A SYSTEMS DYNAMICS APPROACH
TO
CONFLICT RESOLUTION IN WATER RESOURCES:
THE MODEL OF THE LERMA-CHAPALA WATERSHED

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ABSTRACT:

A System Dynamics simulation model of the Lerma-Chapala watershed, in Mexico, was built to develop an improved Surface Water Distribution Agreement among five states of the Mexican Republic and the national water authorities. The model, the main analytical tool in a politically charged and confrontational water resources allocation, has proven to be very useful for conflict resolution because:

- *it presents an objective vision of the complex reality being analyzed that enables its user to focus on the watershed behavior;*
- *it allows the stakeholders of this process to test the policies that they deemed most important to their own states.*

KEYWORDS:
Integrated Water Resources Management, Policy Analysis, Conflict Resolution

1. BACKGROUND

During the second half of the 20th century Mexico's population increased rapidly therefore producing the need to achieve a comparably rapid social and economic growth. Under these circumstances, the Mexican government's planning approach encouraged the use - sometimes excessive - of the country natural resources, including water. Among the water programs that flourished at that time were the creation of large irrigation districts and the exploitation of the country's aquifers to supply the growing population and industry. Over time, an ever increasing water demand, that perhaps was not foreseen, compared to a bounded water supply has proven that the water programs mentioned are not sustainable. This situation has left unfulfilled economic and social commitments among the watershed's water users with the attendant problems. In addition, severe environmental problems have been created.

Several river watersheds in Mexico are facing the consequences of the ambitious development programs of the past, among them the Lerma–Chapala river basin. The River Lerma runs from the Toluca Valley, just west of Mexico City, to Lake Chapala, near the city of Guadalajara, in the western state of Jalisco, for a total span of about 750 kilometers. The river impacts 3% of the central

part of the national territory of Mexico (55,511 km^2), with 12.5% of the nation's population, 13% of the agricultural production and 35% of the industrial product of the country (Marañon 2002, 232).

With a per capita water availability of only 1,000 cubic meters per year, the Lerma-Chapala watershed is considerably lower than the national average that stands at 4,997 cubic meters per year. And, since population in the watershed will continue to grow as a reflection of the country's population growth as projected by the Comisión Nacional de Población, the per capita water availability will fall even lower unless some action is taken in the near future to prevent this from happening.

Today, the Lerma river water supply is below the level it was 20 years ago. In addition to the basin's population driven demand for drinking, agricultural and industrial uses, at the source of the river, water continues to be extracted and pumped over the mountains to supply drinking water to Mexico City. Another significant, and sometimes overlooked contributing factor to Lake Chapala's low volumes, has been the relentless growth of the Metropolitan Zone of Guadalajara (MZG). This zone, geographically adjacent to Lake Chapala, drives the demand for drinking, industrial and agricultural waters that are extracted from the Lake and also from the Lerma River before it discharges in the Lake.

In an effort to stop the deteriorating condition of the Lerma-Chapala watershed, a Surface Water Distribution Agreement elaborated by the National Water Authority of Mexico (CNA) and the five states located within the boundaries of the basin - Estado de Mexico, Queretaro, Michoacan, Guanajuato and Jalisco - was implemented in 1991. (Acuerdo de Coordinación Especial Sobre la Disponibilidad, Distribución y Usos de la Aguas Superficiales de Propiedad Nacional de la Cuenca Lerma-Chapala)

This agreement had two main objectives:

1) to improve the distribution of the Lerma River's water among the many users, and
2) to restore the volume of Lake Chapala and other water bodies within the basin.

The distribution agreement was derived from heuristic rules of operation among water engineers that were knowledgeable about the Lerma-Chapala watershed. The Agreement is a specific set of rules that govern the yearly allocation of the river's waters on the basis of:

1) the level of Lake Chapala on November 1,
2) the levels of the eight largest dams in the watershed system,
3) the expected agricultural use (forecasted)
4) the specific urban use set in the Agreement

From the water engineering standpoint, the performance of the Surface Water Distribution Agreement has been adequate in stopping the desiccation of Lake Chapala, in spite of some persistent problems such as:

1) the lack of control over small irrigated agricultural areas,
2) the need of a better definition of Lake Chapala's role within the watershed, and
3) the pernicious use of discretionary power by the authorities that allow deviations from the letter of the Agreement to accommodate special interest groups.

2.   THE SOURCE OF CONFLICT

Although the Mexican Altiplano (high plateau in center of republic) is for the most part a semi-arid region, over the years the Lerma River watershed located in the southwest portion of this region has flourished as one of Mexico's premier agricultural producers because of the waters of the Lerma River. At the same time, the region has experienced continuous urban growth, primarily in the MZG. These two main users of the Lerma-Chapala waters, agricultural and urban, have very different objectives when it comes to determining how to use the waters. The question in contention is which of the two sector is entitled to the water and why?

In accordance with the Mexican constitution, the Federal Government is charged with the administration of all waters in Mexico. Both sectors would like the federal government to intervene and make the decision as to how the conflict will be resolved since, until recently, that had been the traditional way of solving similar conflicts in Mexico. However, this time the national water authorities are taking a more cautious approach since they realize that the resolution of the problem must be "fair" for all those involved in order to be permanently accepted by both sectors. Thus, fairness is the key concept upon which a workable solution to the use of the waters of the Lerma-Chapala watershed has to be found. With the many stakeholders involved – common citizens, agricultural production organizations, environmentalists, NGO's – the solution hinges upon finding a formula that gives each stakeholder the "right amount of fairness" that will satisfy them and make the conflict disappear, not only in the present but in years to come. In other words, a "win-win" solution is required to resolve the disagreement on a permanent basis.

