Potential Impacts of the Rio Lerma-Lago Chapala-Rio Santiago Watershed on the Presa de Aguamilpa Fishery

Interim Report

January, 2003

Note: This project has been suspended midway due to Administrative/Funding problems. Work should resume when these difficulties are resolved.

Water is the base upon which a fishery depends. Without water there can be no fish. Without fish there is no fishery. In a study of the fishery based on the Presa Aguamilpa. It is, therefore, important to examine the water upon which that fishery will depend.

In this context water has two properties that are of interest: quantity and quality. Both of these properties are highly correlated to the conditions found in the watershed from which the water has been collected. The intention of this part of the study was to examine current conditions and future trends in the Rio Lerma-Lago Chapala-Rio Santiago watershed. This watershed is the source region for the waters of the Presa Aguamilpa. The goal was to determine if there are any outstanding problems related to water quality or quantity, either current or in the foreseeable future.

The location of the Rio Lerma-Lago Chapala-Rio Santiago watershed is shown in Map 1. The watershed upstream from the Presa Aguamilpa occupies an area of approximately 116,649 km.^{2} in the central part of the Republic of Mexico. This area represents 16.6% of the land area of the entire country.

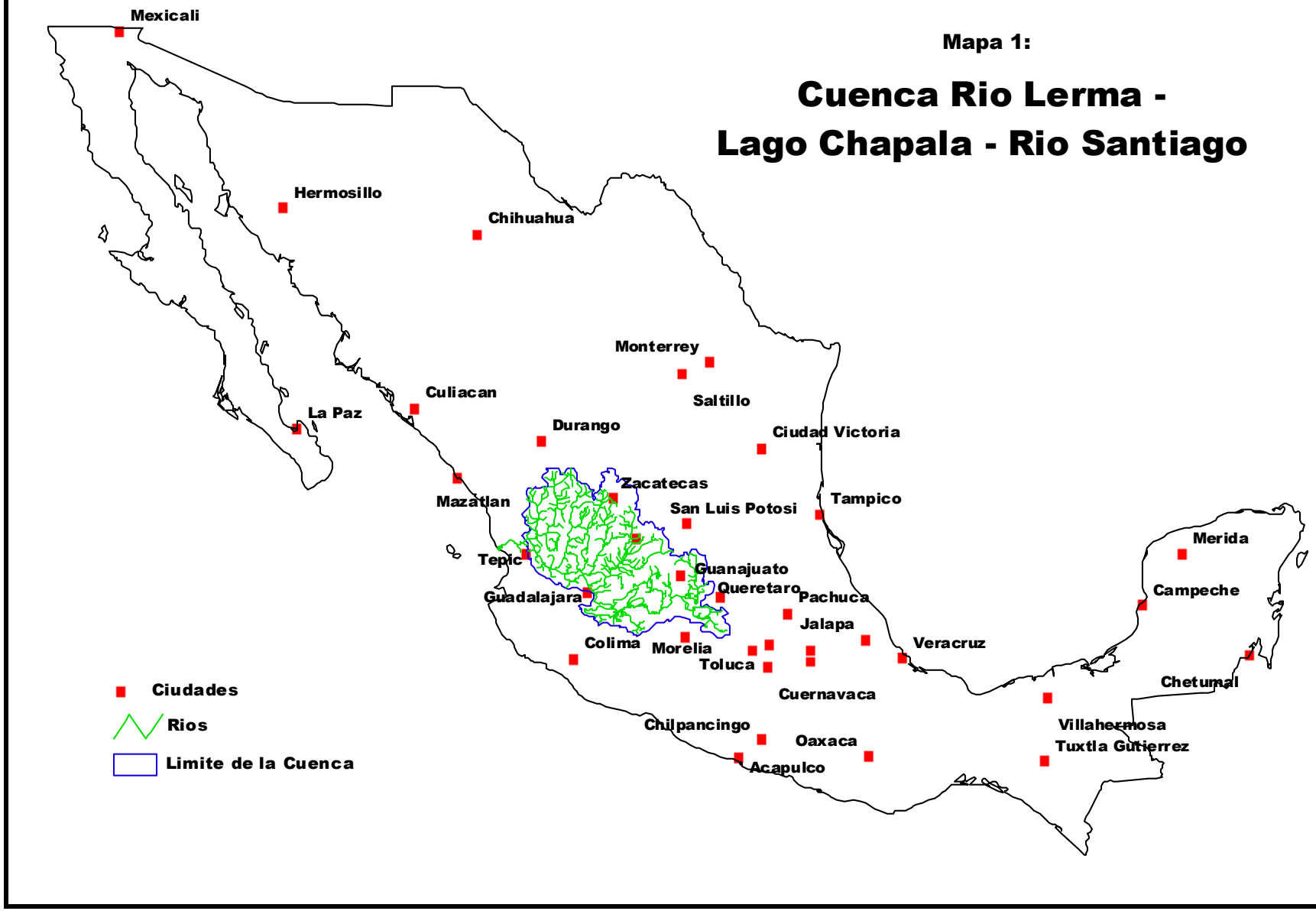
The Presa Aguamilpa has 26 sub-divisions of the the Rio Lerma-Lago Chapala-Rio Santiago watershed which drain directly into it. The location of these sub-watersheds are illustrated in Map 2. Two of these sub-watersheds are quite large: the Rio Lerma-Santiago with an area of 97,570 km.^{2}, and the Rio Brasiles with an area of 17,103 km.^{2}. The other 24 drainage basins are quite small and drain areas immediately adjacent to the Presa. The largest measures 264 km.^{2}, the smallest contains 18 km.^{2}, and the mean area of the 24 is 77.7 km.^{2}. The total area of all 24 is 1,866 km.^{2}. The area covered by the Presa is approximately 106 km.^{2}. Map 2 also shows the locations of the major rivers and streams in the Rio Lerma-Lago Chapala-Rio Santiago watershed. The total length of the rivers shown is 8,632 km.

