Case Study VIII* - Lerma-Chapala Basin, Mexico

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VIII.1 Introduction

In many of its regions, Mexico currently faces an imbalance between water demand and availability, primarily due to natural water scarcity as well as uneven water quality distribution. Rapid urban and industrial growth, among other economic and social factors, have made this worse. Water needs have grown, water users are fiercely competing with each other and conflicts are emerging as a result. Water quality has also deteriorated as urban and industrial effluents are often discharged with no previous treatment. Furthermore, Mexico is slowly overcoming a severe economic and financial crisis which has limited hydraulic infrastructure development and impoverished large population sectors.

Mexico covers 1.97 million km² of the North American continent (Figure VIII.1), with a population of 91.12 million growing at 1.8 per cent a year. Politically, Mexico is divided into 31 autonomous states (each one with its own elected government) and a federal district, which includes Mexico City. A complex system of mountain ranges create 310 hydrological basins which experience different degrees of hydraulic development and water pollution. Of all the Mexican basins, Lerma-Chapala is the most important. Consequently, it receives priority attention at all three government levels, federal, state and municipal, and especially from the National Water Commission (Comisión Nacional del Agua; CNA) which is the sole federal authority entrusted with overall national water resources administration. Public awareness on water issues in Lerma-Chapala has led to the active participation of water users, non-governmental organisations (NGOs) and social institutions with a plethora of interests directly or indirectly linked with the water sector.
VIII.2 The Lerma-Chapala basin

The River Lerma with a length of 750 km originates in Mexico's central high plateau at an altitude above 3,000 meters above sea level (masl). The river ends in Lake Chapala (1,510 masl) which is the largest tropical lake in Mexico (Figure VIII.2), 77 km long and 23 km wide. The maximum storage capacity of the lake is 8.13 km$^3$ and the surface area is about 110,000 ha. The lake is also rather shallow; its average depth is 7.2 m, with a maximum of just 16m. The Lerma River basin, is a tropical region with an average temperature of 21 °C, an area of 54,400 km$^2$ (less than 3 per cent of Mexico's entire territory) and an average rainfall of 735 mm a$^{-1}$, mainly concentrated in the summer, from which a mean run-off of 5.19 km$^3$ is derived. The River Santiago arises from Lake Chapala and flows westwards finally reaching the Pacific Ocean. The Santiago River basin is less developed in terms of population and economic activity, except for Guadalajara, the second largest city in Mexico, and with a metropolitan area with more than 3.5 million inhabitants.

Some 26,000 deep water wells operate within the Lerma-Chapala basin, with very low efficiency rates, due to their high electricity consumption and rather low water yields. Almost 70 per cent of all 38 aquifers in the region are overexploited (Figure VIII.3).
The current basin population is 9.35 million with an annual growth rate slightly less than the national average. The population is distributed between 6,224 localities, 18 of which have a population greater than 50,000 inhabitants; the rural population is currently 32 per cent. Regional socio-economic development has been triggered by water availability and industrial and agricultural production per capita have surpassed national levels. This region boasts 6,400 industries which generate one third of the GNP and 20 per cent of all national commerce occurs within this basin. Furthermore, it currently comprises one eighth of all the irrigated land in Mexico. The agriculture in this area is of such importance that national farm produce exports rely heavily on the performance of this tiny region. With the three economic sectors highly developed and with a superior transportation network, partially financed by private investors, this area is, undoubtedly, one of the richest regions in Latin America.

The Lerma-Chapala basin includes fractions of the central states of Guanajuato, Jalisco, Mexico, Michoacan and Queretaro (Figure VIII.2). Conflicts derived from surface run-off uses (mainly for irrigation and potable water supplies), combined with the general discharge of untreated effluents, have given rise to serious regional, and local, pollution problems. Frequent conflicts over water quality occur in Chapala Lake which plays a key role as the main water source for Guadalajara.
VIII.3 Pre-intervention situation

Before 1989, the regulatory and legal framework provided clear procedures for surface run-off measurement and the related information systems and analysis tools; but there were serious deficiencies in water quality monitoring and recording. In addition, institutional structures, mostly centralised at the federal level, were unable to slow down water quality deterioration throughout the basin. Eventually, this situation became acute, dramatically reducing water availability for many uses. There was, nevertheless, public and official awareness of the key issues relating to water quality and sustainable development. Hence, in 1970, under the Secretaria de Recursos Hidráulicos (Ministry of Hydraulic Resources), the first technical and administrative unit was created to prevent and control water pollution from different sources. The Lerma-Chapala basin was a natural choice for the pilot area to carry out the first water quality assessment and to lay the foundation for future intervention.

