A SYSTEMIC MODEL FOR THE WATER MANAGEMENT IN MEXICO VALLEY

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ABSTRACT

The Mexico City metropolitan area is one of the biggest urban zones of the world, not only in territorial extension but also in population. It has experienced severe water supply problems along all of its history. Such problems have been lately aggravated since its population has grown without specific plans.

After a brief introduction to the problem situation, the four relevant subsystems are described, such subsystems are pluvial precipitations, aquifer exploitation, water treatment and service management. Some critical aspects are pointed out so that they can be addressed in searching for alternatives of solution.

A basic input-output conceptual model is designed to have a better understanding of the current situation of the water supply system. There are two water inputs into the valley, one from rain precipitation and the other from the nearby basins and, two outputs to atmosphere and exportation respectively. Also, there are two feedback: one of them is to infiltrate water into the various aquifers of the basin and the other is to employ the runoffs.

In order to reach a high quality service, it is proposed to manage the System by a central metropolitan water authority.

A special emphasis is made about the importance of utilizing the enormous potential of the two big own water resources of the valley, i.e. the annual precipitation (rainwater) and the wastewater (served water).

Keywords: systemic model, pluvial precipitation, water treatment, relevant subsystems

INTRODUCTION

This is a complement to the previous work named "Systemic Analysis of the Problem Situation of the Hydraulic Service to Mexico City". It has as a main purpose to deeply approach the study on the management of the hydraulic resources to provide with drinking water to all of the inhabitants of Mexico City and its metropolitan area, including all the populations seated in the valley of Mexico.

The drinking water, to cover all requirements of the Mexico City metropolitan area, is obtained from the Mexico Basin (own resources) and from the basins of High Lerma and Cutzamala (imported resources). (CONAGUA, 2005 a, b)

Indeed, in order to complete drinking water requirements to Mexico City, the responsible people of the water service have had to bring water from neighbor basins. This fact has caused important operating costs since enormous amounts of electric energy are consumed (CONAGUA, 2005c, **Ezcurra *et al* 2006, 195**) and, in addition, some social conflicts among the residents of the valley have appeared, v.g., the potential development of the field and industry of such places have been restricted.

Mexico City has had frequent difficulties with the supply of drinking water to satisfy water requirements of its population. There had been periods of time in which the supply of water is so faulty that it compels to consider small range solutions for the service to improve. The service is improved for a short time and then returns to the situation of insufficient supply. (CNI, 1995)

Under the enormous non-planned growth that the city has had for the last decades, the hydraulic system, specifically the water supply system, is facing a new periodic crisis. That is, some problems, lack of enough water volumes for instance, make an important number of the inhabitants to have a rather poor water supply service. So, it is necessary again to carrying out new actions to improve this situation, but this time taking care of arriving at long-range solutions.
With the idea in mind of having a water supply service of better quality for the entire population and be sustainable, it is convenient to adopt a systemic management. Such an organization must be directed to consciously manage the own hydraulic resources of the valley, including water from the basin and residual water. But in order to achieve better results, authorities and users have to assume full responsibility.

CONCEPTUAL MODEL

At the present stage of the research, it was designed a basic input-output conceptual model, with two input, two outputs and two feedback to represent the physical dynamic of the system. The next stage will be to use an appropriate modeling language.

Fig. 1 shows the conceptual model of distribution of water that enters, leaves and recycles to the valley.

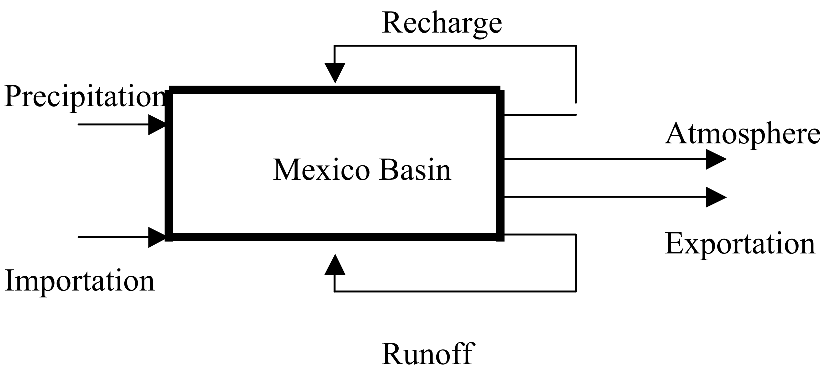

Fig. 1 Conceptual model of the hydraulic system

Relevant subsystems

To reach all of the previously exposed purposes in improving the supply system, it is necessary to undertake studies of the most relevant subsystems. Such subsystems are as follows:

1) Subsystem for the improvement of the use of the pluvial precipitation, under the separation of the rainwater from the wastewater, residential and industrial.
2) Subsystem for the rational exploitation of all the potential aquifers of the valley and construction of conducts to main consumption centers.
3) Subsystem for the treatment of large volumes of waste and combined water, to supply all service that doesn't require drinking water, and increase and maintain in good conditions green areas, forests and lakes.
4) Subsystem for the administration of the hydraulic service, under a single responsible authority for the whole Mexico Valley and supported with appropriate budget.

