Managing the Water Transition in the Lerma-Chapala Basin, Mexico

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Abstract

The Lerma-Chapala basin in central Mexico, with a catchment area of some 54,300 km² and serving a population of over 15 million, is one of the most over-committed basins in the world. Its total water depletion exceeds annual renewable water by 10% on average. To counter this over-exploitation several institutional innovations have occurred in the basin, while water reforms at the national level have also significantly altered the arrangements for water management in the basin. These changes reflect the adaptive capacity of Mexico to manage the transition from supply to demand management. This paper analyses this transition through assessing the effectiveness of the institutional arrangements for water management in the Lerma-Chapala basin in addressing the negative impacts of basin closure. Special attention is paid to stakeholder participation in the Lerma-Chapala River Basin Council and basin-wide water allocation mechanisms. The analysis shows that, while basin level co-ordination mechanisms are clearly necessary, and promising progress has been made, more drastic changes are needed to ensure sustainable water management. In particular, access to water by poor farmers needs to be safeguarded, the overdraft of the basin's aquifers remedied, user representation in basin-level decision-making improved and mechanisms for compensating farmers for the transfer of water out of the agricultural sector drawn up. Lastly, decision-making power and control over financial resources need to be further decentralised to the basin and state levels to enable sustainable water management.

1. Introduction

The recognition that effective water management requires a basin perspective is long-standing and widespread. Especially in closing[1] river basins, where increasing water over-exploitation results in a complex interplay among declines in water quality,

[1]Seckler (1996) coined this term to characterise river basins with no utilisable outflows, i.e. where the use of water that renders it unavailable for further use is approaching or equal to the level of annual renewable water. This definition differs from the hydrologic definition of a closed basin, where there are outflows but these go only to internal seas, lakes or other sinks.

increasing water over-exploitation results in a complex interplay among declines in water quality, intersectoral water transfers, threats to human health, inequitable water allocation and reduced access to water by poor people, the need for effective institutional arrangements is urgent (Vermillion and Merrey 1998). In this regard, Turton and Ohlsson (2000) posit that water scarcity per se is not the key issue, but rather whether a society has the adaptive capacity to cope with the challenges water scarcity poses. They argue that two institutional transitions (need to) occur in the water sector as water becomes more scarce: the first when water abundance turns to water shortage and the second when water shortage turns to water over-exploitation.

The first transition, which occurs when water demand due to population growth overtakes the readily available supply of water, triggers the construction of significant hydraulic infrastructure, usually by the government, to mobilise more water. Reisner (1993) terms this transition to water supply development the birth of the hydraulic mission, embodied in a central government agency consisting of engineers. Whereas before water was controlled locally, after the first transition its development and management becomes highly centralised. During this phase river-basin development is important and one would typically expect to find river-basin authorities.

The supply-oriented phase runs up against a barrier when river basins close, i.e. when water demand continues to outstrip supply even though all available water sources have been developed or are prohibitively expensive to develop. This induces increased competition between water use sectors and calls for a different approach to managing water. However, making the second water transition, from supply-oriented development to water demand management, requires substantial changes in institutional arrangements for water management, possibly including the creation of river basin councils. Under favourable socio-economic and political conditions this transition can be made, resulting in a stabilisation of water demand and the birth of sustainable water management. However, this transition is not automatic and whether and how well it occurs is a function of the adaptive capacity of a society.

The need to make the water transition in the Lerma-Chapala basin is urgent. This basin in central Mexico has reached a crisis point, with total water depletion exceeding supply by 10 percent on average. Unchecked groundwater pumping has produced declines in aquifer levels of 2.1 m/year (Scott and Garcés-Restrepo 2000), while surface water depletion exceeds supply in all but the wettest years, as a result of which Lake Chapala, the receiving water body of the basin, is drying up. In addition, water is being transferred from the agricultural to the urban and industrial sectors, without due compensation to farmers. Lastly, water pollution is serious with significant wastewater reuse for irrigation within the basin (Scott et al. 2000).

In response to the deterioration in the basin's water resource base, several institutional innovations have occurred in the basin since 1989, including the signing of a river basin co-ordination agreement (1989), the creation of a river basin council (1993) and the establishment of aquifer management councils (1995–onwards). Water reforms at the national level, such as the creation of a national water agency in 1989, the transfer of government irrigation districts to users (1991–present) and the promulgation of a new water law in 1992, have also significantly altered institutional arrangements for water management in the basin. These reforms are strongly interrelated and constitute Mexico's attempt to manage the water transition.

This paper partially assesses the effectiveness of these changes in dealing with basin closure in the Lerma-Chapala basin. The rationale of this assessment is to explore the types of institutional arrangements needed to manage the water transition at the basin level. The next section presents a basin water balance and introduces the water management stakeholders in the basin. This brief basin profile provides the backdrop for the description of the institutional arrangements in the basin in the third section, which also assesses stakeholder participation and the representation of interests in the river basin council. The key challenges facing the basin, namely surface and groundwater allocation mechanisms and the representation of interests are reviewed in the final section, followed by conclusions.