The agricultural producers which are located along the entire basin claim that they have been improving the efficiency of their productive processes so that water demand for agriculture per hectare planted has decreased. A recent internal investigation of this sector, done by CNA, seems to confirm the claim of the agricultural producers. At the same time, in years of water abundance, these same producers have managed to use water volumes that are above the stipulations of the Agreement.

The urban sector has chosen a strategy of not clearly defining the uses of the waters of Lake Chapala while at the same time maintaining that the Lake is a patrimony of Mexico and deserves to be preserved in its original state (i.e. same size and same volume of water). They have also adopted an aggressive posture of blaming the Lake's low levels in recent years on the inefficient use of water by the agricultural sector up river but without having scientific proof of this claim.

3.   METHODOLOGICAL APPROACH

The Lerma–Chapala watershed is overseen by a council comprised of the governors of the five states located within its boundaries as well as representatives of the agricultural, industrial and domestic water uses within the region. The council has as one of its responsibilities to advise the CNA on matters pertaining to the future of the water resources. Within the council there is an interdisciplinary group of hydrologists, water engineers, sociologists and economists that has been charged with the task of developing an improved Surface Water Distribution Agreement. The first goal of this group was to take into consideration the changes that have occurred in the watershed since the decade of the 1990s when the current Agreement was deployed.

To develop the improved Agreement, the group decided to create a 20 point road map that goes from a diagnostic of the situation in the Lerma-Chapala watershed, to the construction of policy analysis tools to examine the causes of the watershed problems, and finally, to a proposal for an improved Agreement. This group has agreed that the improved Agreement should satisfy the objectives of the current one.

Among the initial tasks that the group undertook was to characterize the current and future situations of the watershed. As stated above, it is known that population on the watershed will continue to grow and that the water supply is bounded so that the only line of action is "to make more efficient use" of the water available (see Figure 1 below). What this means is that it is necessary to reach a state of sustainability in the watershed such that "…there will be enough water resources for generations to come". This "efficiency", another one of the goals to be met with the improved Agreement, has not been completely defined but it has been agreed that it needs to grow as fast as the water uses, so that the limited resource available can satisfy over time the developing demand.
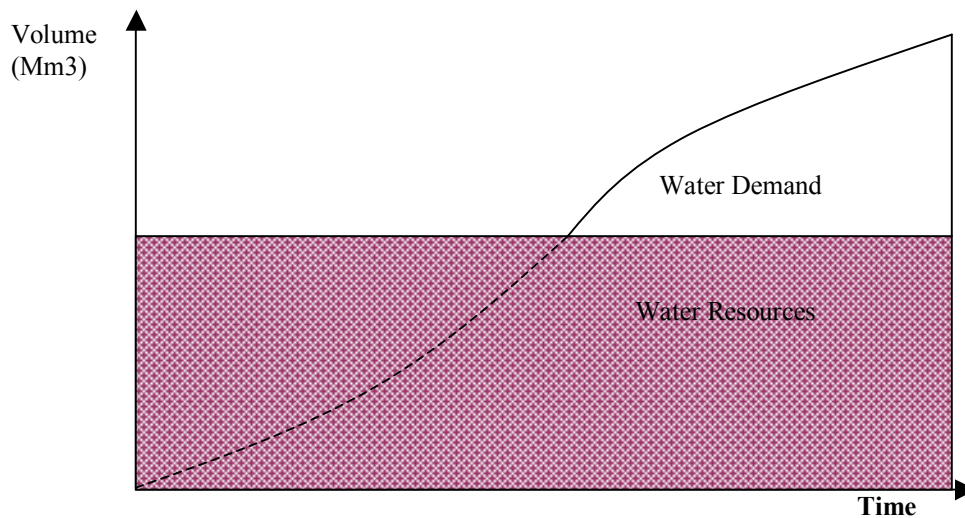

Figure 1. Water supply and demand situation in the Lerma-Chapala watershed

An additional important fact about the Lerma–Chapala watershed is that since the problem of growth is not a confined to one area, the concept of efficiency must be developed for the entire watershed. From this discussion two important characteristics emerge in the Lerma–Chapala watershed situation:

1) that the problem being analyzed has a *temporal* characteristic since it will be impossible to ascertain how sustainable the watershed is and can be without taking a long view of its evolving situation, and,
2) that the problem is *spatially distributed* since it affects all parts of the watershed but differently in each case.

The search for a basic methodology to support the development of analytical tools to tackle the problem being examined quickly identified System Dynamics (SD) as the appropriate approach to use. It was an obvious choice since SD can be used to model and simulate the temporal behavior of problems, and also because a reasonable spatial resolution can be achieved by decomposing the

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problem into smaller sub problems. One additional element in selecting SD was the existence of previous experience in using this approach to examine watershed problems in Mexico.

3.1 Previous experience using SD modeling for water resources planning: The state of Guanajuato long term planning initiative

At the beginning of the decade of the 1990s, the Government of the State of Guanajuato, Mexico, set as one of its highest priorities the need to change the direction of the state development. To do so an effort to identify the strengths and weaknesses of the state was undertaken. Between 1991 and 1994 the project Guanajuato XXI Century (Huerta 2001, Chapter 14), was developed, having as its objective to "find a new mechanism to direct the state development", and also, to "generate possible long term futures that will indicate what actions to take in the present to reach the desirable future". An integral part of this project was the State Foresight Study and, for its preparation a system dynamics simulation model of the state of Guanajuato, called ProEstado–Guanajuato, was built.

Espousing Gaston Berger's idea that the forces that shape the future can be found in today's reality, ProEstado-Guanajuato: (a) portrays Guanajuato's current "reality", (b) identifies the forces that are immersed in this reality and (c) makes the reality and the forces interact to create the future change. Originally built to examine the then Governor Vicente Fox's statewide policies in search of sustainability, ProEstado-Guanajuato was instrumental at uncovering important weaknesses in some of Guanajuato's realities, one of them water resources.