All of the world's fresh water, including the water in the Presa Aquamilpa, is a product of the hydrologic cycle. The only significant source of fresh water is the water vapor created when the sun's energy evaporates water from the world's oceans. The atmosphere transports this water vapor over land where, when conditions are right, it falls from the sky as precipitation (ie. rain, snow, sleet, fog, etc.). The precipitation falls to the ground where several things can happen to it. Some of it will be evaporated soon after it hits the ground and become available to fall again at some other location.

Another part of it will be absorbed into the ground where a portion becomes available to plant roots. Much of this water is released back into the air in a process called evapo-transpiration, and is again available to fall as rain elsewhere. Part of the water that is absorbed forms the ground water which, depending on the nature of the local geology, can either stay in place as an underground reservoir, or flow down any geological gradient that exists like an underground river. Sometimes these waters emerge at the surface in the form of springs and join the surface runoff.

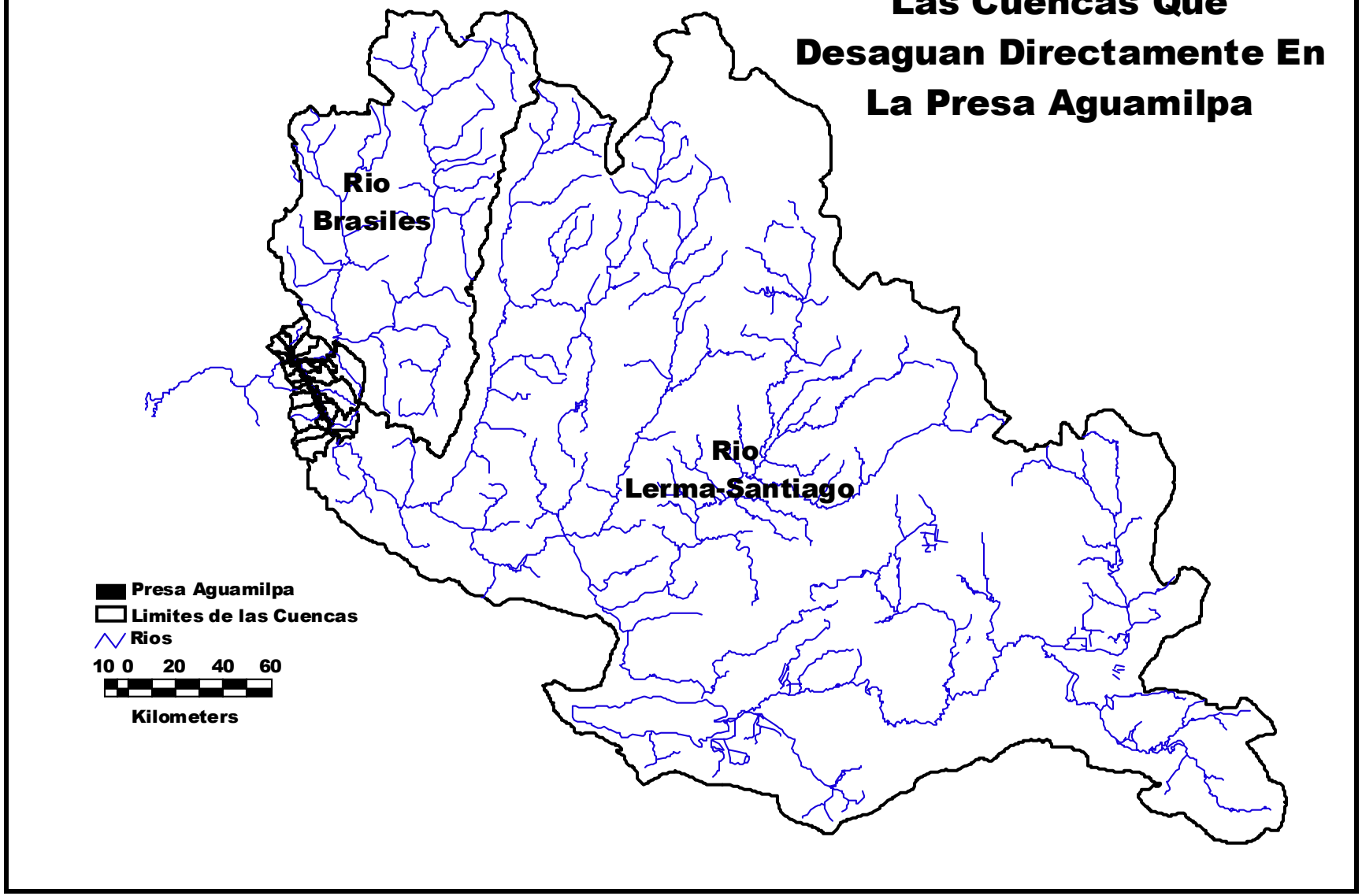
Mapa 1:

