrigators of District #026. The CNA in Nuevo Leon will operate the reservoir to suit the needs of the city of Monterrey. CNA will pass water to irrigators in Tamaulipas, but only to suit its own needs.[12]

The completion of El Cuchillo Dam, in October 1994, corresponded with the beginning of a prolonged drought which has postponed any discharge from the reservoir. Furthermore, the wastewater treatment plants which were to be the source of water to Irrigation District #026 were not yet complete in April 1996. Instead, current wastewater flows from Monterrey are being diverted from the Río Pesqueria to other irrigated land.[13] Thus, irrigators in the lower San Juan have been confronted with severely curtailed supplies of water. Given the powers granted to the CNA in the 1992 *Federal Water Law*, this reduction of water flows to irrigators is not extraordinary, but it significantly reduces the security derived from a legal water concession.[14]

In *Módulo III-3* of the Lower San Juan Irrigation District, rationing of water in times of drought follows a traditional pattern. In wet years, water is divided according to the land area irrigated. In dry years, on the other hand, water is divided equally among users, by equivalent volume, independent of the land area which they irrigate. Under drought conditions, therefore, a farmer with 10 ha would intentionally receive the same equivalent volume of water as the owner of 100 ha. However, due to the limits on conducting and metering water in the canal system, water is allocated by irrigation turn, during which all the canals in a field are flooded. Hence in a dry year, the owner of 100 ha receives one irrigation turn for the whole season, and the owner of 10 ha receives the equivalent volume of water in two irrigation turns. During an irrigation turn, canals have constant flows of water, and irrigation labourers work around the clock.

Since water is not available to the farmer on demand, but is delivered according to schedule, crop selection is not determined independently by farmers. The Executive Committee of the *módulo* and the Hydraulic Committee of the Irrigation District, which includes both farmers, government extension agents, and CNA officials, set crop selection priorities and schedule water deliveries. As a consequence, with the exception of a small stand of oranges, only sorghum will be planted during 1996 in this *módulo.*[15]

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[12] CNA has made a single transfer of 200 MCM of water to the Marte R. Gomez Dam. CNA staff in Monterrey state that water was transferred in order to prevent evaporation in El Cuchillo. It is more likely that the water was transferred to placate the claims of the irrigators of the Lower San Juan Irrigation District.

[13] Much of the information in this section comes from interviews with CNA officials and farmers during March and April 1996.

[14] In Chile one of the most important benefits of a system of transferable water-use rights is the security that farm managers have in water supply (Hearne and Easter 1995).

[15] Interview with *módulo* President.

Because the Irrigation District is located in Mexico's industrialised northern border region, farmers do have alternative employment opportunities. Within the Irrigation District it is estimated that more than 35% of land and water has been leased by *ejiditarios* to small property owners. The cost of leasing both land and water varies between US$ 115-160/ha per year. This can be compared to a market value for land which ranges from US$ 1,000 to US$ 3,000 per ha. Although the growing industrial and residential areas along the border traditionally receive their water supply from the lower San Juan district's canals, no transactions from irrigators to other sectors have been recorded. Because of the traditional priority of municipal water use over agricultural use, the residential and industrial users have security in their supply of water and under present conditions do not need to consider transfers of water concessions form agricultural users.[16]

The situation in irrigation district #026 is similar to that of district #025, the lower Río Bravo, located farther east and downstream of #026. This district receives water from a series of large international dams (Amistad and Falcone), with 45% of the releases going to Mexico. Because of the recent drought, water traditionally used for irrigation is being diverted for urban and industrial uses in Reynosa, Río Bravo, and Matamoros, which have a large concentration of processing and assembly plants (*maquiladoras*). During the 1995-96 season, irrigators in District #025 were promised no water at all for an area of 203,250 ha. After planting more than 140,000 ha of sorghum, these farmers received additional water and were able to irrigate 80,000 ha during the winter season.[17]

Immediately adjacent to farmers in District #025 and District #026, farmers in the US state of Texas share the same climate and, in many cases, the same international water sources. On the US side of the river there are also shortages of water. However, a well established system of proportional reductions of water rights and active water markets have provided security of water delivery to Texas farmers (Chang and Griffin 1992). Pressurised irrigation is also common in Texas, with less dependence on large canal systems than Mexico. South of the border, farmers grow mainly traditional grains, and during drought periods mostly sorghum. In the Texas Rio Grande Valley, on the other hand, high valued crops, fruits, vegetables, and cotton are irrigated. Currently, agricultural markets are not fully integrated, but under the NAFTA agreement Mexican farmers will increasingly enjoy the same market access as US farmers.

The difference in the agricultural activity between farmers in Texas and Tamaulipas demonstrates the importance of water resources management and the security of water delivery to farmers. This security was greatly reduced in the lower Río San Juan District with the construction of El Cuchillo Dam and the transfer of the flow of the Río San Juan to the city of Monterrey. Farmers in this district argue that they do not wish to deny cities

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[16] As part of the 1990 "Special Agreement" which allowed the transfer of Río San Juan water to Monterrey, the State of Tamaulipas was required to locate alternative sources of water for the industrial and commercial cities of Camargo, Diaz Ordaz, Reynosa, and Río Bravo.