Confronted with an uncertain future for state water resources, the State Water Commission required a planning approach based on two ideas:

1) the view that water resources planning and management is a part of a much broader system made up of natural, technical, social, economic, political, environmental and institutional "realities", that had all to be taken into account concurrently in order to understand the true roots of problems and,
2) the need to take a systemic, long view (20 to 30 years) of water resources, because only by looking at the distant future will it be possible to evaluate what policy will make the resources sustainable.

To implement this planning approach, Guanajuato's State Water Commission combined:

1) an integrated water resources management framework as the platform for the implementation of its planning approach and
2) system thinking as the paradigm for viewing the future and generating the requisite scenarios.

The state model, ProEstado–Guanajuato, was used as a starting point for designing and building MAUA (in Spanish, Modelo de Abasto y Uso del Agua, that translates into Water Supply and Use Model). However, a drastic adaptation of ProEstado-MAUA was required to convert it from an aggregate state level model to a watershed specific model. The SD approach of ProEstado-MAUA breaks the single-water use analysis paradigm and focuses on a more important subject, the final use and control of the resource, regardless of who uses it. Once directed towards this central objective, ProEstado-MAUA pinpoints flaws in policies that are being designed to "solve the problems" and

that, contrary to their intended purpose, may even reinforce the existence of the problem. ProEstado-MAUA provided a solid platform for water resources planning since:

1) it has the capability of integrating into a single model the visions of the various water uses that go beyond the traditional single-water use approach,
2) it provides the means to visualize what happens when we simulate the implementation of a policy, and this capability, when shared with others, serves the purpose of improving our communications, and,
3) it handles physical as well as social variables in the same model, helping us to determine the impacts on both sides that result from the implementation of policies over an extended period of time.

ProEstado-MAUA was employed to develop a 25-year state water plan that provides Guanajuato with a road map to stay the course in years to come. It was also utilized to examine the implications on the state of Guanajuato of restricting the volumes of water of the Lerma River, the very subject of the present report but on that occasion viewed from a state perspective. At the end of Guanajuato project the watershed SD modeling and simulation technology was transferred from the state of Guanajuato to the National Water Commission (CNA). In turn, CNA requested that the Mexican Institute of Water Technology (IMTA is the institute's acronym in Spanish) learn from the developers the techniques that made possible the construction and operation of ProEstado-MAUA. The SD model of the Lerma-Chapala watershed discussed here has been built by IMTA under the supervision of the developers of the Guanajuato project.

3.2   Model Description

The Lerma-Chapala watershed SD model LERMA is based on experts' knowledge and field visits to establish the "Ground Truth"; that is, what actually exists on the terrain, as far as natural and man-made water bodies and structures. LERMA breaks down the watershed into 17 sub watershed in order to achieve a better degree of spatial fidelity (See Figure 2, below).

The first sub watershed is Alzate (1) in the outskirts of Toluca, a growing industrial and also agricultural city, just 40 miles west of Mexico City. The last sub-watershed, Chapala (17) harbors Lake Chapala and is located only about 20 miles south of Guadalajara, the second largest city in Mexico.
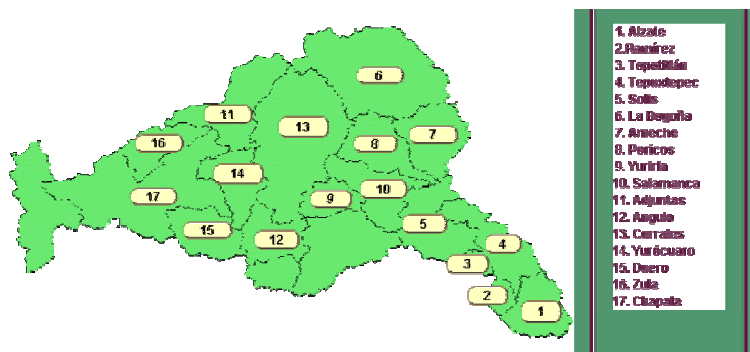

Figure 2. Breakdown of the Lerma-Chapala watershed into sub watersheds

For each sub-watershed LERMA can generate time related behavior at two levels of the physical environment (See Figure 3. below, NOTE: the Underground level was not considered in project):

Atmosphere. The water cycle begins with rain which is a random variable and the principal "motor" of the model. Since LERMA is a deterministic model, time series of rain are exogenous variables that are input to the model.

Surface. LERMA represents the "geometry" of river, lakes and other water bodies that exist on the sub watershed, including their interconnections. For a given level of precipitation the model computes surface runoff, evaporation, and infiltration. It also simulates the operations of rivers and damns.