From an economic and financial perspective, the hydraulic services in the Lerma-Chapala basin did not differ from the general scheme prevalent in the rest of the country. Funding was insufficient to meet demands. Water pricing and actual payments made by users were below real water costs, restricting capital investment and management expenditures. This, in turn, limited the possibility of providing a reasonable water service for irrigation, for industry and for households. Furthermore, such a situation fostered the limited participation of water users and generated a negative attitude towards water
resources management and supply. Even today, when changes are currently being implemented, many users (at all levels and sectors) are still reluctant to pay for water.

Potable water supply had reached acceptable levels of coverage in urban areas but not in rural areas. In townships with a population above 50,000 inhabitants, service coverage was usually close to 85 per cent or more and large cities usually boasted coverage of around 95 per cent. Chlorination of the water was rather uncommon, except in large cities. Water quality control was also extremely limited, notwithstanding the efforts of the water and health sectors. The Limnological Studies Center, established in Chapala in 1975, and the regional laboratory for public health, set up in Leon, Guanajuato in 1981, backed up efforts to promote water quality control.

Urban sewage systems had lower coverage levels than the potable water systems. Untreated effluents were discharged directly into rivers and reservoirs. Furthermore, when treatment facilities did exist, like in the city of Querétaro, their operation was usually inefficient, as a result of faulty design and mismanagement related to financial aspects. Few social sectors were willing to pay for effluent treatment.

The Mexican economy grew considerably after the Second World War. National and international investments promoted industrial growth and this was further aided by a domestic market unable to purchase imported goods. Simultaneously, irrigated agriculture grew steadily in terms of surface area, economic importance and water demand. National and regional economic development policies did not allow for a long-term water conservation strategy and as a result irrigated agriculture is responsible for 81 per cent of all water abstractions in the Lerma-Chapala basin.

This region includes 16 large reservoirs which help to regulate erratic run-off from year to year. They have also helped considerably to reduce flooding risks. However, as a result of an excess of nutrients derived from untreated effluents, the reservoirs were seriously affected by massive infestations of water hyacinths.
Industries as well as most towns, located in the basin are mainly supplied by groundwater sources (90 per cent). The most important industries concentrate their activities on meat, dairy and other agricultural produce, beverages, pulp and paper, leather goods, petrochemical and chemical products, all with little or no emphasis on wastewater treatment and recycling.

Development in the Lerma-Chapala basin is largely sustained by intense water use. Industries in the basin generate around $0.608 \times 10^3$ m$^3$ a$^{-1}$ wastewater with 130,500 t a$^{-1}$ biochemical oxygen demand (BOD) coming from urban waste and 424,260 t a$^{-1}$ chemical oxygen demand (COD) coming from industrial discharges. These organic and inorganic pollutant loads and a scarcity of wastewater treatment capacity have intensified water quality problems and severely reduced water availability (Figure VIII.4). Diffuse pollution caused by drainage containing fertiliser and insecticide residues from irrigated areas, together with solid waste washed away by rain from rural households lacking domestic waste disposal systems for excreta and rubbish, have also contributed to the water quality problems.