[17] Irrigation District 025, Lower Rio Bravo has been selected as a case study in the current IIMI study of the turnover of Mexican irrigation systems to WUA management.

residential water supply, nor do they ask to be compensated with money. Instead they would like to be compensated with investments in canal infrastructure. This type of compensated water transfer copies a famous agreement between the city of Los Angeles and the Imperial Irrigation District of California. The much needed investments in canal infrastructure could reduce water losses in conduction as well as facilitate the irrigation of non-traditional crops. The municipal water supply company in Monterrey argues that the farmers in Irrigation District #026 are sufficiently compensated by the investments being made in wastewater treatment.

B. *The Lagunera Region*

Irrigation District #017, The Lagunera, is located in an interior basin in Mexico's north-central region, within the states of Durango and Coahuila (see Map 3). This is a semi-arid region with average annual precipitation of 277 mm, average evaporation of 1,929 mm, and maximum temperatures of 44 degrees Celsius during June, July, August and September. The district surrounds the industrial cities of Torreon in Coahuila, and Gomez Palacio and Ciudad Lerdo in Durango, with a total population of over 1,200,000.

The district has a total of 223,674 ha but only 112,696 of these are irrigatable. This land is divided among 35,084 *ejiditarios* and 2,734 private owners. The average *ejido* farm is 2.34 ha of irrigated land plus another 2 ha of dryland. Similarly, the average privately owned farm has 11.13 ha of irrigated land and some other dryland.

This district is divided into 17 modules which are irrigated by the Río Nazas, and 3 more modules irrigated by the Río Aguanaval. Major crops are cotton, alfalfa, beans, sorghum, walnuts, and maize. Recent trends show an increase in the cultivation of higher valued crops such as melons, grapes, alfalfa, and watermelons.[18] Water to irrigate this district comes from the Lazaro Cardenas Dam, with a capacity of 2,779 MCM, and the Francisco Zarco Dam, with a storage capacity of 368 MCM. Annual surface flows from these sources averaged 1,348 MCM for the four years prior to the 1995-96 drought.[19] There are also over 2,500 tubewells in the irrigation district and additional tubewells to supply water for residential and industrial uses. Total withdrawals of groundwater are estimated at 600 MCM per year.

Out of 17 *módulos* in the district, management responsibility has been partially transferred to 9 of these. Water fees for O&M expenses range from US$ 15.00/ha/season to US$ 27.14/ha/season, with expected volumes of 5 TCM per hectare. Water is distributed on a rotational basis, with four irrigation turns scheduled during the 1995-96 drought year.

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[18] Much of the information for this section comes from interviews with investigators from the National Agriculture and Forestry Research Institute and IIMI.

[19] Given that this latest drought has lasted for three years this average may be lower than a long term average.

Alfalfa remains an important crop because of the large dairy industry in the region.[20] However, the CNA does not allow the use of surface water to irrigate alfalfa even when reservoirs are full. Given the high returns to alfalfa, CNA officials believe that farmers can afford the cost of pumping groundwater for this purpose. Groundwater is thus used to irrigate alfalfa as well as to provide for residential and industrial water supply. However, groundwater levels have fallen at an annual rate of between 0.5 to 1.0 metres, which implies that the ban on surface irrigation of alfalfa will eventually threaten the water supply for the Torreon urban area.

During the 1995-1996 season - a period of severe water shortage - water availability was reduced to allow for only 26,000 ha of irrigation. This water was divided equally between the two states, with 93% assigned to *ejiditarios* and 7% to private owners. To minimise conduction losses, only a few *módulos* close to the main canals were to be irrigated. Those owning land outside this area could lease their water-use concessions to farmers in *módulos* that were to be irrigated, or they could 'request' the use of land in irrigated areas and move their water-use concessions to this land.[21] Land and water are leased together, but water is considered the more valuable resource. During this season the cost of leasing water increased from a range of US$ 4.00/TCM to US$ 5.10/TCM (US$ 57/ha to US$ 71/ha) in an 'average' year, to US$ 10.20/TCM (US$ 143/ha). This can be compared to land values ranging from US$ 1,857 to US$ 2,143 per hectare. During this year more than 140 MCM of water was leased in this fashion, usually from *ejiditarios* to private owners. This corresponds to 35% of the *ejiditario* land that was allocated irrigation water during this season.