Each sub-watershed model of the LERMA model has four main elements that interact dynamically with each other. They are: (1) surface water, (2) underground water, (3) demands due to the various uses, and (4) a mechanism to test allocation policies, which is the main reason for the creation of the LERMA model. The upper left side of the diagram in Figure 4. shows the surface water module of the LERMA model. There are two algorithms in this module, one that converts rain into runoff and the other that simulates the time related behavior of rivers and dams. While the current work being done with LERMA only includes surface water, the model has a fully developed underground water module that receives infiltration from the rain-runoff algorithm. The infiltration is used by an aquifer model that simulates its behavior under each sub watershed. On the demand side of the model water demand is computed as a function of the area to be planted by type of crop. Currently the model only handles one type of crop per production cycle and considers the autumn-winter and spring-summer cycles aside from the perennial crops.
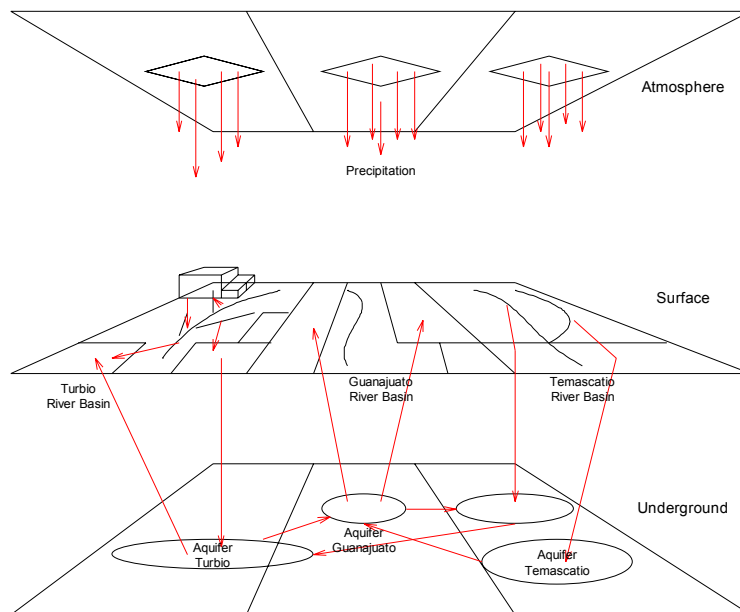
Figure 3. The LERMA model view of a sub watershed

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The mechanism to test allocation policies has as inputs

1) the volumes demanded by the agricultural producers,
2) the levels of the various reservoirs in the watershed, including Lake Chapala, the last date of October of every year, and
3) the rain forecasts based on climatology.

With these inputs, the current Surface Water Distribution Agreement evaluates a set of allocation rules to determine the volumes of water that will be allocated for the next agricultural production year.
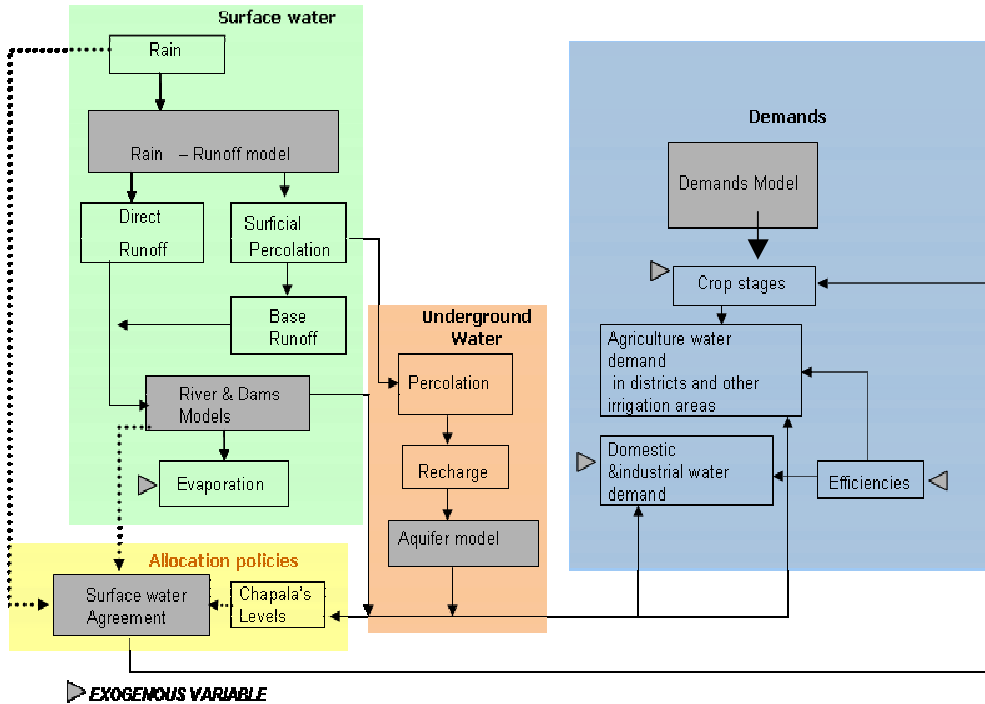

Figure 4. The LERMA sub watershed structure

The construction of LERMA is based on the system dynamics approach that considers the behaviors of individual systems components as well as the dynamic interactions among them. These two effects are simultaneous. Under this paradigm of analysis, time is considered the independent variable and it is also the axis along which the simulated phenomenon is being observed. To simulate time-related behavior, the model utilizes a system of differential equations of the form:

$$\text{(Equation 1)}\ldots\ldots d\mathbf{X}(t)/dt = \mathbf{A}(t)\mathbf{X}(t) + \mathbf{B}(t)\mathbf{U}(t)$$

Where t: time is the independent variable and

$\mathbf{X}(t)$:   the "state" vector variable that defines the status of the system at time t.

$d\mathbf{X}(t)/dt$: the rate of change of the "status" in the time interval $t + \Delta t$.

$\mathbf{A}(t)$:   vector variable of parameters, used to specify the "reality" of the modeled system.

$\mathbf{B}(t)$:   vector variable of coupling parameters for policies implemented in modeled system.

$\mathbf{U}(t)$:   a vector variable that contains the policy being tested.