2. The Lerma-Chapala basin: water balance and stakeholders

2.1 Water balance

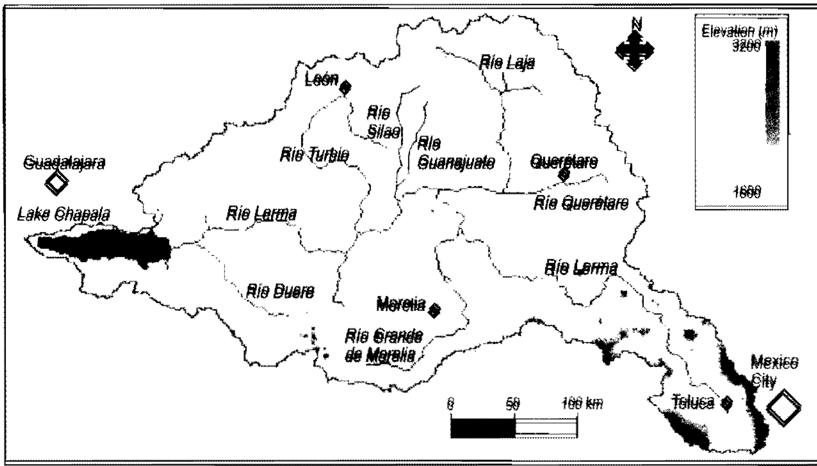
The Lerma-Chapala basin covers some 54,300 km^2 and crosses five states: Querétaro (5%), Guanajuato (44%), Michoacán (28%), Mexico (10%) and Jalisco (13%). The basin is home to a dynamic agricultural sector and a rapidly growing industrial sector, and accounts for 9 percent of Mexico's GNP. It is the source of water for around 15 million people (11 million in the basin and 2 million each in Guadalajara and Mexico City) and contains 13 percent of the irrigated area in the country. The average annual runoff in the basin from 1940 to 1995 was 5,757 million cubic meters (MCM), a little over one percent of Mexico's total runoff (CNA 1999a).

The headwaters of the Río Lerma rise in the east of the basin near the city of Toluca at an elevation of 2600 m above sea level to discharge into Lake Chapala in the west at an elevation of 1,500 m.a.s.l. The total length of the Río Lerma is 750 km and eight major tributaries discharge into it. Lake Chapala, with a length of 77 km and a width of 23 km, is Mexico's largest natural lake and at full capacity stores 8,125 MCM and covers 111,000 ha. The shallow depth of the lake (7.2 m) results in the loss of a large percentage of its storage to evaporation each year[2]. At times of high water levels Lake Chapala discharges into the Santiago River, which flows in a north-westerly direction and then drops to the Pacific Ocean after 524 km. The topography and stream network of the basin are shown in Figure 1, which was derived from the DEM at 30-sec resolution issued by the United States Geological Survey (USGS).

The climate in the basin is semi-arid to sub-humid, with 90 percent of the rains falling between May and October. Rainfall is highly variable, with an average annual rainfall over the 1945–1997 period of 712 mm, and a minimum of 494 mm in 1999 and a maximum of 1,022 mm in 1958 (CNA 1999e). Average monthly temperatures vary

[2]On a scale of 1:10,000 the dimensions of the lake are 7.7 m by 2.3 m and less than 1 mm deep.

Figure 1: Topography and stream network of the Lerma-Chapala basin



from 14.6°C in January to 21.3°C in May, thus a range of crops can be grown throughout the year. The potential evapotranspiration mirrors the temperature variation, with a peak in April/May, and an annual total of some 1,900 mm. In every month except July and August there is a net deficit between rainfall and evapotranspiration, indicating the importance of irrigation for agricultural production in the basin.

A total of 40 aquifers, largely interconnected, have been identified in the basin (CNA/MW 1999). Up to depths of over a hundred meters from the surface, the aquifers are composed of alluvial and lacustrine materials while the lower layers, several hundred meters in depth, are composed primarily of basaltic rocks and rhyolite tuff (Chávez 1998). The aquifers are recharged through rainfall infiltration, surface run-off, and importantly deep percolation from surface irrigation. Various sources report wildly different data on annual extraction and recharge rates, making it hard to portray with any precision the groundwater situation in the basin. What is clear is that 30 of the 40 aquifers are in deficit and falling fast, at 2.1 m/year on average (Scott and Garcés-Restrepo 2000). The most recent data from CAN (National Water Commission) indicate that average annual recharge is 3,980 MCM, while average annual extractions are placed at 4,621 MCM giving a deficit of 641 MCM per year (CNA 1999a).

Table 1 presents current average consumptive water use for different sectors in the basin compared to average annual renewable water, showing a deficit of 900 MCM. The percentage of available water that is developed and put to use in the

Table 1: Water balance of the Lerma-Chapala basin

	Surface Water		Groundwater		Total	
	MCM	%	MCM	%	MCM	%
Agriculture	3,424	57	3,160	68	6,584	62
Urban	40	>1	751	16	791	7
Out-of-Basin Transfer	237	4	323	7	560	5
Industry	39	>1	239	5	278	3
Other	6	>1	148	3	154	2
Total Consumptive Use	3,746	62	4,621	100	8,367	79
Lake Evaporation	2,270	38	-	-	2,270	21
Total Depletion	6,016	100	4,621	100	10,637	100
Runoff / Recharge	5,757	96	3,980	86	9,737	91
Balance	-259	-4	-641	- 14	-900	- 9

Source: CNA 1999a

basin is 110 percent[3], showing its degree of over-commitment. The out-of-basin transfers are to Guadalajara (surface water) and Mexico City (groundwater) for urban water supply.