Furthermore, in an emergency measure, the CNA – in consultation with state governors, other political leaders, and WUAs – mandated that only cotton would be irrigated with canal water during the 1995-1996 season. This is said to be a political decision intended to maintain employment of agricultural labour, since cotton is a labour intensive activity.[22] In mandating the crop selection for an entire surface irrigation system, the CNA is applying a liberal interpretation of its substantial powers to restrict water-use in times of scarcity. Although this is not a unilateral decision, and certainly not taken lightly, it does reinforce centralised control over what in other circumstances would be a decision made by individual farmers. Thus, the CNA is reverting to its historic role of overseer of irrigation systems and sponsor of irrigation based *ejidos*. It is also risking the long term consequences of destabilising the production of alternative crops, such as melons, which often require stable marketing contracts, and perennial crops, such as grapes and walnuts, which may be severely damaged by lack of irrigation water.

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[20] Annual output from dairy farm production in this region is estimated at US$ 85 million.

[21] The agronomist from the National Agriculture and Forestry Research Institute (INIFAP) with who I spoke in April 1996 suggested that the value of land without irrigation water was sufficiently low as to allow the CNA to temporarily allocate parcels of land in the irrigated *módulos* to farmers who wanted to transfer their water-use concessions.

[22] The Lagunera, and especially the cities of Torreon and Gomez Palacio, is an area where the closure of old industrial plants has caused high unemployment.

C. *The Mexicali Valley*

The lower Colorado River enters Mexico with an annual flow of 1,850 MCM. It then irrigates The Río Colorado Irrigation District #014, which is located in the Mexicali Valley in the states of Sonora and Baja California (see Map 4). This is an arid area with average annual precipitation of 59 mm, average annual evaporation of 2,251, and maximum temperatures reaching 45 degrees Celsius during July, August, and September. The district borders the city of Mexicali, with a large *maquiladora* industry and a 1990 population of 438,000.

The Irrigation District includes 136,600 hectares of surface irrigation and 71,365 hectares irrigated by 1,100 MCM/year pumped from 725 deep tubewells. The irrigators include 7,067 *ejiditarios*, with an average farm size of 17.9 hectares, and 7,627 private owners, with an average farm size of 14.2 hectares.[23] The Mexicali valley's main crop is cotton.[24] Although the quality of fibre is the best in Mexico, water requirements reach 13,700 cubic metres per hectare, reducing farmers' profits. Light textured soils, high salinity levels, and poor irrigation technology are among the reasons for this high level of water-use.

Salinity has been a critical issue in the lower Colorado River Valley, and in the Mexicali Valley this has been complicated by a dispute between the USA and Mexico on salinity monitoring. A 1973 accord regulated the salinity levels of transboundary water flows, but this water was to be monitored at the Imperial Diversion Dam located 40 miles north of the border and upstream from Yuma County's discharges. Thus, the water that actually reaches Mexico sometimes has saline levels that make it unsuitable for most agriculture.

The management of Irrigation District #014 was transferred to 22 *módulos*, ranging in size from 13,260 hectares to 4,758 hectares, during the period from 1993 to 1995. As of 1996, however, water fees were not completely 'negotiated' with the irrigators. There are three types of fees:

- water service fees for surface and groundwater, which average US$ 3.64/TCM;
- an annual 'rehabilitation' fee, which averages US$ 7.50/ha; and
- a 'soil' use fee for private wells, which averages US$ 2.03/ha/year.[25]

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23 The size of the *ejido* farms is atypical of a Mexican irrigation district in which most of these farms are no more than 10 ha large. Part of this is attributed to President Lazaro Cardenas who wanted to create prosperous "social" farmers when the Government expropriated lands from the Colorado River Land Company. Also, in 1942 the President General Manual Avila Camacho decided that the *ejido* parcels in the Mexicali Valley should be no less than 20 ha in size (larger than private owners'!).

24 From 1992 to 1994 low international cotton prices compelled many farmers to switch to winter wheat.

25 There are 236 private wells irrigating 18,271 hectares and 489 "federal" wells irrigating 53,100 hectares.

Estimated cost recovery for O&M during the 1994-1995 season was 61%. So far, these fees do not cover the cost of maintenance and repair of the system's deep tubewells. The canal system includes 470 kilometres of main canals, of which 74% is concrete lined; 2,432 kilometres of secondary canals, of which 77% is concrete lined; and 1,662 kilometres of open ditch drainage.

Due to its unique mix of surface and groundwater, as well as private and federal tubewells, a market for water-use concessions is relatively well developed in the Mexicali Valley. Indeed, water-use rights have been sold and leased without the accompanying land – a rare occurrence in Mexico. In 1994-95, prices for annual leases have ranged from US$ 100/ha to US$ 214/ha. Recorded leases during this season show 13,749 hectares leased to 'enterprises' and 46,702 to farmers. This amounts to an estimated 857.5 MCM of water transferred during the year.

In addition to irrigation water, the district delivers 100 MCM of water annually to the borderland cities and urban centres in north-western Sonora and northern Baja California, including Mexicali and Tijuana.[26] This water does not form part of the 1,850 MCM allocated to the district from the Colorado River, but is pumped from 67 deep wells located to the east of Irrigation District #014 at the Mesa de San Luis. Annual water yield from these wells should not exceed 197 MCM/year. By the year 2,000 however, the cities' annual water requirements are expected to reach 270 MCM. The future growth of Tijuana and the border area cities provides Mexico with a powerful motivation to initiate transfers of water from agricultural to urban uses. The scarcity of alternative water sources and the confined land area leaves the CNA with little opportunity for further catchment and delivery systems.