4. MODEL COMPUTER IMPLEMENTATION

For the computer implementation of LERMA, the dynamic simulation environment Stella Research ®, Version 7.0, for Windows was selected. The Stella diagram shown in Figure 5 below presents an overview of the more than 35 modules that represent sub watersheds, irrigation districts, aquifers, potable and industrial water supply and demand. In all, there are over 240 state variables that represent the water levels of the dams and Lake Chapala, agricultural production, potable and industrial water demands for the 17 sub watersheds in which the Lerma-Chapala watershed was broken down. There are also a large number of accumulators and counters to report the execution of a simulation in ways that are similar to the water reporting format in real life.
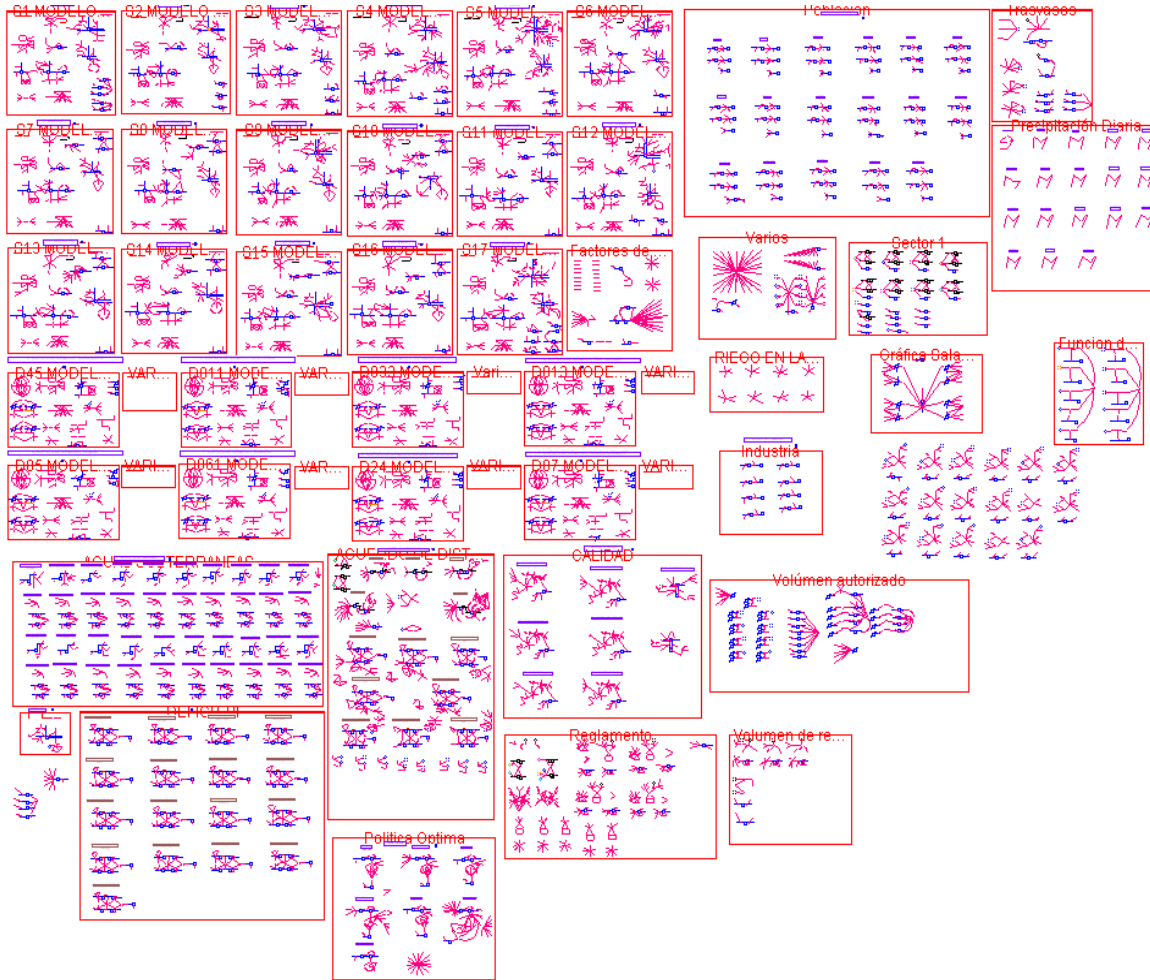