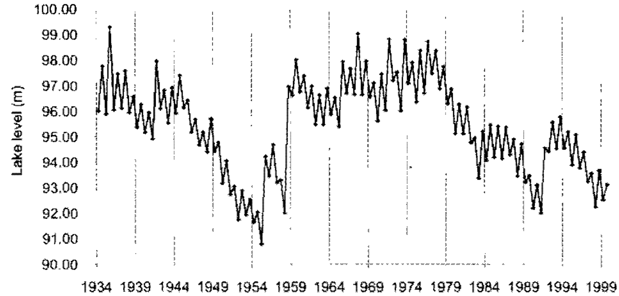
To portray basin closure in the Lerma-Chapala basin it is instructive to analyse fluctuations in the water levels of Lake Chapala. Figure 2 shows these fluctuations from 1934 to 1999 and relates them to developments in the basin. Starting in 1945, water levels in the lake declined sharply, from around 97 m[4] on average to 90.8 m in 1954, due to a drought combined with significant abstractions from the lake. At this time around 250,000 ha were irrigated, mainly with surface water, and the constructed storage capacity in the basin was 1,817 MCM. This period was the first time the basin headed towards closure as far as surface water is concerned. However, thanks to good rains towards the end of the 1950s, the lake recuperated, and levels fluctuated between 95.5 m and 98.5 m from 1960 to 1979.

In 1979 a second period of decline set in leading to basin closure in the mid-1980s. Constructed storage capacity in the basin had increased to 4,499 MCM and the average irrigated area had grown to around 650,000 ha, with a significant increase in groundwater irrigation. Even though abstractions from the lake for hydroelectricity had ceased, the combination of these factors resulted in declines of the lake level, from around 95 m at the start of 1980 to 92 m in 1990. After a modest recuperation in the early 1990s, lake levels in October 2000 are at their lowest since 1954, due to continued over-exploitation of surface and groundwater. It is unlikely that the lake will recover without exceptional runoff as generated through a major hurricane.

[3]This basin water exploitation indicator is arrived at by dividing total depletion (process and non-process) by annual renewable water (see Seckler et al. 1998 and Molden 1997).

[4]A locally defined benchmark where 100 m is defined as the high shoreline. (de Anda et al. 1998)

Figure 2: Lake Chapala water levels and basin developments



Rainfall (mm)[1]	670	648	685	757	740	668	720
Population (millions)[2]	2.5	3.0	3.6	4.5	5.9	8.7	11.0
Storage Capacity Dams (MCM)[3]	747	1,628	1,817	3,269	3,840	4,499	4,499
Irrigation (ha)[4]	n.a.	175,843	250,500	408,746	681,668	657,734	689,743
Lake Inflow from Lerma (MCM)[5]	2,864	1,652	1,692	1,773	1,931	590	n.a.
Lake Extractions (MCM)[5]	2,638	1,049	674	1,350	1,817	309	293

Sources for lake levels: de P. Sandoval (1994) and CNA (1991–1999b)

(1) Decade average from de P. Sandoval (1994) for 1934-1949 and CNA/MW (1999) for 1950–1999.

(2) Population data for the end of the decade. Sources: de P. Sandoval (1994) for estimates for 1939, 1949, 1959, 1969 and 1979 and CNA/MW (1999) for actual figures for 1989 and 1999.

(3) Constructed storage capacity at end of decade. Source: de P. Sandoval (1994) and CNA (1999e).

(4) Average actual irrigated area over the decade. Source: CNA (1999e).

(5) Decade average, excluding evaporation from de P. Sandoval (1994) and CNA (1991, 1992, 1993a, 1994, 1995, 1996, 1997, 1998, 1999b).

2.2 Major users of water

2.2.1 Irrigated agriculture

The main water user in the basin is irrigated agriculture, causing 57 percent of the total depletion of surface water and 68 percent of the total depletion of groundwater (see Table 1). Eleven large-scale canal irrigation systems (termed irrigation districts in Mexico) command around 285,000 ha and some 16,000 farmer-managed and private irrigation systems (termed *unidades de riego* in Mexico) cover 510,000 ha. Twenty-seven reservoirs with a storage capacity of 2,500 MCM provide 235,000 ha in the irrigation districts with surface water while around 1,500 smaller reservoirs serve 180,000 ha in the *unidades*. An estimated 17,500 deep tubewells provide around 380,000 ha in the basin with groundwater, of which 47,000 ha is located in irrigation districts (CNA 1993b; CNA/MW 1999).

There are an estimated 88,000 water users (70,000 *ejidatarios*[5] and 18,000 *pequeños propietarios*[6]) in the irrigation districts, and 100,000 water users (84,000 *ejidatarios* and 16,000 *pequeños propietarios*) in the *unidades* (CNA/MW 1999). Data on cropping patterns and productivity for the whole basin are not available, although studies on parts of the basin or selected irrigation systems are available (e.g. Flores-López and Scott 2000; Kloezen and Garcés Restrepo 1998; Silva-Ochao 2000).