[26] Tijuana is a rapidly growing city with a 1990 population of 728,000.

IV. Conclusions & Observations

In many respects the 1992 Mexican *Federal Water Law* provides an excellent basis for improved and more flexible allocation of water. By giving user groups the opportunity to manage their own canal systems, the law allows for greater accountability of irrigation services to the farmers. And by giving individual users the freedom to buy, sell, or lease water-use concessions, the law provides a mechanism for water to move to more productive uses, while giving concession holders the security of water delivery. Furthermore, the law provides a balance between market forces and state control. The continued role of the federal government in water resources management, through the CNA and the underlying federal ownership of water, is ensured.

The Water Law gives the CNA broad discretionary powers to regulate transfers of concessions, restrict the use of water resources, renew concessions, and determine the parameters for protecting water quality. The CNA also has considerable power to restrict water-use (under Title Five of the Water Law), especially in times of emergency water shortages. These discretionary powers must be utilised with moderation and consistency, however, to avoid undermining the benefits of secure water-use concessions.

Three case studies shed light on the implementation of the 1992 *Federal Water Law* in three northern valleys, with special attention to water markets. Because two of these case studies featured water allocation problems during the third year of a three-year drought, it is relatively easy to criticise water managers. However, it is appropriate to assess water management during times of water scarcity. In both the Lagunera and the Río San Juan Irrigation Districts, centralised solutions to water scarcity problems were imposed at the expense of allowing individual actors with secure water-use rights to negotiate solutions among themselves.

In the Lagunera, the CNA chose to minimise conduction losses in secondary canals and to limit irrigation to only a few *módulos* near the main canals. Furthermore, cotton was selected as the only crop to be irrigated by the entire surface irrigation system. The avoided productivity losses from conduction losses may compensate for the cost of forcing farmers to move from their own un-irrigated land to the land that CNA chooses to irrigate. But the hidden cost of lost opportunities to develop alternative crops may be quite high and not fully considered during the centralised decision-making process.

The diversion of water from the Río San Juan Irrigation District to the city of Monterrey was initiated before the 1992 Water Law. This diversion is an important contribution to the growth of Monterrey and the economy of northern Mexico. But the reluctance of negotiators to fully compensate irrigators with either the same quantity of water as that diverted, or with improvements in their irrigation infrastructure, demonstrates that water-use concessions can be quite tentative. The future implementation of a system of wastewater re-use is a positive feature of this diversion, especially since wastewater re-use would be a difficult solution for independent actors to negotiate among themselves. However, the precedent that water can be diverted away from irrigation systems without full compensation threatens the security of water supply to all irrigators in Mexico.

One of the sources of insecure water supplies is the volumetric definition of water-use concessions. Unless a system of proportional reductions or well-defined priorities are in place, volumetric specifications are almost meaningless in times of water scarcity. Such a system may be in place when irrigation districts have firm bylaws on the allocation of water during droughts. But these systems need to be respected, as they are in the USA and in Chile, where systems of timed priorities and proportional reductions provide the owners of water-use rights the security that their share of water will be available. In Mexico, water scarcity allows the CNA to impose emergency command and control regulations which effectively eliminate the security of a water-use concession.

In order for water markets to effectively reallocate marginal amounts of water, systems to properly measure and divide flows are required. In irrigation systems that rely on a strict rotation system transfers of water present a particular challenge. In Mexican systems, where irrigation turns are not strictly measured by periods of time, the simple trades of hours of irrigation, as practised in South Asian *warabundi* systems, can not be implemented. Furthermore, in irrigation systems where conduction losses require water managers to restrict the land area to be irrigated in times of drought, the free movement of water is severely restricted. In order for the full advantages of water markets to be present in Mexico, additional investment in both the capacity of users/canal managers and canal infrastructure may be needed.

Because the benefits from transfers of concessions from an irrigation district to an outside user are reserved for the district, the potential for intersectoral transfers of water are limited. Such intersectoral transfers may be limited to the type of transfer that was made between the city of Los Angeles and the Imperial Irrigation District of California. In this trade the city received water-use rights but compensated the irrigation district by agreeing to pay for improvements in the water delivery system. Although this type of transfer limits the incentives received by individual farmers, it does provide an opportunity for a mutually beneficial transfer (Easter and Hearne 1995, Rosin and Sexton 1993). In the case studies presented, transfers of irrigation water to municipal and industrial users, with compensation in the form of improved irrigation technology, could prove to be beneficial to all parties.