Figure 5. LERMA model overview

The model behavior is generated at the sub watershed level by the following four models: (1) synthetic rain, (2) rain-runoff, (3) reservoir operation and, (4) agricultural production. These four models are interconnected as shown in the Stella diagram of Figure 6, below.
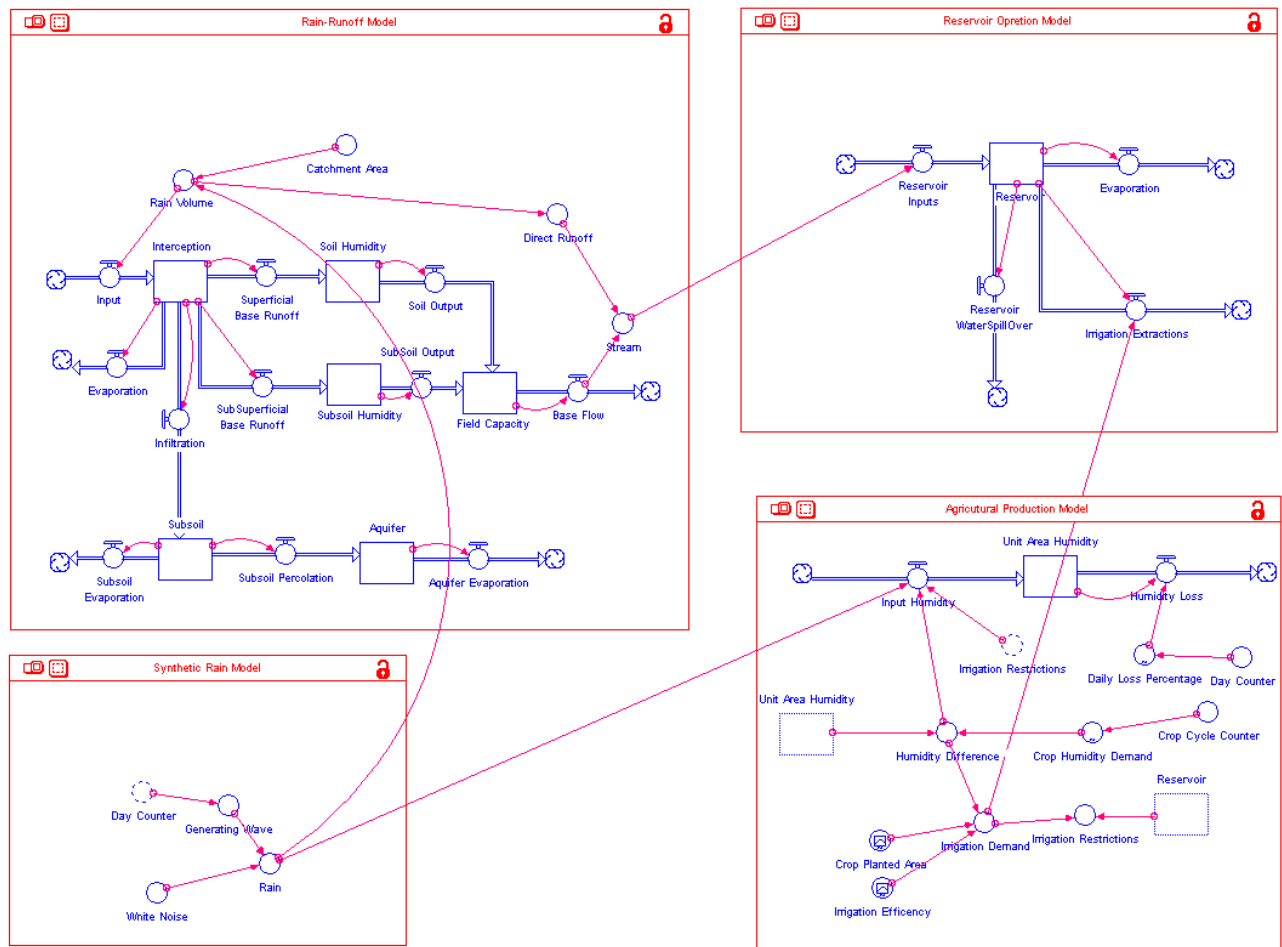
Figure 6. The four basic models of a sub-watershed

Synthetic Rain Model – Daily rain is the main "motor" of the LERMA model. It can be entered into the model as an exogenous time series of daily rain values (not shown) or, as a sine/cosine wave generating formula derived from the spectral analysis of 50 years of rain historical data for each of the sub watersheds (shown). Daily rain values are the outputs of this model that connects with the Rain-Runoff Model and also with the Agricultural production model.

Rain – Runoff Model – The daily rain (in millimeters) falling in the sub watershed is converted into rain volume which then becomes either direct runoff or is applied to the interception process that distributes, after a delay, the remaining rain volume as base flow, evaporation and infiltration. Since the LERMA model was used to examine alternatives for a surface water distribution agreement, during model calibration, it took special care to match the base flow and the stream produced by the model with historical values from the real system. The output of this model is the stream that becomes the input to the reservoir in the sub watershed.

Reservoir Operation Model – The operation of the reservoir is straightforward, on the input side a reservoir has the stream and the rain that falls directly over the reservoir. On the output side, the reservoir has losses for evaporation and, when the level of the water in the reservoir exceeds its capacity, there are water spills. The majority of the reservoirs in the Lerma-Chapala watershed were

built to supply water to adjacent irrigation districts that were created from the 1950's to the 1970's as a major piece of a long term development plan of the Mexican government that sought to rationally develop the agricultural sector of the economy.

Agricultural Production Model – The dynamics of this model is produced by the continuous balance between the humidity of a plot of agricultural land where a crop has been planted and the humidity requirements at each instant by the type of crop planted. As it can be seen in Figure 6, humidity is naturally increased by rain, but it can also be increased with irrigation. Since irrigation demands are dependent on the water available in the reservoir, a Restriction (0=<restriction=<1.0) is utilized to reduced the volume demanded if this is grater than the water available in the reservoir.

5. MODEL USE

The LERMA model, as described in previous section, represents the processes that take place in the Lerma-Chapala watershed with emphasis on the hydrological cycle; the operation of the river, dams and lake Chapala; and agricultural production, since this last activity alone utilizes about 85% of all surface water available in the watershed. These selected processes which are incorporated into the LERMA model are the "*plant*", as it is called in control engineering, that provides the "realistic picture" of the watershed behavior to enable analysts to examine the problem at hand and to propose solutions to it. The LERMA model has also been provided with a set of control variables (**U**(t) in equation 1 above) whose purpose is to control the behavior (generation of trajectories) of the *plant* in search of solutions that satisfy a given criteria, such as sustainability. The table below presents the control variables associated with the LERMA model.

Table 1. Sub models of the LERMA and their control variables

Sub Model	Control Variable
Surface Water Supply	Annual Irrigation Supply
Agricultural Production	Cultivated Area Irrigation Technology
Domestic & Industrial Demand	Population Growth Rate Demand Per Capita Demand Per Unit of Industrial Output

From the available control variables, the *Annual Irrigation Supply* and the *Cultivated Area* have been tested with the LERMA model as two separate control approaches on the water supply and water demand sides respectively. The other control variables have not yet been utilized. The *Annual Irrigation Supply* was used to simulate the current Surface Water Distribution Agreement which is a set of rules to allocate water to the various sub watershed, taking into account the previous year's runoff and the level of Lake Chapala at the time that the allocation takes place. The *Cultivated Area* control variable was utilized as part of a tracking control mechanism. In this case, values of water body levels through one full year (measured daily), when the operation of all water

bodies in the watershed was considered near optimal, were utilized as the reference pattern to be followed year after year by the tracking algorithm. The operation of this control is the following:

1) For every agricultural year, the objective is to utilize the water stored in a dam for irrigation in a form that at the end of the year the level of the dam will be as close as possible as it was at the beginning of the year. If it is possible to attain this level, sustainability is ensured. This process takes into consideration a precipitation forecast that becomes modeled as future runoff that will recharge the dam and will increase the humidity of the agricultural soils.