In the early 1990s the Mexican government transferred the government-managed irrigation districts to Water Users' Associations (WUAs) to reduce public expenditure on irrigation (Espinosa-de León and Trava 1992; Trava 1994; Gorriz et al. 1995; Johnson 1997a). In the Lerma-Chapala basin 10 irrigation districts were transferred, after a comprehensive social mobilisation campaign, to WUAs, who now manage secondary canal units varying in size from 1,500 to 30,000 ha. The WUAs were formed as legally recognised non-profit associations to whom CNA granted concessions for the use of water and the irrigation infrastructure, for periods ranging from 5 to 50 years.

In all the districts CNA continues to manage the dams, headworks and main canals and delivers water in bulk to the WUAs, except in the Alto Río Lerma irrigation district where a federation of WUAs has been formed to manage the main system (Kloezen 2000). Although user involvement in irrigation management has increased, at the same time the state's control over water was reasserted through IMT. This is apparent from the new water law, which reaffirms federal control over the nation's waters as well as the irrigation infrastructure and makes CNA ultimately responsible for the management of the irrigation districts.

[5]*Ejidatarios* are members of *ejidos*, land reform communities created after the Mexican Revolution of 1910. Land holdings per *ejidatario* are typically less than 5 ha.

[6]*Pequeños propietarios* are private farmers with a limit on land ownership of 100 ha; however, holdings may be managed in much larger blocks, with nominal ownership in the hands of family members, friends and others.

The management structures in the *unidades* are much more diverse, and may consist of informal WUAs, government recognised WUAs, water judges, pump groups or commercial management. As state intervention in the *unidades* has been piecemeal in comparison to the districts and has usually only consisted of assistance in construction and the granting of water rights, their representation in formal decision-making forums is weak. In the case of groundwater *unidades* this is changing, with the recent creation of *Consejos Técnicos de Aguas* (COTAS; aquifer management councils) in 17 aquifers. These COTAS are to serve as forums for reaching agreement on aquifer management, taking into consideration the needs of the different sectors using groundwater.

2.2.2 Urban water supply

Domestic water supply in the basin depends mainly on groundwater (95%), with total consumptive use standing at 791 MCM. In addition, water is transferred out of the basin to provide Guadalajara (237 MCM surface water) and Mexico City (323 MCM groundwater) with urban water. The population in the basin has increased significantly, doubling from 2.1 million inhabitants in 1930 to 4.5 million in 1970 and then more then doubling in the next 30 years to 11 million in 2000 (CNA/MW 1999). During this period Mexico's population grew from 16.6 million to 100.6 million. The population's annual growth rate in the basin between 1990 and 1995 was 2.16 percent, implying that the basin's population will double in around 30 years if this rate remains the same (CNA/MW 1999). Besides a five-fold increase in the population in the past 70 years, the basin's population has become strongly urbanised. Population in the seven largest cities in the basin increased from 267,197 in 1930 to 4,500,643 in 2000 (CNA/MW 1999). Understandably, population growth has led to increasing pressures on the basin's water resources. Scott et al. (forthcoming) project that urban water demand in the medium term will increase by some 4.1 percent per year.

Starting in 1983 domestic water supply, wastewater collection and more recently wastewater treatment were decentralised to the municipalities. The creation of water utilities has been promoted, to separate these activities from other municipal responsibilities. However, according to CNA (1999d: 8) "most of the water utilities have a poor performance and need to be greatly improved to achieve technical and economical sufficiency."

2.2.3 Industry

Although industry only uses a small amount of the basin's water (278 MCM or 3 percent of consumptive use) it generates 35 percent of Mexico's industrial GNP and pays around $42 million in water taxes to the federal government (CNA/MW 1999). The 6,400 registered industrial firms in the basin are still a major source of water pollution (figures are not available), although officially they must have a permit from CNA indicating effluent standards to discharge wastewater.

3. Institutional arrangements for water management in the Lerma-Chapala basin

A watershed year for water management in Mexico was 1989. Whereas the previous 100 years were characterised by increasing federal control over water, since 1989 decentralisation has been the norm. Currently states, municipalities and water users have a much larger say in water management decision-making. These changes are all part of the transition from supply to demand management in the Mexican water sector and the reconfiguration of the relationships between water users and the three levels of government (federal, state and municipal). In this regard, two aspects of how Mexico is structured as a country are important, namely that it is a highly centralised federation[7] and that surface water is defined in the Constitution as national property, placed in the trust of the federal government.

3.1 Water rights

In Mexico the federal government, as the holder of water property rights, has the right to grant surface water-use rights as concessions to users (Kloezen 1998). The concession titles set out the quantity of surface water a user is entitled to, although in practice the actual quantity a user receives may be adjusted annually to reflect water availability, with priority accorded to domestic water use (CNA, 1999c). Thus, for allocating surface water Mexico follows the proportional appropriation doctrine and in theory all concession holders share proportionally in any shortages or surpluses of water.[8]

The situation surrounding groundwater is more complex, as the Constitution does not define it as national property, but rather states that overlying landowners may bring groundwater to the surface as long as this does not affect other users. In 1946 the Constitution was amended to the effect that the federal government can intervene in aquifers in overdraft, by issuing pump permits or declaring that new pumps may not be installed. Based on a ruling of the Supreme Court in 1983 groundwater is now considered national property, although this is not reflected in the Constitution or the 1992 water law (Palacios-Vélez and Martínez 1999). Groundwater concessions in Mexico are granted on a volumetric basis with a maximum extraction or pumping rate specified (and limited by electrical power transformer capacity).