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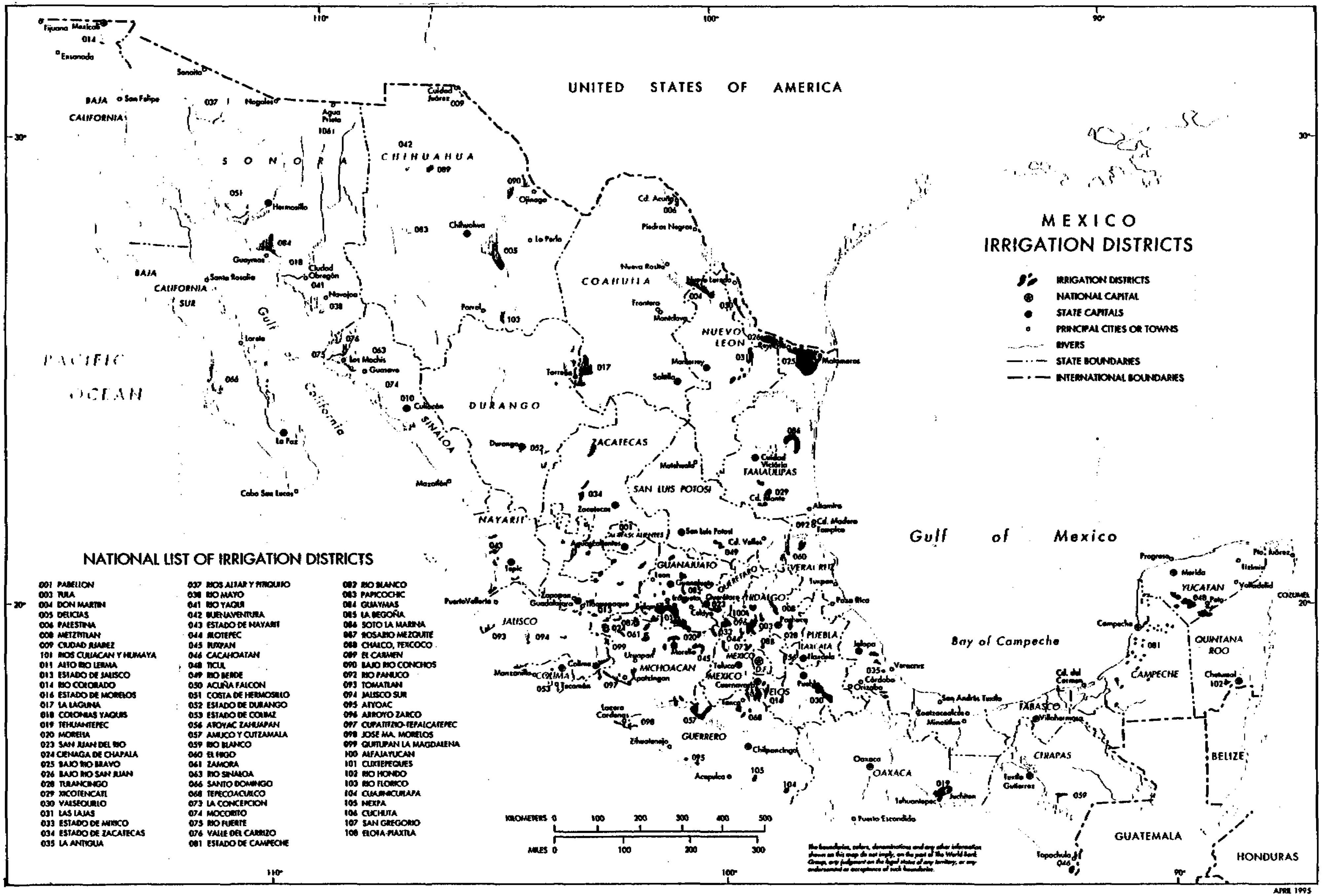