Cuenca Rio Lerma - Lago Chapala - Rio Santiago



Mapa 2:

Las Cuencas Que Desaguan Directamente En La Presa Aguamilpa



A third portion of the water that falls as rain will remain on the surface and flow downhill as runoff. This water eventually collects at the low point to form streams and rivers. Where the flow of a river is blocked for some reason the result is a lake or wetland. Some of these surface waters are absorbed into the ground and become part of the groundwater, and as was mentioned in the previous paragraph, some of the groundwater emerges from the ground to join the surface waters.

Eventually, after some short or long period of time that depends on a multitude of factors, the water returns to the ocean, where it mixes with the salt water and is no longer fresh water. It is once again available for evaporation at this point and the cycle starts over again.

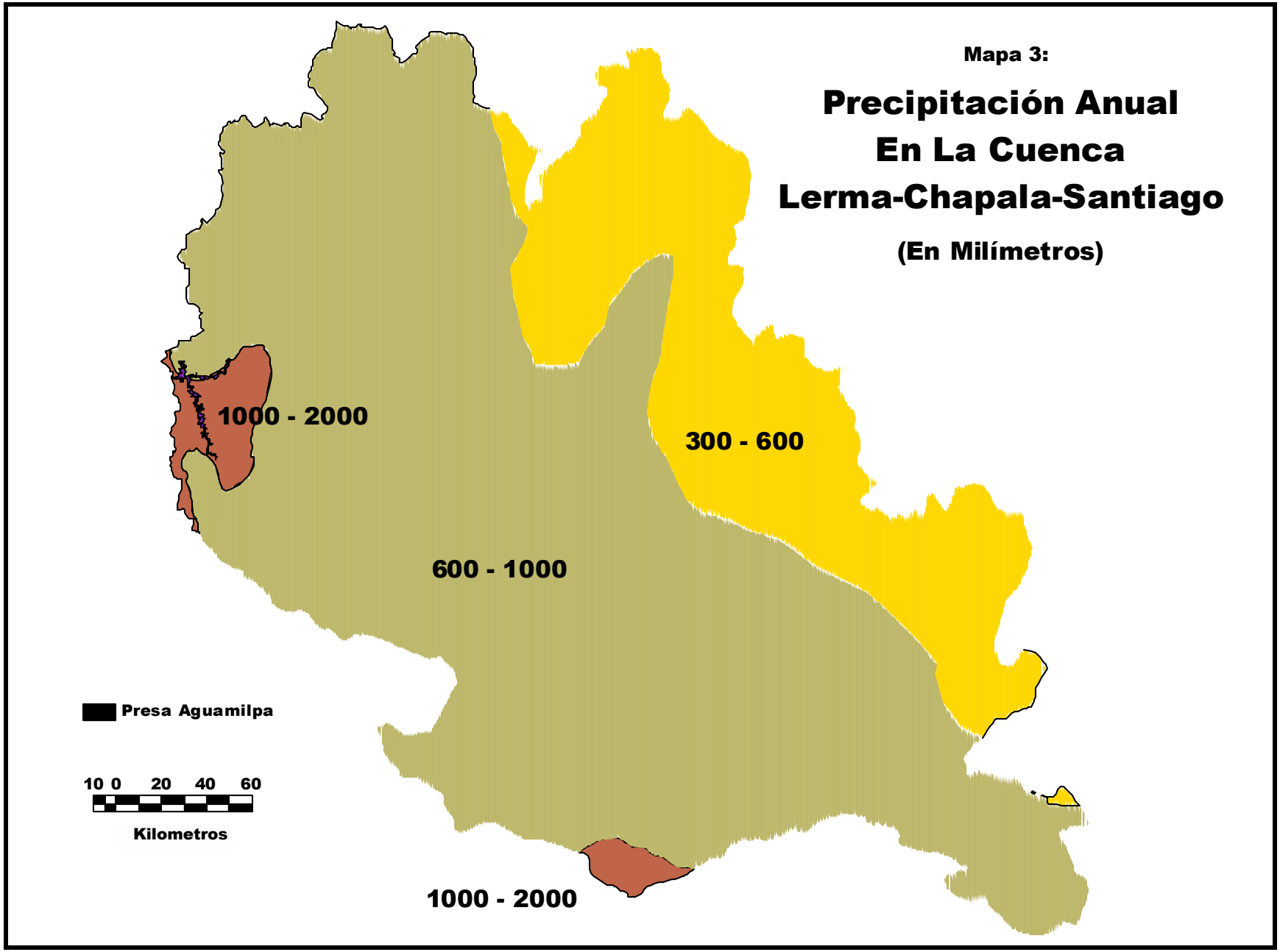
During the course of this cycle the water interacts with the land in many ways that effect both the land and the water. For example, through the process of wasting and erosion the flowing water is a dominant influence in sculpting the landscape into its current form. Over time this process destroys mountains and moves them into the sea. At the same time the water changes it's chemistry as it moves over the landscape and takes on different characteristics depending on the route that it has followed on it's journey back to the ocean.