Next, a brief exploration of each one of those subsystems:

1. - Subsystem of pluvial precipitation

The pluvial precipitation is the main source of water supply for the inhabitants of the valley. In accordance with data provided by Comisión Nacional del Agua, 2005 (National Commission of Water, 2005), the annual average pluvial precipitation on the region of Mexico Valley, with a surface of 9674 km2 is of 6820 hm3 (705.8 mm) which corresponds to 216.4 m3/s.

A great portion of this volume goes to the atmosphere by the evaporation process; from the rest, one part runs off outside of the valley and the other one infiltrates into the aquifers. Table 1

Table 1. Distribution of the annual precipitation

EVENT	FLOW (m3/s)	FLOW PERCENTAGE * (%)	FLOW INPUT (m3/s)	FLOW OUTPUT (m3/s)
Precipitation	216.4	100.0	216.4	------
Evapo-transpiration	149.3	69.0	------	------
Aquifers recharge	36.8	17.0	------	------
Runoff	27.3	12.6	------	------
Exportation	------	8.1		27.4
Importation	------	5.9	19.8	------
Total	------	-----	236.2	27.4

* In regards with precipitation Source: Estadísticas del Agua, CONAGUA 2005c

The rainwater that precipitates on the Mexico Basin has 4 destinations: evapo-transpiration (69%), aquifers recharge (17%), superficial runoff (12.6%) and a part of exportation.

From table 1, the water for benefit of the valley's inhabitants is given by aquifers recharge (36.8 m3/s) plus runoff (27.3 m3/s), which gives 64.1 m 3/s. If this last figure is compared against pluvial precipitation, it can be seen that, in general terms, only about 30% of that pluvial precipitation is used.

This is really a paradoxical situation, since being the precipitation so abundant, however, its use is very reduced. Therefore, it is necessary to take actions guided toward the reach of more benefits from this resource.

Table 2 shows the water availability for each of the four political entities that share the geo-hydrologic Mexico Basin. It should be observed that this assignment of water corresponds to what can be taken from the available resources (64.1m3/s) and with their own current facilities, but that, however, This volume is not enough to cover demands of the towns seated in that region of the country.

It can be seen that the total water availability (92.75 m3/s) is bigger than the total consumption (82.1 m3/s). So, it is advisable to have a better distribution and control of underground water of Mexico Basin.

Table 2 Assignment of water to political entities of Mexico Valley

DRINKING WATER [1]					
Population			Assigned volume		
Federal entity	Inhabitants millions	Consumption* m3/s	Superficial m3/s	Underground m3/s	Total m3/s
Distrito Federal	8.81	34.67	9.84	25.85	35.69
Estado de México	10.68	42.03	16.23	30.4	46.63
Hidalgo	1.30	5.12	7.36	2.60	9.96
Tlaxcala	0.07	0.28	0.05	0.42	0.47
Total	20.86	82.10	33.48	59.27	92.75

* Based on 340 l/inhab/day average and 30% leakage

Source: Estadísticas del Agua, CONAGUA, 2005c

[1] The World Agency of the Health (WHO) recommends a water use of 150 lts/inh/day for under development countries and 50 lts/inh/day as minimum quantity to prevent problems of health

Since Mexico City had suffered disastrous periodic floods, extremely serious some of them, the Mexican government decided to put an end to the lakes of the valley, including the Mexico Lake where the city was built. This caused certain things as, decrease of humidity in the atmosphere, aridity of the land, abundant dust storms, decrease of green areas and, what is more serious, an important increase of the evapo-transpiration. The problem in this sense aggravates, due to trees pruning without control.

In natural woodlands, leaf litter piles up in drift on the forest floor. But when trees and shrubs are pruned without control the leaf litter disappears. “The problem is that trees and shrubs beneath the forest canopy depends on the leaf litter for food. Without it, rain water leaches away nutrients formerly stored in the liter” (Mann, 2007). At the end, understory and the tree seedlings die, the soil dry and the evaporation increase. Worst of all, “Some of the protected green spaces had loss its vegetation” (Ezquerra *et al* 2006, 187)

With regard to the urban development, the city and their surroundings grew in a rather anarchical way. There appeared many constructions, paved or cemented streets, a unique drainage for combined waters (rainfall and residual water), scarce green spaces, etc., and, also, uncontrolled population growth.