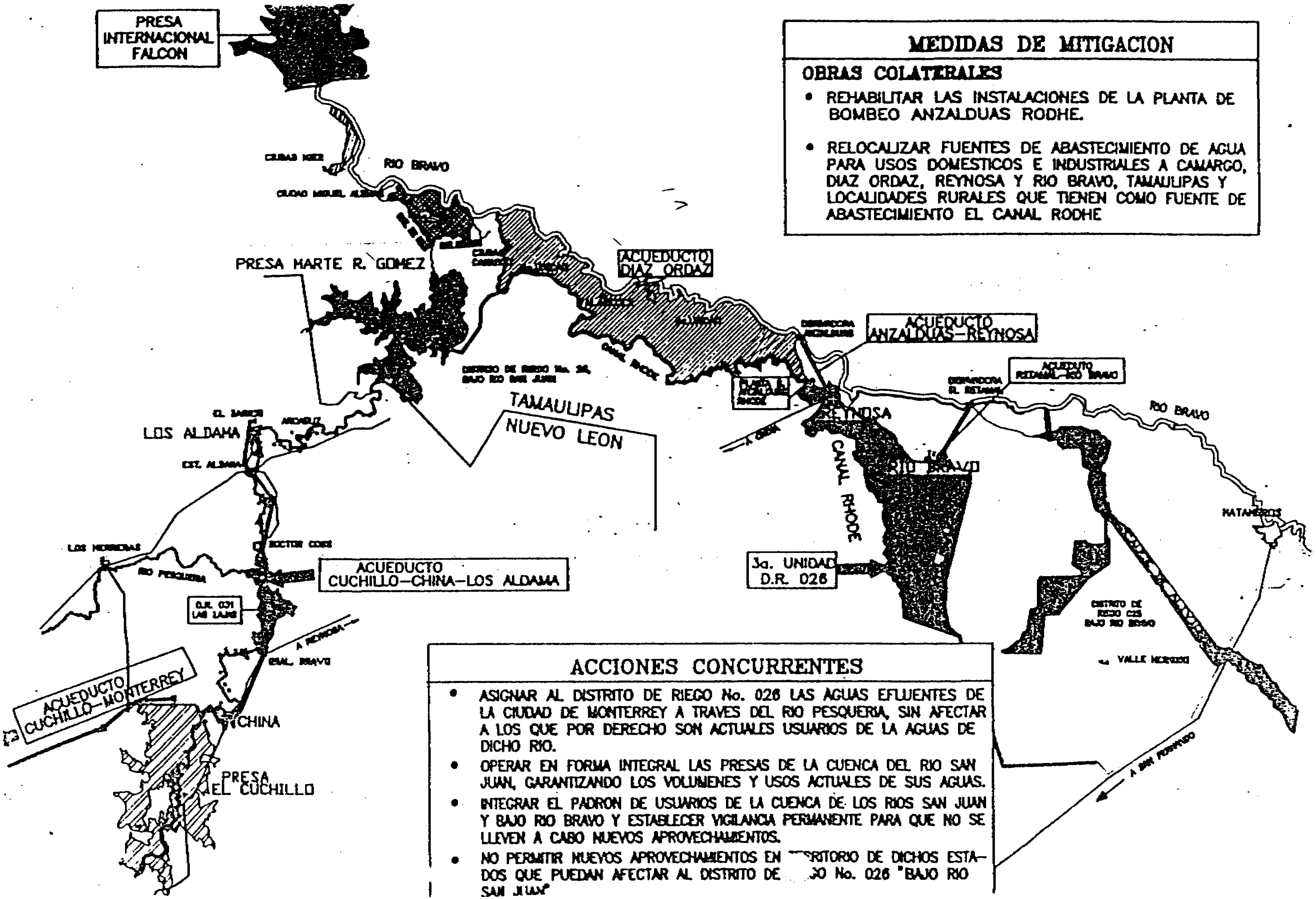
VI. Appendix