Lake Chapala is the most important water distribution centre in the region and was seriously threatened by growing biological and chemical water pollution. This generated a public outcry in the state of Jalisco and eventually became a matter of national concern.
VIII.4 Intervention scenario

By the end of 1988 it had become apparent to society and government institutions that a complex and serious situation existed in Lerma-Chapala basin. Water demands were higher than natural availability and to such extent that even all the effluents were also already committed for use. Water allocation was a chaotic process because most water rights were granted with no clear strategy to protect water users downstream or to cope with regional water scarcity caused by frequent droughts. Users were competing with each other, usually industry and cities were exerting heavy pressure on irrigated farmland. Conflicts were not uncommon at all levels including disputes for water among neighbouring states. In general, water quality had fallen to a new, unacceptably low level. In specific locations, water quality had deteriorated so badly that life itself, in all its forms and manifestations, was challenged. River basin protection was almost non-existent. Erosion had increased in former forest areas and grasslands were disappearing at an astounding rate as a result of irrational livestock practices. Silt sedimentation eventually reduced the hydraulic capacities of streams, rivers and reservoirs and dramatically reduced the lifespan of several dams.

Society began demanding swift and effective executive action to remedy the situation in the basin. In April 1989, the Federal Government and the governments of the five states which share the basin formally, agreed to co-ordinate their efforts to carry out a "Program for Water Allocation among Users" under a new set of rules and simultaneously to undertake a "Large-Scale Sewage Treatment Program in the Lerma-Chapala Basin" (Programa de Ordenamiento de los Aprovechamientos Hidráulicos y el Saneamiento de la Cuenca Lerma-Chapala). The four main objectives derived from this dual programme were:

• To reduce water pollution.

• To establish a new system in water allocation.

• To give a thorough impetus to all activities that may help raise water efficiencies.

• To establish some sound basic rules for soil and water management, to enable and encourage biological canopy protection and recuperation, practical (and profitable) approaches for rational soil management and other preventative action.

These four objectives were accepted and adopted by society which, in turn, has played a key role in reviewing the results, evaluating the actions and even by arguing for the introduction of changes proposed by social sectors.

Government agencies installed a "Consulting Council for Evaluation and Follow-up" of all sub-programmes and activities derived from the basin programme. The Council was integrated by Federal Government ministers, state governors and chairmen from decentralised public enterprises (mainly petroleum refining and electricity). This Council was, in fact, a predecessor of the present River Basin Councils.

The Consulting Council resulted in continuous social pressure and gave rise to a paramount change in government policy on prevention and control of water pollution.
because the administrative decentralisation process was accelerated. As its functions and responsibilities grew with time, the Consulting Council eventually became a River Basin Council. A Work Group was created as a flexible instrument to review conflicts and all actions in detail, and to raise proposals to the Council. It had representatives of each Council member; these representatives were empowered to vote and to establish commitments on behalf of the institution he or she represented. A chairman was elected who was always a public servant from the National Water Commission. The Work Group met every two months, whereas the Council had a solemn public session every year or so, usually with the President of the Republic present. The Council work agenda for every session had been discussed previously and had been approved by the Work Group. All key issues, such as financing or law enforcement, which were voted on by the Council had already been approved either in the Work Group itself or by means of bilateral lobbying. Hence, all key issues were always approved by consensus. This mechanism itself has proved invaluable. Many potential, bitter confrontations and outdated standpoints were avoided.

The Consulting Council created an appropriate atmosphere that eventually attracted water users. Hence, within the Consulting Council, a Water Users' Assembly was created as a powerful body that could listen to a plethora of water demands, as well as provide a swift vehicle for raising to the Council level the needs, hopes and means of water users for contributing to the improvement of the hydraulic situation in the Lerma-Chapala Basin. Eventually, water users' representatives became Council members with identical rights to speech and vote as Government members.

Three years later the new National Water Act (December, 1992), inspired by the Consulting Council process, enforced the creation of basin councils throughout the country to improve institutional co-ordination and to enhance all forms of fruitful relationships amongst users and water institutions. The water act assigned CNA a key role in regional water management within the federal government. Furthermore, it encouraged greater participation by state and municipal authorities (Article 13). Hydrological basins (defined either by surface or groundwater borders) were finally, and legally, recognised as the ideal geographical unit for rational water management. The National Water Act could perhaps have gone further with its definition of Basin Councils because, for all practical purposes, the Consejo de Cuenca Lerma-Chapala was already further advanced than was required by law.