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[7]Mexico is a federation composed of 31 states and a Federal District. Each state is subdivided into municipalities, has its own constitution and laws as well as a governor who serves as the highest executive authority. The co-ordination of federal and state affairs is achieved through federal legislation and by compacts. Concerning water, the federal government may enter into co-ordination agreements with the states in order for them to take on specific responsibilities.

[8]This contrasts with the prior appropriation system, where first rights have seniority implying that water rights issued later are the first to be curtailed in times of shortage.

Once issued, water concessions need to be registered in the *Registro Publico de Derechos de Agua* (REPDA; Public Registry of Water Rights), maintained by CNA. After registration the concessions become fully tradable within river basins, although the CNA needs to be notified of the trade and needs to approve it (Kloezen, 1998).

3.2 Water management organisations and stakeholders

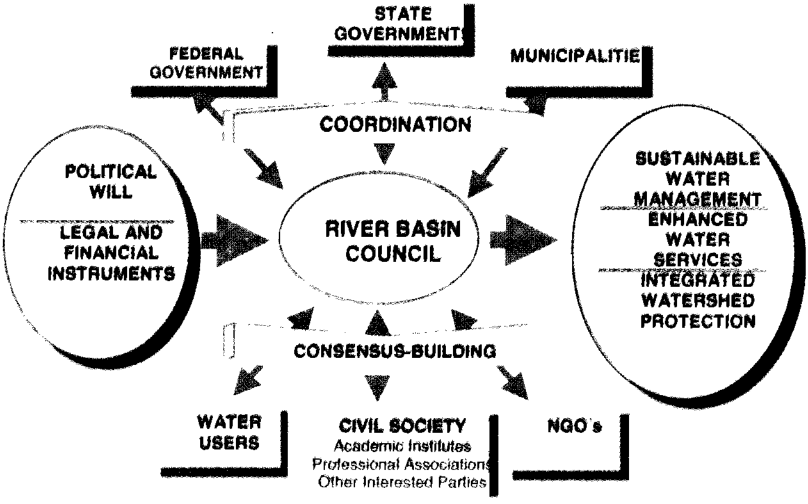
In the Lerma-Chapala basin a wide array of organisations and stakeholders are involved in water management, of which the major ones are described below. The government agency responsible for water management in the basin is the CNA. Created in January 1989 the CNA is a semi-autonomous federal agency charged with defining water policy, granting water concessions and wastewater discharge permits, establishing norms for water use and water quality and integrating regional and national water management plans.

The role of states in the water sector has been limited to regulating the municipal water utilities and supporting those utilities which show poor technical and economic performance. State legislation regulates the domestic water industry, establishes the basis for the creation of water utilities and sets the rules for determining water tariffs. As part of the "new federalism" policy during the Zedillo administration (1995–2000), the federal government promoted the delegation of water sector responsibilities and programmes to the states, but notably not financial resources. Although the federal government has encouraged the modification of state laws to promote the participation of state governments in all water sector activities through the creation of State Water Commissions, the response has been lukewarm. This is not the case in the state of Guanajuato, where CEAG (*Comisión Estatal del Agua de Guanajuato*; Guanajuato State Water Commission) has taken on its new role with vigour.

The official aim of unifying all government responsibilities related to water in the CNA was to create the necessary conditions for moving towards sustainable water management (CNA, 1999d). To complement this move a modern and comprehensive water law was promulgated in 1992. This law defines an integral approach for managing surface and groundwater in the context of river basins, which it considers as the ideal geographical unit for the planning, development and management of water. It also promotes decentralisation, stakeholder participation, better control over water withdrawals and wastewater discharges, and full-cost pricing.

A key provision of the 1992 water law is the stipulation that stakeholder participation is mandatory in water management at the river basin level. To this end river basin councils, which are forums where federal, state and municipal governments as well as water user representatives share the responsibility for allocating water resources and fostering integral water management at the basin level, have been established in 26 river basins. The government's philosophy behind the river basin councils, detailed in the 1992 water law, is that they are to be co-ordination and consensus-building bodies, as shown in Figure 3. In addition, the CNA has divided the country into 13 hydrologic regions and established an office in each region to improve river basin planning and the interaction with stakeholders.