Quite evidently, this is an enormously complex process. The strategy of this study was to examine the way this process plays itself out in the source regions of the Presa Aguamilpa. It was anticipated that we could thereby gain some insight into how these processes will influence the prospect of the fishery.

It is useful to divide the analysis of the watershed into two parts: the influences of natural processes outside the influence of species *homo sapiens*, and the influences of human beings. The former are long term processes, taking place on a time scale of eons, while the later are of very recent origin. The irony is that it is likely that the short tem human activities will have a much greater impact on the quality of the fishery than the millions of years of natural processes that have proceeded them.

Based on the description of the hydrologic cycle above, there are three closely related and interacting elements that are important to the quantity and quality of the water that eventually arrives at the Presa Aguamilpa. These elements are the atmosphere, the geology and the natural vegetation. It was the original intention of this study to examine all three of these elements in some detail to describe their impacts on the fishery. The curtailment of the project has made this impossible, and there was only time to collect data on the atmosphere and that in less detail than would have been ideal.

Map 3 shows the Annual Precipitation in the Rio Lerma-Lago Chapala-Rio Santiago watershed. The watershed falls within three rainfall zones: 300-600 mm/year. 600-1,000 mm/year, and 1,000-2,000 mm/year. The areas covered by each of the rainfall zones is shown in Table 1. It is interesting to note that the majority of the local sub-watersheds are


Mapa 3:
Precipitación Anual
En La Cuenca
Lerma-Chapala-Santiago
(En Milímetros)
1000 - 2000
300 - 600
600 - 1000
1000 - 2000
Presa Aguamilpa
10 0 20 40 60
Kilometros

located in the highest rainfall zone (1,000-2,000 mm/year).

Tabla 1: Precipitación En La Cuenca Lerma-Chapala-Santiago		
Precipitación (mm/año)	**Area ($Km.^2$)**	**Porcentaje**
300-600	27,871	23.9%
600-1,000	85,652	73.4%
1,000-2,000	3,125	2.7%