List of Maps

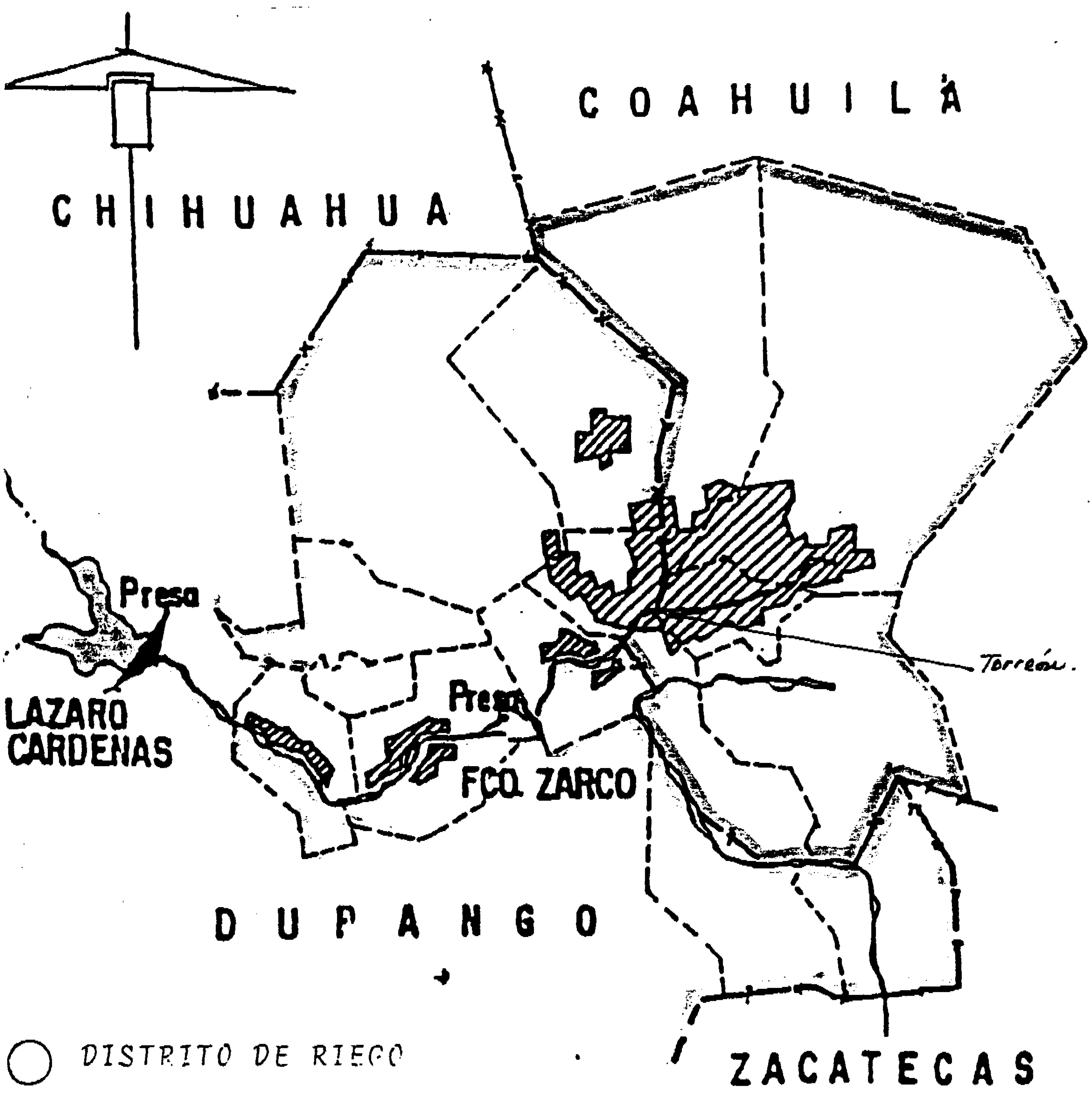
Map 1: Irrigation Districts in Mexico



Map 2: Lower San Juan Irrigation District and San Juan River Dams



Map 3: Lagunera Region and Irrigation District



Map 4: The Mexicali Valley

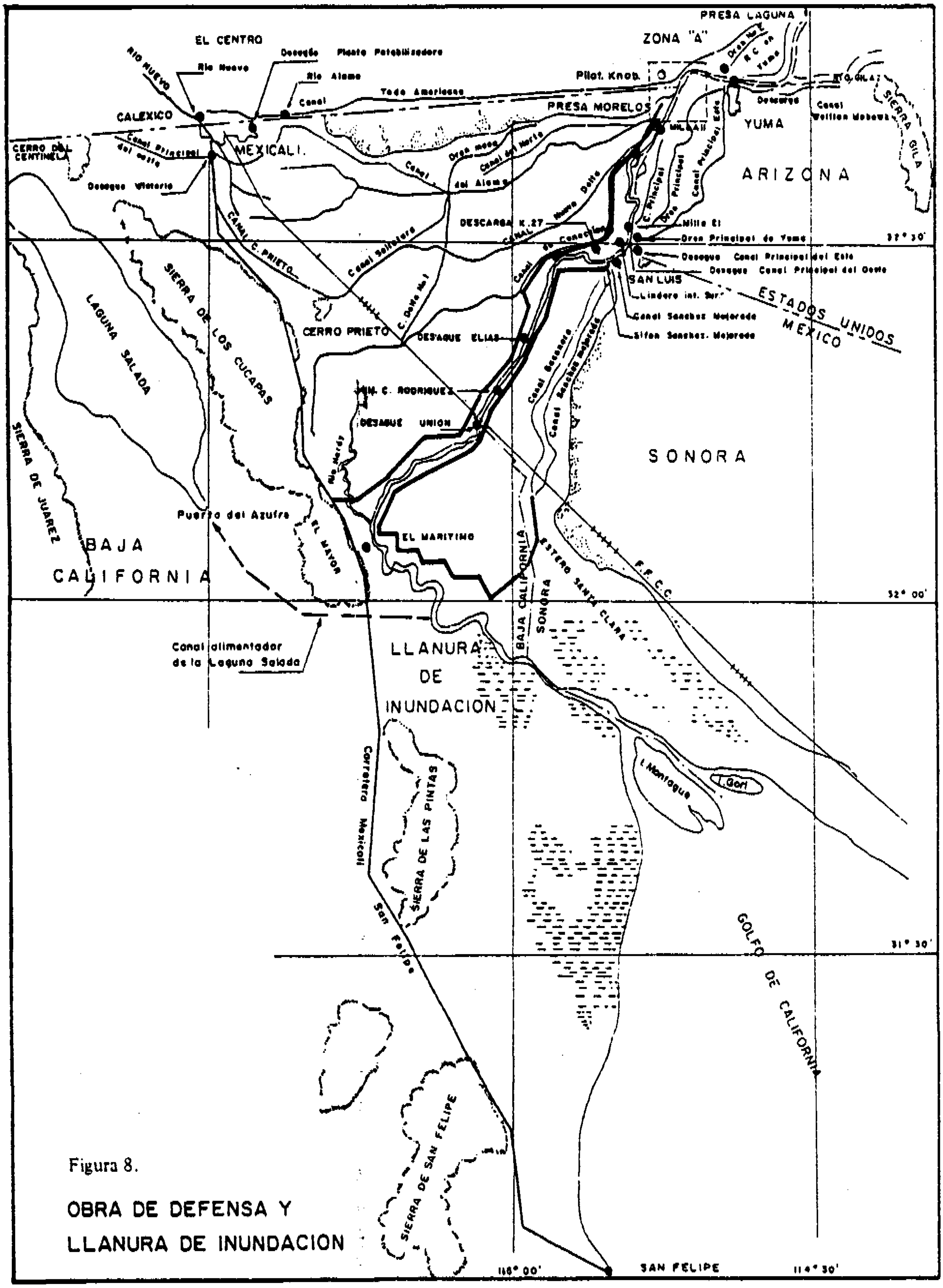


Figura 8.

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Edward B. Barbier, Joanne C. Burgess, Timothy M. Swanson and David W. Pearce

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Earthscan, London, 1990. £10.95

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Sustainable Development: Economics and Environment in the Third World
David W. Pearce, Edward B. Barbier and Anil Markandya

The authors elaborate on the concept of sustainable development and illustrate how environmental economics can be applied to the developing world. Beginning with an overview of the concept of sustainable development, the authors indicate its implications for discounting and economic appraisal. Case studies on natural resource economics and management issues are drawn from Indonesia, Sudan, Botswana, Nepal and the Amazon.
Earthscan, London, 1990. £11.95

Blueprint 2: Greening the World Economy
David W. Pearce, Edward B. Barbier, Anil Markandya, Scott Barrett, R. Kerry Turner and Timothy M. Swanson

Following the success of *Blueprint for a Green Economy*, LEEC has turned its attention to global environmental threats. The book reviews the role of economics in analysing global resources such as climate, ozone and biodiversity, and considers economic policy options to address such problems as global climate change, ozone depletion and tropical deforestation.
Earthscan, London, 1991. £9.95

Economics for the Wilds: Wildlife, Wildlands, Diversity and Development
E.B. Barbier and T.M Swanson (eds.)

This collection of essays addresses the key issues of the economic role of natural habitat and wildlife utilization in development. The book argues that this role is significant, and composes such benefits as wildlife and wildland products, ecotourism, community-based wildlife development, environmental services and the conservation of biodiversity.
Earthscan, London, 1992. £12.95

The Economics of the Tropical Timber Trade
Edward B Barbier, Joanne C Burgess, Joshua Bishop and Bruce Aylward

This book is based on a major study of the economic linkages between the trade in tropical timber products and sustainable forest management prepared for the International Tropical Timber Organisation by the London Environmental Economics Centre. It examines current and future market conditions in the tropical timber trade, the linkages between trade and tropical deforestation, and the role of trade and forest sector policies in encouraging sustainable forest management. Through the use of extensive case studies and empirical evidence the authors argue that, although the timber trade is not the major source of tropical deforestation, policy distortions encourage excessive timber related deforestation whilst discouraging sustainable management. The book concludes by examining the necessary international policy measures required to improve the role of the timber trade in sustaining tropical production forests.