Figure 3: The philosophy behind river basin councils in Mexico



Mexico's first river basin council was established in the Lerma-Chapala basin, in response to the drying up of Lake Chapala in the 1980s, combined with the severe contamination of the Lerma River. It was clear that something had to be done to preserve Lake Chapala, which generates significant tourism revenues and supplies two million inhabitants of Guadalajara with domestic water. In addition, its symbolic value as Mexico's largest natural lake is high. According to Mestre (1997:144):

> *"A wide-ranging water diagnosis existing by mid 1989 clearly presented four capital problems in the Lerma River basin: scarcity, as well as unsuitable water allocation, pollution, inefficiency of water use, and environmental depredation. To turn the tide, it became clear that it would be insufficient and imprudent to maintain that the federal government was solely responsible for this chaos and for its solution or mitigation."*

Hence, the federal government and the governments of the five states falling in the river basin signed an agreement in Chapala on 13 April 1989, adopting four main objectives to improve water management in the basin:

- Allocate surface and groundwater fairly among users and regulate its use;
- Improve water quality by treating municipal and industrial effluents;

- Increase water-use efficiency; and
- Conserve the river basin ecosystem and protect watersheds.

On 1 September 1989 a formal Consultative Council was formed to follow up on these objectives. Based on the 1992 water law the Consultative Council became the Lerma-Chapala River Basin Council on 28 January 1993. A challenge for the River Basin Council has been ensuring effective user representation—critical in the consensus building and co-ordination role envisioned in the law. Until the end of 1998, the Council was very top heavy: its president was the federal minister of agriculture until 1995 and the federal minister of the environment from 1995 to 1998, while its members were the governors of the five states making up the basin, the federal ministers of five key ministries and the Directors General of CFE, PEMEX and CNA. It is evident from this choice of institutional design that control over water and financial resources was a driving force in the inter-agency alignments within the basin. In 1998 this changed, with user representatives from six different sectors (agriculture, fisheries, services, industry, livestock and urban) being appointed to the Council. Also, the Director General of the CNA became the president of the Council, while the remaining members are the five state governors.

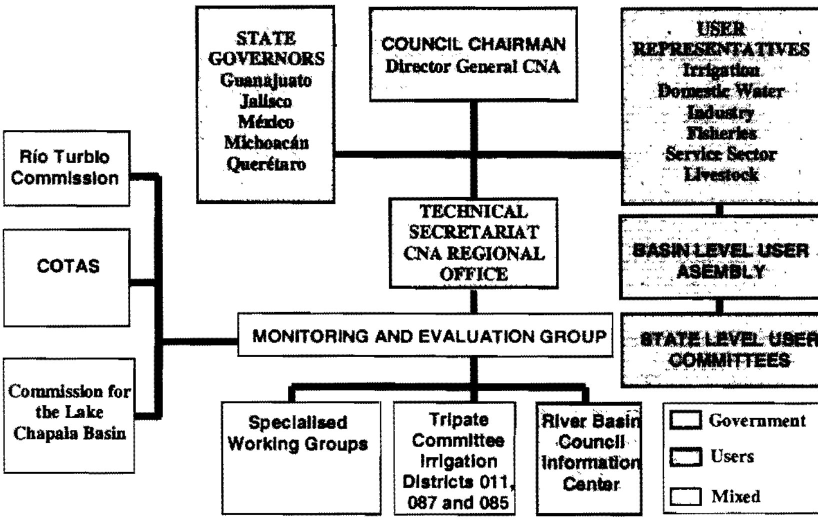
This change was based on a modification in 1997 of the water law and its regulations, to allow for larger representation of users. However, the users on the Council have been nominated by CNA, and do not necessarily reflect the interests of the water use sector they represent. To rectify this, CNA is currently working to establish a stepped form of user representation consisting of user committees in each state of the basin for each of the six water use sectors represented on the Council, giving a total of 36 user committees. These committees will each vote for a representative to sit in the user assembly at the basin level, which in turn will elect the six user representatives on the Council. In addition, forums at the sub-basin level, such as Commissions and COTAS complement the Council (see Figure 4).

As part of the process of strengthening stakeholder participation in the River Basin Council a participatory planning process was started in the Lerma-Chapala basin in 1998, based on the hypothesis that local stakeholders have a better understanding of the problems within the region and will play a decisive role in plan implementation. To mobilise stakeholders and build consensus, the CNA organised 15 workshops in the Lerma-Chapala basin, attended by 160 user representatives and 33 representatives of civil society (NGOs, research institutes, etc).

4. Over-arching issues

Through the Lerma-Chapala River Basin Council, promising progress has been made towards improved water management in the basin. This progress is remarkable, in light of the complicated transition from highly centralised water management to one in which states, municipalities and water users have a larger say. Nonetheless, from a water perspective the Lerma-Chapala basin is still in crisis and time is running out. The efforts of the council in the past 10 years need to be redoubled to tackle the significant challenges lying ahead of it. Three challenges stand out, namely surface and groundwater allocation and the representation of interests in the council.

Figure 4: Structure of the Lerma-Chapala River Basin Council



4.1 Surface water allocation

To allocate surface water fairly among users in the basin, the governors of the five states in the basin and the federal government signed a treaty in August 1991 (CCCLC, 1991). An important objective of the treaty is to maintain adequate water levels in Lake Chapala and to ensure Guadalajara's domestic water supply. To preserve Lake Chapala the treaty sets out three allocation policies, namely critical, average and abundant, based on the volume of water in the lake (less than 3,300 MCM, from 3,300 to 6,000 MCM and more than 6,000 MCM, respectively). Each year the council verifies the volume stored in Lake Chapala to determine the allocation policy to be followed for the next year. For each allocation policy, formulas have been drawn up to calculate allocations to the irrigation systems in the basin, based on the surface runoff generated in each of the five states in the previous year. Table 2 indicates how this works for the Alto Río Lerma irrigation district. Based on extensive modelling of these formulas it was concluded that the resulting water allocation would not impinge on the 1,440 MCM needed by Lake Chapala for evaporation.