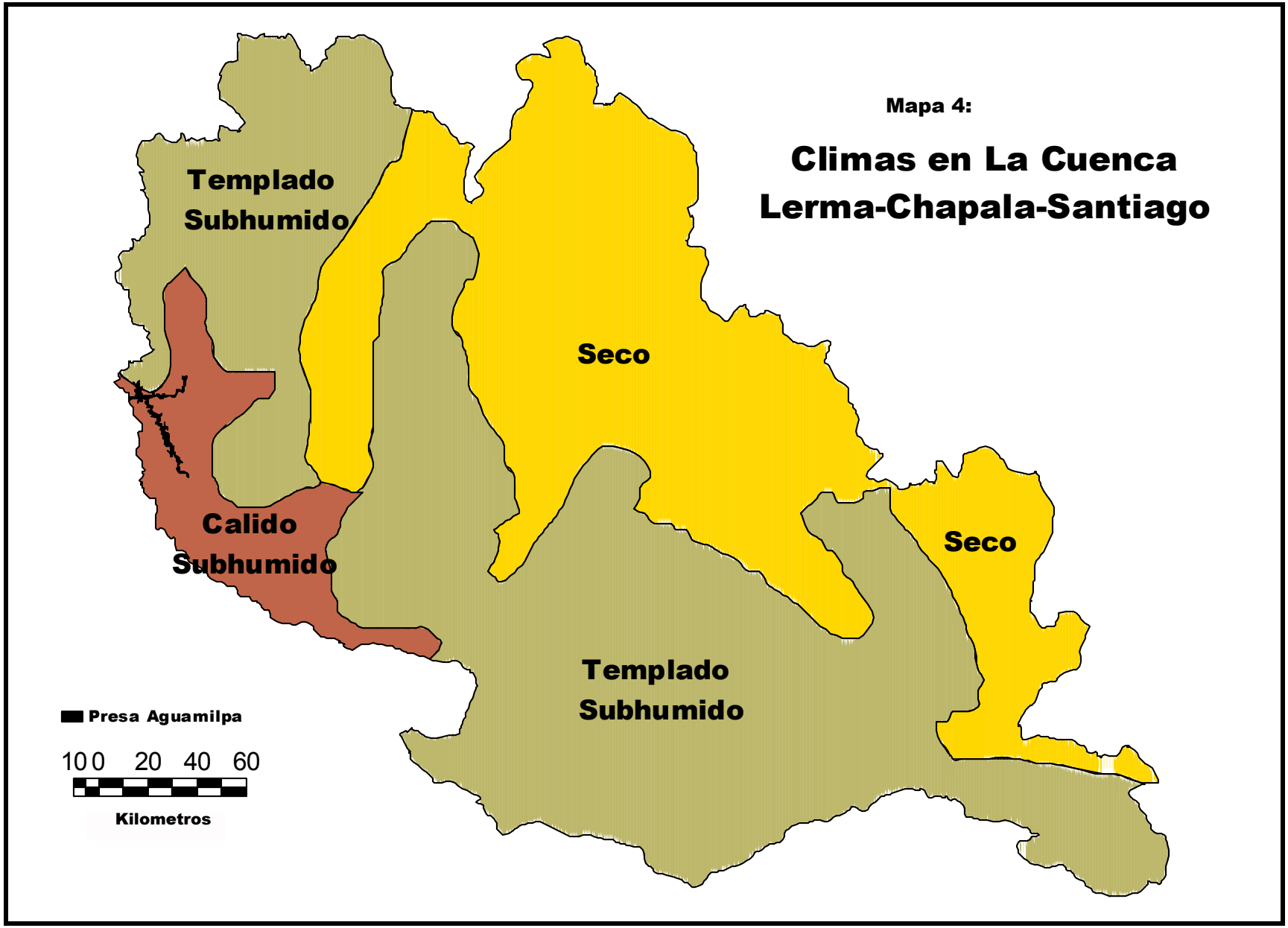
A somewhat different view of the atmospheric processes is shown in Map 4. This map shows the different climate zones found in the Rio Lerma-Lago Chapala-Rio Santiago watershed. Once again, there are three zones found in the watershed: Seco, Templado Subhumido, and Calido Subhumido. All three of these climate zones are relatively dry, with potential annual evapo-transpiration exceeding annual precipitation.

The difference between the climate map and the precipitation map is that the former incorporates temperature in its definition. This gives a more complete view of the actual state of the hydrologic cycle. Temperature is important because higher temperatures increase transpiration by plants and evaporation which results in less water being available for runoff and ground water recharge. Note that the shape of the climate zone boundaries is much more irregular than the precipitation zone boundaries. This irregularity reflects the influence of the topography due chiefly to differences in temperature at different elevations.

The aerial extent of the different climate zones is detailed in Table 2. Note that the distribution between the three zones is much more equal than the three zones in the Annual Precipitation shown in Table 1. This reflects the effect of temperature on the hydrologic cycle.