2) To match the daily reference pattern, the user of the model increases (decreases) the *Cultivated Area* in order to increase (decrease) the water demand which in turn increases (decreases) the water extraction from the dam. The objective of this process is to reduce the error that exists between the daily reference values and the simulated values. Since the LERMA model is not equipped with a dynamic minimization algorithm, there is no automatic procedure to perform the calculation of the difference, which is therefore performed by trial and error. A set of minimization rules has been deployed that facilitates the analyst's work.

Figure 7 below, shows a LERMA control and result displays. Within the display, a graphical comparison of the *Cultivated Area Tracking* and the *Annual Irrigation Supply* control approaches to the watershed is presented as it affects Lake Chapala. The time horizon of the simulation presented is of 18,980 days, or 52 years. Similar graphics exist for each water body within the watershed. Table 2 shows a comparison of the ending values of both policies tested.

Table 2. Comparison of Cultivated Area and Annual Irrigation Supply

Variable	Cultivated Area Tracking (CAT)	Annual Irrigation Supply (AIS)
Annual Average Irrigated Area	131,802 hectares	134,529 hectares
Annual Average Volume Demanded by Irrigation Districts (ID)	1,614 MM3	2,895 MM3
Annual Average Volume Supplied to ID	1,374 MM3	1,407 MM3
Annual Average Volume Demanded Other Irrigation	1,039 MM3	1,106 MM3
Annual Average Volume Supply Other Irrigation	817 MM3	887 MM3
Annual Average Volume of Chapala	4,979 MM3	4,900 MM3
Annual Average Volume Entering Chapala	2,300 MM3	2,207 MM3

Table 2, indicates that the *Cultivated Area Tracking* (CAT) irrigates 131,802 hectares, almost the same area as the 134,529 hectares of the *Annual Irrigation Supply* (AIS) with less water (1,614 MM3) being utilized for CAT than the for AIS (2,895 MM3). With CAT, supply for irrigation districts has a 85.1 % efficiency, as opposed to 48.6% for the case of the AIS. However, the efficiency of in the case of Other Irrigation is only 62.5% as opposed to 80.2% for the AIS. Lake Chapala also improves with CAT.
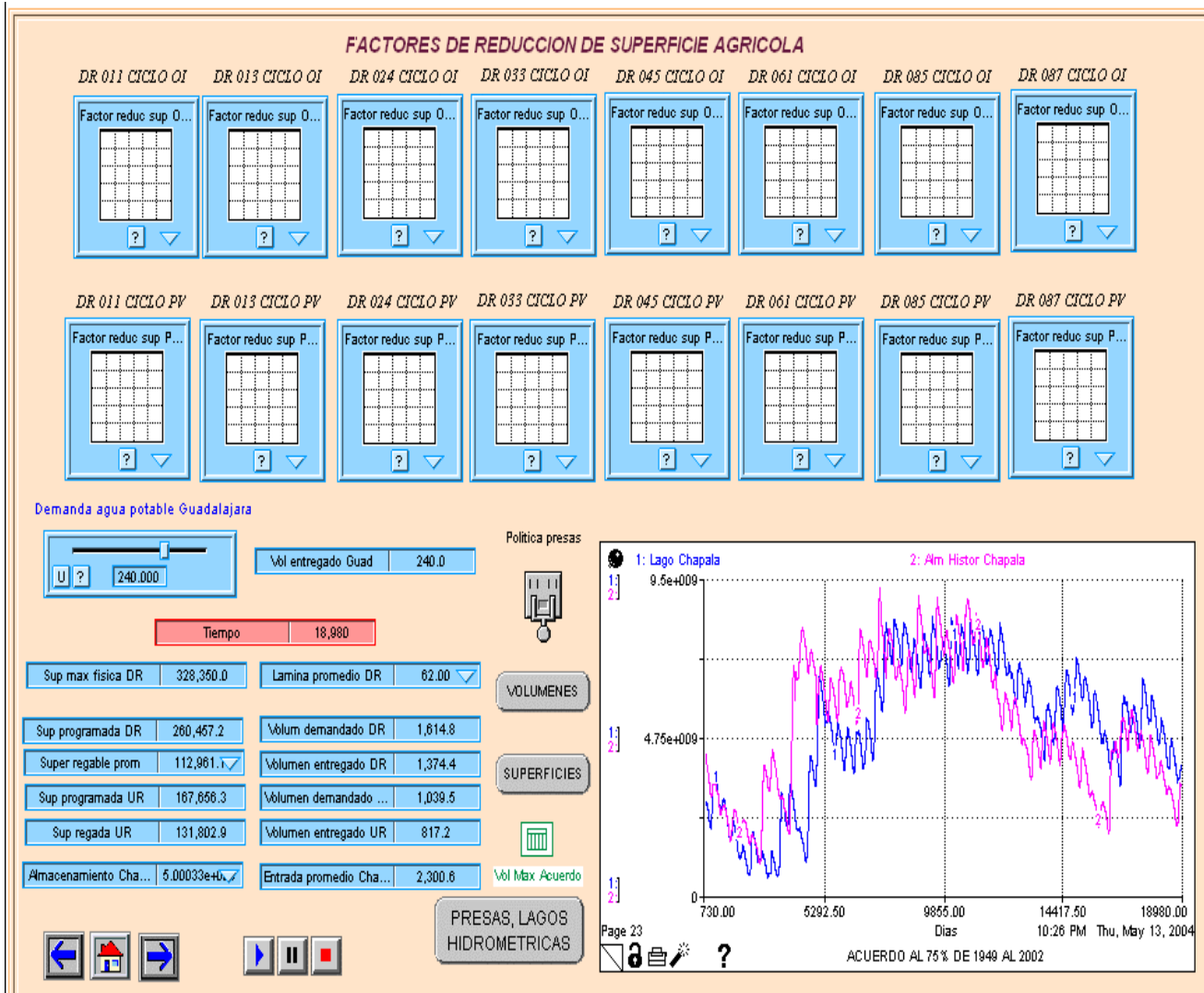
Figure 7. One of the Stella Control Displays of the LERMA Model

6. PROJECT FINDINGS

There several aspects of this project deserve to be highlighted. Two are presented here.