Table 2: Water allocation principles for the Alto Río Lerma Irrigation District

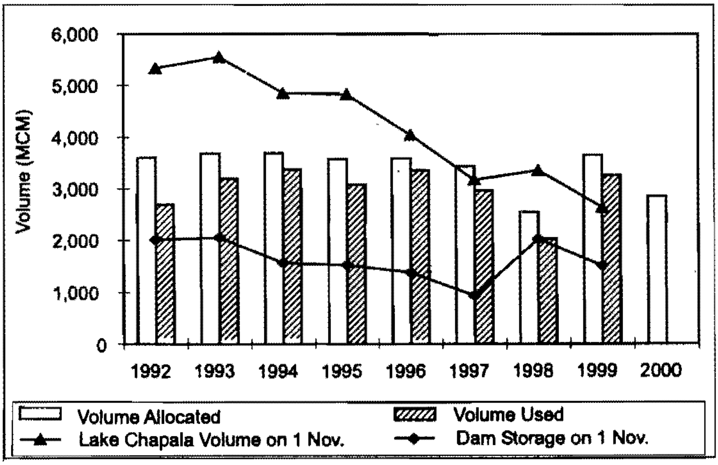
Lake Chapala Volume	Surface Runoff Generated (SRG) in the State of Guanajuato (MCM)	Volume Allocated (VA) to Irrigation District (MCM)
Critical	if SRG between 280 and 1,260	then VA = 94.2% of SRG –262.8
	if SRG > 1,260	then VA = 924
Average	if SRG between 144 and 1,125	then VA = 94.2% of SRG –135.6
	if SRG between 1,125 and 1,400	then VA = 924
	if SRG > 1,400	then VA = 955
Abundant	if SRG between 19 and 1,000	then VA = 94.2% of SRG –17.9
	if SRG between 1,000 and 1,200	then VA = 924
	if SRG > 1,200	then VA = 955

Source: CCCLC (1991)

Since 1991, the Monitoring and Evaluation Group of the Council has met each year and has applied the water allocation rules set out in the treaty. Figure 5 sets out the volumes of water allocated and used from 1992 to 2000 as well as the volume of water stored in Lake Chapala. This shows that the 1991 treaty has been enforced, as actual use has never been higher than the allocated values. A caveat here is that only the extractions by irrigation districts are accurately measured, thus actual withdrawals may have been higher as the amount of water going to the *unidades de riego* is unknown.

Sources: CNA (1991, 1992, 1993a, 1994, 1995, 1996, 1997, 1998, 1999b)

Figure 5: Surface water allocated and used in the Lerma-Chapala basin



Despite the apparently good performance of the surface water allocation mechanisms at the basin level through the application of the 1991 treaty, Lake Chapala's volume has halved in the past eight years. This is so because the surface water treaty takes the surface runoff generated in the previous year to determine water allocations. In 1997 rainfall was 645 mm and dam storage (used here as a proxy of surface runoff) was consequently low. Combined with a lake volume below 3,300 MCM the critical allocation policy was followed for 1998, leading to the lowest allocations since the treaty was signed. However, rainfall in 1998 was exceptionally good, at 810 mm some 100 mm above average, leading to a recuperation of the volume of water stored behind dams and a slight increase in the volume of Lake Chapala to 3,361 MCM. As a result, the average allocation policy was followed for 1999 and 3,664 MCM were allocated to water users, the highest level since the signing of the treaty. Unfortunately, rainfall in 1999 was a historic low of 494 mm. These two factors resulted in Lake Chapala dropping to its lowest level since the signing of the treaty.

Although the signing of the surface water treaty in 1991 was historic, the members of the council have recognised and discussed its shortcomings candidly. In 1999 the council decided to revise the treaty as it was clear that it was not rescuing Lake Chapala. In 1999 and 2000 detailed hydrological studies were carried out using data from the 1945 to 1997 period (an improvement over the 1950 to 1979 data used for the previous treaty) to develop a new model for calculating surface runoff (CNA, 1999e). The council signed the amendment of the 1991 surface treaty on 24 August 2000 (Consejo de Cuenca Lerma-Chapala, 2000). However, various states feel that they did not have sufficient input in the design of the surface runoff model and that the federal government forced the treaty on them, thereby negating the co-ordinating role of the council. In addition, consultation with water users concerning the new treaty has been minimal, although the user representatives voted in favour of it. Although the signing of the new treaty shows the adaptability of the council and the commitment of its members to construct a water allocation policy that meets urban and agricultural needs while safeguarding the environment, the process by which it was arrived at needs improvement.