For the first time in Mexican history, the Water Act included a single chapter on water pollution prevention and control. This section clearly holds CNA responsible for promoting and, when necessary, operating federal infrastructure and services essential to preserve, conserve and improve water quality in hydrological basins and aquifers (Article 86). All purveyors of water supply and effluent treatment have a direct responsibility to comply with the law. In effect, a large-scale decentralisation process has been under way in the water sector for the past two decades. If unpredictable events occur, and for the sake of public interest direct intervention by CNA is required, then (and only then) the Federal Government will provide water services until such extreme events cease or are brought under control.

As direct result of a Master Water Plan (an achievement in itself, derived from public hearings and intense discussion amongst council representatives to the Work Group) and in close co-ordination, CNA and the Lerma-Chapala Basin Council have
implemented an ambitious "Large-Scale Sewage Treatment Program" to clean up the region. This is the first large-scale water treatment programme in Mexico, undertaken as a result of widespread participation and not only as a federal programme. The programme deals with freshwater supply disinfection and building treatment facilities able to cope with urban-industrial effluents. The projects were mostly generated by State and Municipal authorities and funding was raised by federal water rights (a payment similar to tax), subsidies (both federal and state originated), domestic and foreign credits, private sector investments and water supply savings derived from water pricing strategies. All construction activities were usually run by local authorities via contractors and by private sector investors.

In the case of treatment facilities the decision-making process was clearly defined; several key townships were identified by the Council as those most directly responsible for domestic pollution levels either on a general or local basis. These city authorities were invited to consider joining the Sewage Treatment Program and those that agreed (and a large proportion did agree) had technical, financial and institutional support provided when required. The details of this scheme were rather complex given that, for example, sewage systems were incomplete in several cases and billing procedures were underdeveloped in some other sites.

Before the Clean Water Program was enacted in April 1991, potable water was mainly disinfected using chlorine. On a regional basis 5,763 l s⁻¹ were disinfected water, equivalent to 31 per cent of the total water supply, to service 2.2 million inhabitants at 10 sites. By the end of 1994, chlorine disinfection had increased to 18,000 l s⁻¹, which represented 85 per cent of the total water supplied to 5.7 million inhabitants in 594 localities.

A permanent monitoring system is run by CNA based on residual chlorine determination. Regular maintenance is also provided to chlorinators exclusively when required, without interfering with local water supply policies and responsibilities. Other organisations are responsible for operating the systems. In order to preserve standards in its drinking water sources, CNA has updated its source inventory. Presently, 498 sources are protected, i.e. 20 per cent of all registered water sources.

The wastewater treatment programme was planned in three stages. The first stage, which ended in December 1994, was aimed at reducing the organic pollution impact on the Lerma River basin by 50 per cent and by 65 per cent in Lake Chapala. The goal was to build and operate 48 plants for municipal waste-water treatment, with an overall capacity of 3,700 l s⁻¹. Global capital investments have been close to 367 million pesos (approximately US$ 80 million).

By 1997, 45 plants with a treatment capacity of 5.72 m³ s⁻¹ were operating on a regular basis with an average running efficiency of around 70 per cent. Furthermore, 40 per cent of the operating plants have to improve their efficiencies whereas the remainder are discharging within legal BOD limits. Six further treatment facilities were under construction to raise the regional capacity to 9.56 m³ s⁻¹ (on a regional level the present domestic effluents are close to 17 m³ s⁻¹). On the shores of Lake Chapala, 17 municipal plants have been completed (treating a total of 643 l s⁻¹ at 90 per cent efficiency in BOD removal). In this particular zone, to ensure the operation of the facilities, given that most plants are quite small, a special technical administrative unit was created entirely run
and funded by the local state government. This scheme has now evolved to a point where most expenditure is provided by municipal authorities and funded through integral water tariffs. On average in May 1989, almost 90 per cent of all water in Lake Chapala had been reported as poor quality (Figure VIII.5). By contrast, 85 per cent is now considered of good quality and 15 per cent of adequate quality (Figure VIII.6). These results clearly indicate actual achievements in reversing Lake Chapala's former severe environmental deterioration.