In such a situation, various processes appeared, such as decrease of infiltration areas, woodlands, near-surface phreatic water, etc. and over exploitation of the aquifers.

Many of the problems of water supply to the populations of the Mexico Valley would be solved, if it were possible to increase the percentage of use of the rainwater. In this respect, two actions might be possible: decrease of the evaporation and storage of more rainwater volumes.

Some ways to diminishing the enormous evaporation could include a massive reforestation of the whole basin and the restitution of some of the lakes already disappeared.

Rainwater storage has been making by means of non-natural reservoirs located in the West Side of the metropolis, but only one of them is used for water supply purposes. The rest of reservoirs are only to regulate runoffs from strong precipitations, i.e., water is stored for short periods of time and later it is released little by little. In this way possible floods are avoided to the historical center of Mexico City.

Some of the reasons by which that captured water is not used for the population's benefit, are as follows: discharges of wastewater through the runoffs toward the reservoirs, pollution caused by garbage, minimum maintenance and scarce surveillance.

The water stored by means of west dams might be good enough provided appropriate measures were taken to preserve it from pollution or to build others sufficiently protected and watched over.

In previous years, the Mexico City government began the construction of a 3m diameter peripheral aqueduct, skirting the city limits. The purpose of that peripheral aqueduct was to give a better distribution to the water that enters into the system coming from the basins of Lerma and Cutzamala. As first stage, it was contemplated to providing water to Ixtapalapa located east side, where there are important lacks of drinking water. After having approximately built a fifth part of the length projected, the works stopped.

It would be worthy to recapture the project, extending its coverage and employing it as water storage of the annual pluvial precipitations, and later to extract it, make it drinkable and conduct it toward diverse consumption centers.

Any alternative, or combination of alternatives, that were chosen to improve the water storage from the annual pluvial precipitations, it will be necessary to separate rainwater from wastewater, by tubing only the wastewater.

2.- Rational exploitation of the basin

Approximately, the 1/5 part of Mexico Valley is urban zone (services and industries included) where, naturally, there is a big demand of drinking water and it is very important to keep a good water service. Unfortunately, in that area exists the biggest water extraction from underground and the smallest recharge spaces. (DGCOH, 1995)

This way, the corresponding aquifer of the urban zone is exploited beyond its input-output equilibrium, while the rest of the basin aquifers remain in a situation of sub-exploitation.

Table 3 shows the number of aquifers of Mexico Basin. The third column is to show the difference between water extracted (pumped) and water infiltrated (recharge). It can be seen that the aquifer of the Metropolitan Zone is exploited above its real capacity. The high exploitation of such aquifer gives place to three important events:

1) Differential sinks of the soil of the Mexico City Historical Center;
2) Deeper pumping from subsoil each time
3) Diminution of pumping level up to extraction is limited to recharge: this means, little recharge little pumping and, consequently, less water.

Table 3. Characteristics of Mexico Basins aquifers

AQUIFER	Recharge (m3/s)	Assigned Volume (m3/s)	Real deficit (m3/s)
ZMCM *	8.85	39.59	30.75
Tecocomulco	0.88	0.00	0.00
Apan	3.15	0.25	0.00
Chalco-Amecameca	2.35	2.87	0.52
Texcoco	1.48	2.93	1.39
Cuautilan-Pachuca	6.43	7.72	1.28
Soltepec	0.61	0.57	0.00
Total	23.75	49.93	33.94

* Mexico City Metropolitan Zone Source: Estadísticas del Agua, CONAGUA, 2005c

Thus, It might be convenient, to study all of the aquifers of the basin and determine each individual potential of exploitation. Also, It is worthy to find alternatives to increase infiltration and plan and control the functioning of this system about aquifers. Any study should include all necessary arrangements to take advantage of aquifers with enough potentiality.

However, in carrying out studies of this nature, some political complications could arise due to the fact that the basin is shared and managed by three federative entities (D.F., Estado de México and Hidalgo), and for the existence of many particular, legal and not legal, wells. (CNI, 1995)

Some geo-hydraulics studies have shown the existence of an aquifer at 1000 m in depth. It is necessary to profound in these studies and to verify results, and whether they are satisfactory, then carry out all of the necessary actions to take advantage of its exploitation. Santoyo E. et all, 2005, Birkle et al, 1995, cited in Ezquerra et all 2006, 112)

3. -Treatment of wastewater and combined water

Table 4 shows the volumes of combined water (residual and rain) that are treated at the present time in the three big entities that share Mexico valley.

If it is compared the provisioning of freshwater with the treated volume of combined water, it is observed that this last is only a 6% of the first. There are several reasons for which this resource (water treated) is sub-utilized but, perhaps, the most important of them is lack of interest about it.