6.1 The Lerma – Chapala Watershed Behavior

The LERMA model, as the principal analytical tool of this project, yielded a much needed under-standing of the watershed behavior. It was possible to understand that:

1) The Lerma-Chapala watershed is dynamically fragile. A ten year simulation test with LERMA showed that any brisk operational change, such as a sudden water transfer (of about 200 MM3 from up river dams to Lake Chapala), could produce a sharp oscillation in the system that would take considerable time to dissipate and whose intensity and duration affects the future operation of the watershed.

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2) The application of any policy that favors one part of the watershed above the others would produce only a temporary advantage that some time in the future could reverse itself to become a liability. For example, a water transfer from up river dams to Lake Chapala may result sometime later in low water levels for the entire watershed; this would hamper irrigation as well as additional transfers to Lake Chapala.

3) The watershed breaks down naturally into two main sections: (1) an upper section that goes from the Lerma river source to the Solis dam, less that mid course, and (2) the other, that goes from Salamanca (about 50 miles down river from Solis) to Lake Chapala. The LERMA model showed that the large volumes of water that Lake Chapala requires to maintain a level over the 2,000 MM3 are generated mainly by precipitation that falls from Salamanca on down. The upper section of the river contributes very little to these volumes. This statement, together with (1), suggests that water transfers from Solis to Lake Chapala in conditions other than emergencies are not going to save the lake from desiccation. This is because the lake needs about more than 2,000 MM3 yearly, while water transfers can only be of 200 MM3.

6.2 The Use of a System Dynamics Model in a Conflict Resolution Situation

When the multidisciplinary group of the Lerma-Chapala water council was convened to undertake the development of the improved Surface Water Distribution Agreement, each state representative seemed to interpret his/her role in the group to be a strong voice of his/her state view point, with the additional purpose of making it prevail over the others. This was not an auspicious beginning of a process in which the only satisfactory outcome of the ensuing negotiations had to produce a "win-win" outcome for all stakeholders in the watershed.

At that time it became clear that the goals of the various states participating in the project were far apart. For example, Guanajuato, a prime agricultural producer, claimed that its irrigated districts were in compliance with the current Agreement and, that programs already in place to improve irrigation efficiency were producing results and would continue to do so as part of a continuous process improvement plan. As a result, Guanajuato was unwilling to give up additional volumes of their continuously decreasing water allocation to Lake Chapala. Meanwhile, Jalisco claimed that Lake Chapala was close to dissecation as a result of the diminishing volume entering the Lake, and blamed upstream agriculturists for their wasteful use of water. In accordance to Jalisco, the remedy was to transfer, as soon as possible, all surplus water in the watershed to Lake Chapala, with little regard for the fact that this could jeopardize the agricultural production in the states of Guanajuato and Michoacan.

Realizing that endlessly arguing one state position against the others was not going to result in an improved water agreement, the multidisciplinary group agreed to develop the system dynamics methodology described above. The methodology enabled the members of the group to focus on a common understanding of the time related behavior of the Lerma-Chapala watershed. Armed with this understanding, the group was able to elaborate the improved agreement through the design and testing of water distribution policies. Although it was never clearly stated, it was assumed that the chosen methodology would also provide a mechanism to examine the conflicting objectives of the various states and find a "win-win" solution.

One of the limitations encountered by the multidisciplinary group was the lack of the requisite "SD culture" that would enable the team members to understand precisely the functioning of the

LERMA model and the results it would produce. This problem, present in many similar situations, stemmed in this case from the fact that the majority of the members of the group were seasoned "managerial-engineers" with no recent water resources modeling experience. Only the members of the state of Guanajuato were "analytical-engineers" with deeper knowledge of SD modeling. Although this issue was widely discussed from the onset of the project, the consensus reached was, that due to the superiority of LERMA model over other analytical paradigms, it was better to continue the development of this model despite the limitations of the group. Nevertheless, the lack of this common SD culture among the group member has produced misunderstandings and an uneven participation by the group members. It has also produced continuous delays that have pushed back the final delivery of the model results by six months.

7. CONCLUDING REMARKS

The use of an SD model of a large scale river watershed as the center piece of a confrontational water resources allocation has proven to be very useful for the following reasons:

1) it presents a unified vision of the complex reality being analyzed,
2) it allows the stakeholders in this allocation process to test the policies that they deemed most important to their state interest and to compare them with the results of the policy testing of other states, and
3) it provides the analysis required to elaborate a new and improved distribution agreement of the Lerma river water utilization.

In a politically charged situation the SD modeling approach brought focus on the behavior of the watershed and away from the issued representing the individual agendas of the stakeholders. In this sense the SD modeling diminished dramatically the level of confrontation producing instead a better climate for collaboration.

The lack of an adequate SD culture among the multidisciplinary group members as well as among the recipients of the reported work has created at times credibility concerns and distrust. As it was said before this is by no means the exception since SD methodologies are not well known by many. On the other hand, it will be difficult to identify an alternate approach that can accomplish as much in the time that the multidisciplinary group dedicated to this project.

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