Tabla 2: Zonas Climaticas en la Cuenca Lerma-Chapala-Santiago		
Zona Climatica	**Area (km^2)**	**Porcentaje**
Seco	43,352	37.2%
Templado Subhumido	65,093	55.8%
Calido Subhumido	8,203	7.0%

An important fact relating to the life of the Presa Aguamilpa should be mentioned here. Dry areas generally tend to have higher erosion rates than wet areas. This is due to the relative scarcity of vegetation in dry areas. Vegetation fixes soil in place when it rains. Thus, though rain is less frequent in dry areas, it tends to move more sediment when it


Mapa 4:
Climas en La Cuenca
Lerma-Chapala-Santiago
Templado
Subhumido
Seco
Calido
Subhumido
Seco
Templado
Subhumido
Presa Aguamilpa
100 20 40 60
Kilometros

does fall. Since all of the watershed is relatively dry, the lifespan of the Presa Aguamilpa can be expected to be shorter than it would have been if located in a more humid watershed. This is one of the areas in which further investigation had been planned but which was cut short by the project termination.

Though the analysis of non-human influences is far from complete, we turn now to the evaluation of human impacts on the hydrologic cycle in the Rio Lerma-Lago Chapala-Rio Santiago watershed. Human beings have only exerted an influence in the watershed for a period measured in thousands of years. This is opposed to the time scale of hundreds of millions of years that processes discussed above have functioned. As was mentioned above, it is highly likely that despite this enormous difference in time scale, human activities are much more likely to influence the water quality and quantity in the Presa Aguamilpa than are the non-human processes. The reason is that the natural systems that form the basis to the hydrologic cycle have long ago reached a relatively stable balance. Human activities, on the other hand, tend to disrupt this long established stability.

But even speaking in terms of thousands of years overstates the time period during which human influence has been important to the watershed. Though pre-industrial man had the capacity to considerably modify his environment, principally through the use of fire, I have found no evidence to indicate this to be the case in the Rio Lerma-Lago Chapala-Rio Santiago watershed.[1] In reality it has only been in the last two centuries, with the rise of urban-industrial that human beings have been able to cause large changes in the natural processes that govern the functions of the planet. But the magnitude of change induced in that brief period is truly astonishing. In fact, the existence of the Presa Aguamilpa is itself a human intervention.

The national constitution of the Mexican Republic declares water to be a “Patrimony of the Nation.” Thus, the basic law of the land assigns the management of water use to the Federal Government. In theory this is quite straightforward. The reality is not quite so simple. Water is such a basic requirement for all aspects of human activity that its allocation is frequently a matter of grave local interest and frequent conflict. This is especially the case in areas where water is relatively scarce, which is the case in the Rio Lerma-Lago Chapala-Rio Santiago watershed. The way humans have organized themselves, therefore, has tremendous influence on the quantity of water that are allocated to which uses. The complexity of this issue is illustrated in Map 5, which shows the distribution of the Rio Lerma-Lago Chapala-Rio Santiago watershed by state. Table 3 shows the area occupied by each state.

Note that there are 10 state governments that have control over some portion of the watershed. Clearly the interests of all these different governments and their constituents do not perfectly coincide. Conflicts and compromises are inevitable. The situation is further complicated by the current attitude of the Mexican Federal Government to encourage decentralization of power to more local authorities, and a bias that it exhibits

[1] Note that the search has been far from exhaustive.


Mapa 5:
Estados En La Cuenca
Lerma-Chapala-Santiago
Fresnillo
SLP
Guadalupe
Zacatecas
Dur.
Zac.
ACal.
Aguascalientes
Nay.
Lagos de Moreno
Jal.
Leon
Guanajuato
San Fransisco
del Rincon
Guan.
Quer.
Zapopan
Irapuato
Queretaro
Guadalajara
Salamanca
Celaya
Ciudades
Presa Aguamilpa
10 0 20 40 60
Kilometros
Mich.
Mex.

Tabla 3: Estados en la Cuenca Lerma-Chapala-Santiago		
Estado	**Area (Km.^{2})**	**Porcentaje**
Jalisco	37,901.72	32.5%
Zacatecas	28,935.12	24.8%
Guanajuato	22,688.04	19.5%
Nayarit	8,939.19	7.7%
Michoacan	7,908.84	6.8%
Aguascalientes	5,478.63	4.7%
Durango	3,844.28	3.3%
Queretaro	653.74	0.6%
Mexico	238.55	0.2%
San Luis Potosi	59.89	0.1%
Total	116,648.00	