Table 4 Treatment of combined water in Mexico Valley

COMBINED WATER				
Federative entity	Municipal		Industrial	
	Installed capacity m^3/s	Treated flow m^3/s	Installed capacity m^3/s	Treated flow m^3/s
Federal District	6.76	3.46	0.00	0.00
State of Mexico	2.77	2.10	1.60	1.18
Hidalgo	0.07	0.01	1.60	0-94
Tlaxcala	0.1	0.04	0.02	0.02
Total	9.70	5.61	3.22	2.12

Source: Estadísticas del Agua, CONAGUA, 2005c

To obtain higher benefits from this source, it is convenient to consider a number of factors. Some of those factors are: required water volumes, types of water treatment, class of water to be treated, localization of the supply sources regarding the consumption centers, facilities for transportation of treated water, distribution and control of the water already treated and disinfected, etc. This is so, because it is necessary to define facilities and treatment quality.

Treatment of residual water in small portions would benefit to industrial groups in processes that don't require drinking water, residential units of any size, and in sport and recreational centers. For these last two activities, treated water would be good for sanitary and watering services, basically.

Under an appropriate legislation, any group of industrial enterprises could be served by a small treatment plant, which had to be managed (planned, operated, maintained, etc.) by that same industrial group.

In the case of the residential units already established, residents should organize, install, operate and maintain and manage a system of treatment of its served water. In case of new constructions, corresponding permission would not be granted, unless the project includes an appropriate system of treatment water. These actions should be carried out under an appropriate legislation. Likewise, sport and recreational centers

On the other hand, treatment of big volumes of wastewater would bring many benefits for residents of Mexico Valley, v.g., to maintain and increase woodlands, green spaces, inside and outside of cities and towns of the valley, etc.. Also, to maintain the levels of the current lakes, or, if it is possible, increase such levels and build new lakes, and what can be very important, increase recharge of aquifers, etc..

In addition, other actions should be contemplated such as making users to be aware of the value of the resource, so that they commit, consciously and individually, to use, insofar as possible, treated water for those uses and services that don't require drinking water for their operation.

Studies that be carried out for the use of treated water should contemplate not only facilities to make required treatment, but also the complementary and indispensable works, structures for separation of water, rain from residual, and capture, transportation, distribution and control.

Costs of integral projects for treatment and use of served waters are costly, since there is generally not the necessary infrastructure. However, the use of this resource is certainly very important in problems solving of water supply of any city, therefore, careful financial studies should be carried out before undertaking for this road.

4.- Management of the hydraulic service

As it was said formerly, Mexico Basin is shared by four federative entities, although they are only three for practical purposes, since Tlaxcala is very small in comparison with the other three Mexican states.

Due to this fact, it has not been possible to make appropriate planning, control, surveillance, etc. in the exploitation of the aquifers of the basin; consequently, the exploitation of the basin has not been done in a rational and conscious way to having enough water for the entire population. Under this circumstance, water from neighboring basins has had to be brought and many of the aquifers have been over-exploited.

Each time, fortunately, authorities are more aware of the necessity of taking care and exploiting rationally the hydraulic resources of Mexico Basin, which, by it alone, is able to provide enough water for the entire population of the valley, more than 20 million residents.

For the last two years, the responsible agency to supply water to Mexico City was constituted as a decentralized organism. Now this agency is constituted as a non-concentrate organ. The agencies for the water supply to other entities, inside Mexico Valley, are also decentralized organisms.

Many opinions coincide that the best way to reaching the best benefits from the exploitation of the hydraulic resources and, this way to provide a higher quality service, it is by creating a single organism that integrates all the administrative aspects in hydraulic matter.

Such an organism should operate in certain autonomy to prepare its own plans and programs, distribute its budgets meetly and look for its own developments, among other things, this is, it should be constituted as autonomous organism.

La Comisión de Aguas del Valle de México (The Waters Commission of Mexico Valley) was founded around the 80's, with the idea of coordinating the appropriate use of the resources of the valley. Given that this institution encompasses the management of all hydraulic resources of the nation, such a management is not specialized for the Mexico Valley.

CONCLUSIONS

The water supply service for the Mexico City metropolitan zone will stay in acceptable levels and at smaller costs, when the hydraulic resources of the basin are managed with more effectiveness and responsibility. Besides, it can be avoided import of complementary volumes of water from the nearby basins, and political costs and the social conflicts that arise from that process.

The aspects of the service that is necessary to have under strict control to maintain a quality service, in what refers to the hydraulic resources, are: *1)-aquifers recharge, 2)-storage of more water volumes, 3)- decrease of evaporation-transpiration and 4)-more volumes of wastewater treatment*, among the most important.

Also, in order to have the best results in the operation of the hydraulic service, it is necessary a *unique central metropolitan water authority for the whole valley* at least in what refer to planning, operation, maintenance and conservation of supply sources.

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