**Figure VIII.5 Map of Lake Chapala showing water quality distribution determined by a water quality index in 1989, prior to the sewage treatment programme**
Sewer systems have expanded as a consequence of newly-constructed treatment plants. Furthermore, as a general rule, primary treatment systems and stabilisation lagoons in particular, are now the "preferred" method of wastewater treatment, providing clear-cut technical and financial advantages over other conventional methods. Since early 1997, the decision-making process has been directly affected by newly enacted Federal Official Regulations (Normas Oficiales Mexicanas), promoting realistic discharge standards according to present economic and financial parameters throughout the country. In most situations, raw domestic sewage effluents may meet the new standards after primary treatment.

Federal Government-owned electrical and petroleum industries in the basin have also built large-scale treatment plants to purify and reuse their wastewater; their overall capacity is 415 1 s⁻¹.

The second stage of the Lerma-Chapala clean-up programme, which is already under way, aims to increase treatment capacity to 10,670 1 s⁻¹ of municipal and industrial wastewater by means of constructing and operating 52 new plants and expanding five existing facilities, with a total investment of 1,200 million pesos (US$ 150 million). Funding is provided by federal, state and private investment as well as by credits and water supply enterprise savings. Several turnkey operations (build-operate-transfer schemes) are either already operating or under construction. At the end of this stage, 100 treatment facilities will dramatically reduce water pollution. Almost 85 per cent of all domestic effluents will be potentially treated. In all cases, Federal Government, acting through CNA (exclusively when required) may provide technical support in project
design and may contribute to supplement investment funding. Almost half of all funding will have been furnished by private investors and their participation in design, construction and operation activities will be of paramount importance.

A third stage of the Large-Scale Sewage Treatment Program includes building 50 additional facilities orientated to meet the needs of small townships and rural communities. These plants will boast a total treatment capacity of 1,833 m⁻³.

In order to control and monitor water quality in the basin, CNA keeps a regional water agency with headquarters in Guadalajara. This agency regularly inspects and maintains a network of 50 monitoring stations, 22 of which are located in the Lerma River and 28 in Lake Chapala. It also runs two specialised water quality laboratories in the region. All information is systematically processed and analysed with digital model tools, some of which were developed through joint ventures with the International Institute of Applied Systems Analysis (IIASA) at Laxenburg, Austria, Thames Water International in Reading, England, and Canada’s Centre for Inland Waters near Toronto, Canada. By means of such models, a detailed Lerma River classification that complied with the Water Act has been produced and officially published for the various river stretches. The models allow forecasting based on alternative scenarios derived from constructing new facilities and modifying water quality policies.

Information systems are kept by CNA and by the Lerma-Chapala Basin Council. They can be accessed and queried via the Internet and are periodically being overhauled to improve information and to offer user-friendly systems. Regional water sector statistics are now being offered either in a printed form, following a similar pattern to the French Water Information Network (Réseau National des Données sur l'Eau) managed by the International Office for Water (Office International de l'Eau) in Limoges, France, or on CD-ROM, through proprietary procedures provided by the Mexican Institute for Water Technology (Instituto Mexicano de Tecnología del Agua).

Efforts are being made by CNA and the Lerma-Chapala Basin to improve water use efficiency in the basin, mainly in agricultural and urban use systems. Water pricing policy that keeps in touch with reality and adjusts billing and collecting systems to increase payments has proved a successful strategy. Irrigation service payments, for example, have increased by 500 per cent since 1990. These actions are aimed at increasing treated water reuse, at constitutionally strengthening operating agencies and at controlling physical water loss, amongst other things.