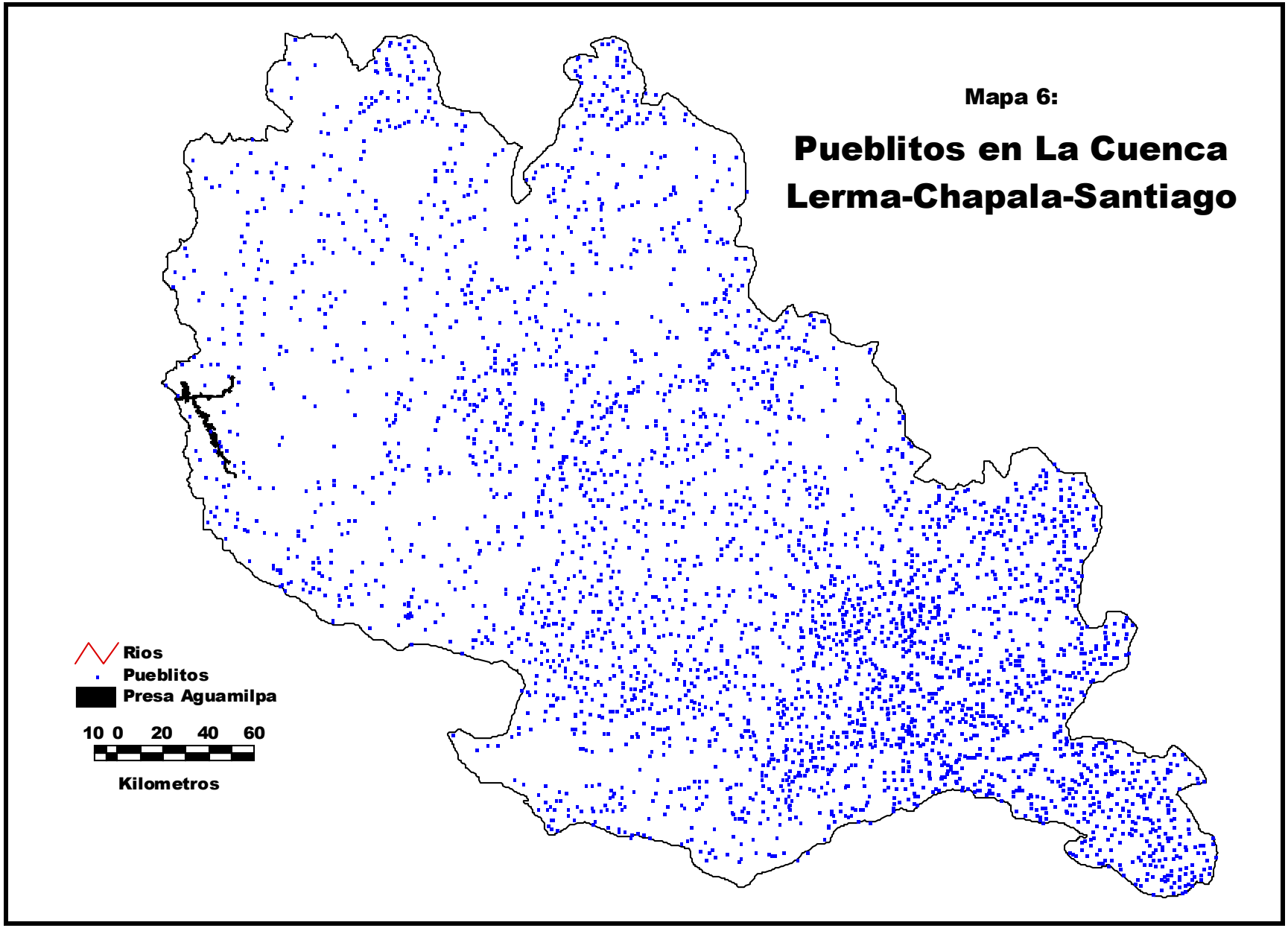
towards privatization. This was the thrust of the National Water Law enacted in 1992 and the Federal Law of Regulations in Water Matters of 1994[2]. These tendencies particularly affect the agricultural use of water, but similar tendencies are also influencing the urban use of water. While the new policy directions promise to allocate water to the "highest and best use," as defined by the market, it is far from clear how they will eventually effect the various user communities, including the fishery of the Presa Aguamilpa. Time will tell, but this promises to be a rich and active field of research and debate for the foreseeable future. The outcome of the debate is certain affect the Presa Aguamilpa fishery, and the cooperative would be well advised to follow it closely and participate where appropriate.

Examining where the people live provides another view of human impact on the watershed. In general, Mexicans live in settlements: villages, towns, and cities. It is uncommon to find isolated habitations in the countryside, as is the case in the United States and Canada. Maps 6 and 7 show the locations of the settlements in the Rio Lerma-Lago Chapala-Rio Santiago watershed. Table 4 presents a statistical summary of these data.

The settlements are classified into four different categories, based on population size: villages, towns, large towns and cities. Villages are small places, usually based on agricultural activities, with very few urban services (maybe a food store, cantina, and a primary school). Their environmental impact tends to be quite minimal.