Earthscan, London, 1992. £13.95

Beer and Baskets: The Economics of Women's Livelihoods in Ngamiland, Botswana
Compiled by Joshua Bishop and Ian Scoones

This report examines the economics of basket making and beer production in two sites on the western edge of the Okavango delta in Ngamiland, Botswana. Using Participatory Rural Appraisal methods, the study focused on the priority concerns expressed by villagers and explored women's use of wild species. Income generating activities based on the use of wild resources were situated and evaluated in a total livelihood context. Based on this analysis, options for resource conservation and management are then identified. The work forms part of the research project *The Hidden Harvest: The value of wild resources in agricultural systems*, conducted jointly by the Sustainable Agriculture and Environmental Economics Programmes of IIED.
IIED 1994. £5.00

Whose Eden?: An Overview of Community Approaches to Wildlife Management
A report by IIED to the UK Overseas Development Administration.

This report challenges the traditional practice of separating the management and conservation of wildlife from the livelihood of local communities. It shows there is a growing recognition that a community's rights to ownership and tenure of wildlife resources is integral to sustainable wildlife management. Wildlife management will only be sustainable ecologically, socially and economically if it can be made sufficiently attractive to local communities for them to adopt the practice as a long-term livelihood strategy.
IIED 1994. £14.95

Economic Evaluation of Tropical Forest Land Use Options: A Review of Methodology and Applications.
A draft Report prepared for the UK Overseas Development Administration

Rapid deforestation in the tropics and increasing public concern about the social and environmental consequences of land use changes have created demand for methods to evaluate alternative land use options in a way that reflects social and environmental impacts, as well as economic costs and benefits. This report reviews a wide range of methods which may be used to carry out a comprehensive assessment of the economic, environmental and distributional consequences of alternative tropical forest land use options, including copious examples from recent empirical studies.
Environmental Economics Programme, 1994. £10.20

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