The transfer of irrigation districts to users' control has also contributed to improved efficiency. To date, 214,000 ha have been transferred, i.e. 74 per cent of all the irrigated area in the basin. Prior to this, irrigation districts were rehabilitated and modernised, with an overall investment of 445 million pesos (US$ 55.6 million). Users are particularly encouraged to participate in decision-making and planning processes, as well as in water management. Furthermore, they are also invited to develop and to conserve infrastructure and to provide services directly. This experience, linked to the Lerma-Chapala Basin Council, has been of paramount importance. Irrigation farmers have acquired a mature approach to water issues; they now successfully run their irrigation districts, most former federal employees are no longer needed, water distribution has improved and money collection has increased. Problems do arise from time to time but most of them are solved locally with little or no government intervention.
Pilot programmes have also been implemented in several micro-regions to tackle and prevent soil erosion and hence to reduce accelerated sedimentation in water bodies (Figure VIII.7). Aquatic weed infestations, which currently cover over 11 per cent of all water surface, are another problem that has been successfully addressed by CNA, specially in Lake Chapala where less than 4 per cent of the water surface is presently covered.

There is a permanent campaign, through the media and the Internet, focused on widespread knowledge and understanding of the objectives and activities of the Basin Council. These activities are also helpful in promoting different independent user organisations, with a view to integrating an even more powerful Water Users' Assembly, whose representatives would continue to support and participate jointly in the Council activities.

**VIII.5 Conclusions and lessons for the future**

The Lerma River water quality, and especially the present condition of Lake Chapala, has shown a considerable improvement in the last seven years as a result of integrated action within the hydrological basin (conceived as a management unit) (Figures VIII.5 and VIII.6). The most important lessons learned will refocus the attention of CNA, the Basin Council and society itself towards:
• The need to increase political willingness towards resource allocation, administrative decentralisation, co-ordination of efforts and undertaking commitments.

• Completion of a new institutional and legal framework in which CNA is the regulatory agency at the national level, and the Basin Council at the regional level, and with the Federal Water Authority resting exclusively in CNA.

• Strengthening Basin Council's role in the water sector, establishing clear regulations for their individual participation and their joint collaboration with municipal, state and federal government institutions.

• Pursuing and completing an integrated water information system, that is now available to authorities, and pushing forward the expansion of the number and versatility of measuring equipment and sites, and the power and flexibility of analysis and decision-making tools.

• Improving planning and evaluation tasks, encouraging joint and effective water users' participation and fostering a permanent commitment by society on regional water issues.

• A new water culture within society; individuals and communities most become aware of water scarcity, pollution and erosion; they should also be willing to accept that they have to pay the price for a better future in terms of water availability and quality; and sustainable development should become a matter of general knowledge, for politicians, scientists, technicians, lawyers and lay persons alike.

• Expanding, and improving, the Lerma-Chapala experience (both institutional and non-governmental, with all its complex technical, political, financial, legal, social and human features) to other hydrological basins throughout Mexico.

VIII.6 Final reflections

The continuity of Lerma Chapala's sewage treatment programme must be ensured because water quality goals can only be achieved through time and with effort. Treatment plants not only need to be constructed, but they need to be operated efficiently and permanently. As in many other places in the world, the key issue is financial. People must be willing to pay for water treatment, and water companies (whether official or private) must evolve to reduce water losses, to raise efficiencies and to improve substantially metering, billing and collecting procedures.

The results achieved so far must be consolidated by complementary action guaranteeing the operation of treatment plants through widespread and permanent training and certification of operators, through an effective system of discharge permits (both to sewers and natural water bodies) and other preventative measures to restrain industrial pollution by encouraging in-house pre-treatment, and through greater emphasis on widespread non-point source pollution generated by irrigated farmland effluents and inadequate sanitary conditions (i.e. excreta disposal) in rural dwellings. In conclusion, water quality improvement will be triggered whenever an effective approach to law enforcement is seriously adopted.
The master plan, its activities and results, must be systematically evaluated so that positive results can be incorporated into other basins in Mexico.

Water quality goals established by users must be consistent with their willingness to pay the cost to fulfil such objectives. Concern over water quality deterioration must be raised, stimulating public awareness of current pollution problems.

Finally, there is still a long way to go to achieve success in this, or in any other, region in Mexico. However, steps are being taken in the right direction and the momentum is gradually increasing.