An issue that the council has not yet started to consider is how to compensate farmers for water transferred out of agriculture for urban and environmental demands. In closed basins inter-sectoral transfers are inevitable and it will invariably be the irrigation sector that will need to cede water. A key institutional challenge in closed river basins is how to deal with these transfers in a just and equitable manner. Scott et al. (forthcoming) calculate that the benefits forgone for farmers in the Alto Río Lerma irrigation district as a result of the reduced allocation to the district for 2000 amounted to US$ 14 million. Although sufficient water was available in its main dam to cover its full allocation (955 MCM) the district was allocated only 648.2 MCM under the treaty, due to the critically low volume of water in Lake Chapala and the minimal surface runoff generated in Guanajuato in 1999. To shore up water levels in Lake Chapala the council decided to release the additional storage in the Solis Dam, the first time that surface water was physically transferred from the agricultural sector to the urban and environmental sector under the 1991 treaty. The Lerma-Chapala River Basin Council provides a good forum for drawing up and enforcing compensation mechanisms and for safeguarding the water rights of farmers.

4.2 The allocation of groundwater

Another serious challenge that the council and other water management stakeholders in the basin need to deal with urgently is the serious overdraft of the basin's aquifers. Although the council signed a co-ordination agreement to regulate the groundwater extraction in the basin in 1993, progress on the ground has been much slower (CCCLC, 1993). A key problem is that the council, through the CNA, does not physically control the water extraction infrastructure (the wells), as it does in the case of surface water (the dams). Although the constitution mandates the federal government to intervene in aquifers in overdraft by placing them under *veda*, entailing that it is prohibited to sink new wells without permission from the federal government, the experience with *vedas* has been mixed (Arreguín, 1998). The reality of groundwater extraction in Guanajuato clearly shows how groundwater regulation by the federal government has run aground. According to Vázquez (1999) ten *vedas* were issued in Guanajuato between 1948 and 1964, prohibiting the drilling of new wells in large parts of the state while in 1983 the remainder of the state was placed under *veda*. Notwithstanding these legal restrictions, the number of wells increased from approximately 2,000 in 1958 to 16,500 in 1997 (Guerrero, 1998).

Based on the recognition that *vedas* have not worked, and to counter the continued depletion of groundwater in the Lerma-Chapala basin, the CNA started promoting the formation of COTAS in selected aquifers in 1995, as an outflow of the 1993 agreement. Through the establishment of COTAS, which fall under the River Basin Council, the CNA is seeking to stimulate the organised participation of aquifer users with the aim of establishing mutual agreements for reversing groundwater depletion, in keeping with Article 76 of the water law regulations (CNA, 1999d). Based on recent developments in the State of Guanajuato, where CEAG enthusiastically promoted the creation of COTAS (Wester et al. 1999), the structure of the COTAS has been defined at the national level in the rules and regulations for river basin councils (CNA, 2000). In these rules the COTAS are defined as full-fledged user organisations, whose membership consists of all the water users of an aquifer. They are to serve as mechanisms for reaching agreement on aquifer management taking into consideration the needs of the various sectors using groundwater (CNA, 2000).

To date, 17 COTAS have been formed in the basin. However, none of them has yet started to devise ways to reduce groundwater extraction. Considering that some 350,000 ha in the basin are irrigated with groundwater and that industrial and domestic uses depend nearly entirely on groundwater, it is fair to say that groundwater is the strategic resource in the basin. The long-term consequences of its continued depletion easily overshadow those of Lake Chapala drying up. Although the COTAS are a timely institutional response to the pressing need for innovative approaches to managing aquifers in the basin, it is unclear whether they will succeed in reducing aquifer over-exploitation.

4.3 Representation of interests

The institutional arrangements for water management in the Lerma-Chapala basin revolve around who controls water. With basin closure, the competition for access to water is becoming more severe and poor people are losing their access to water, due to reductions in surface irrigation and increased costs for groundwater irrigation. Unfortunately, meeting the water needs of poor people and including poor women and men at all levels of water management decision-making is not a priority of the council, nor of the larger set of institutional arrangements for water management in Mexico. The council needs to start considering seriously how to safeguard and improve the access of the poor to water, and how to combat the current *de facto* concentration of water rights in the hands of the few.

5. Conclusions

The paper has presented a classic scenario of change management, with crises occurring over time, each being met with a different response. The drought and water shortages between 1945 to 1954 resulted in a doubling of the reservoir capacity within the basin. However pressure on available resources continued to increase, with the irrigated area increasing almost four-fold up to 1989, and population increasing almost three-fold. With no opportunity available for further increases in stored water, dramatic institutional reforms have been introduced from 1989, devolving responsibility for water management in irrigation systems to water users, and initiating participatory water management bodies at the basin level for high-level decision-making on water allocation.

A central component in this reform has been the 1992 water law, though of equal importance has been the institutional capability to put the law into practice, and to adapt to a dynamic situation with further measures for controlling and managing available surface and ground water resources. An essential component of this decision-making process, both in relation to overall strategy and to day-to-day management, has been professional data collection, processing and analysis.

Though the institutional measures have had a significant impact in restructuring the way in which water resources are managed, the basin is still in crisis, with the level of Lake Chapala still in decline. It is anticipated that further radical measures will need to be taken in the near future, especially in the irrigated agriculture sector, as this is the major consumptive user of available water resources. At the heart of this change will be the need to protect the livelihoods of those most at risk, farmers with small landholdings who are already close to the poverty line.

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