Small towns are larger than villages, but still mainly rooted in the agricultural economy. They tend to have more urban services, such as agricultural chemical and equipment suppliers and repair shops, some local government services like a police office, a health clinic, primary and possibly a secondary school. There may be some packing and

[2] Saleth ,R. Maria and Ariel Dinar ,Water Challenge And Institutional Response: A Cross-Country Perspective, World Bank, 1999


Mapa 6:
Pueblitos en La Cuenca
Lerma-Chapala-Santiago
Rios
Pueblitos
Presa Aguamilpa
10 0 20 40 60
Kilometros

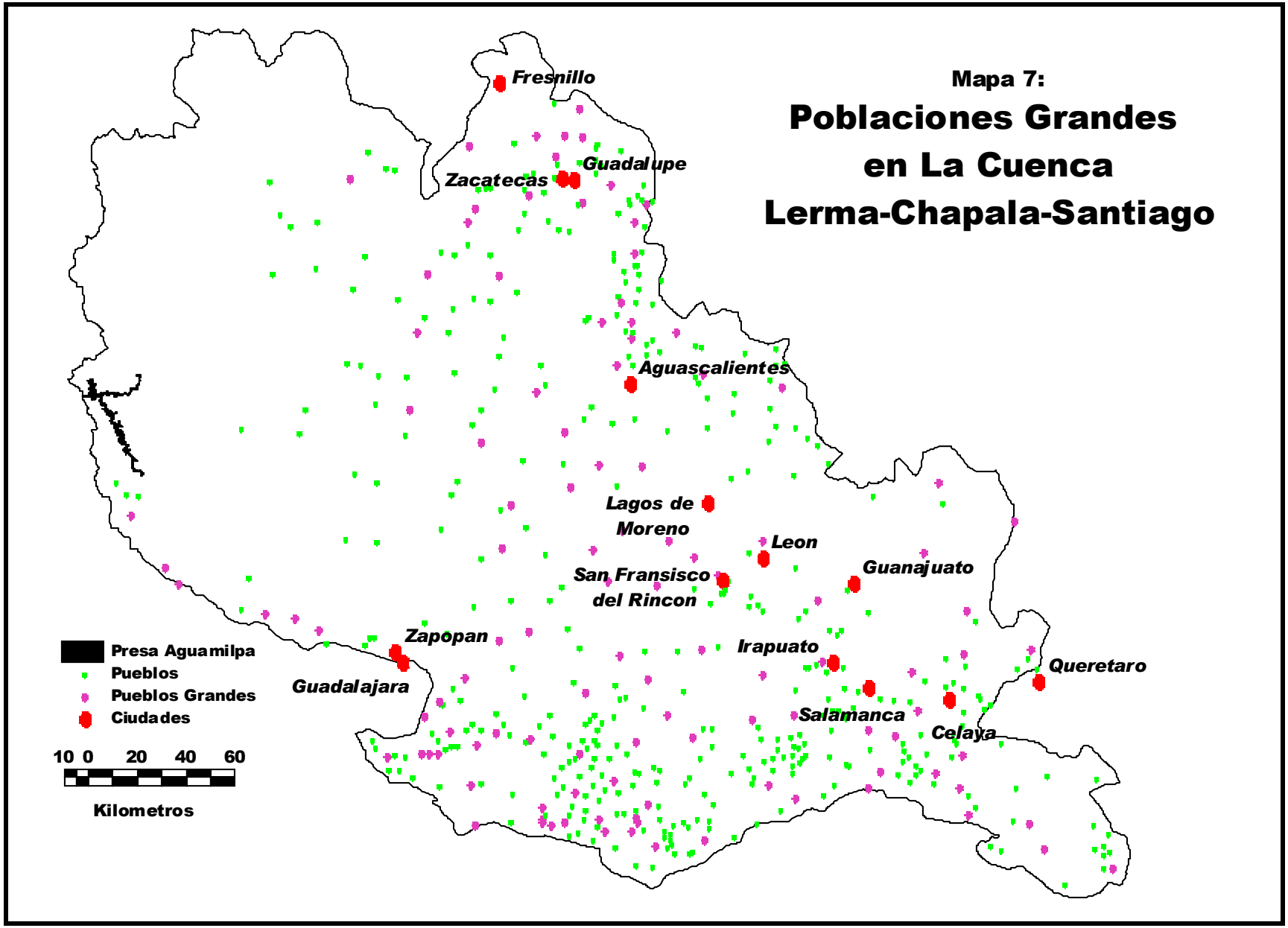

Mapa 7:
Poblaciones Grandes
en La Cuenca
Lerma-Chapala-Santiago
Fresnillo
Zacatecas
Guadalupe
Aguascalientes
Lagos de
Moreno
Leon
San Fransisco
del Rincon
Guanajuato
Zapopan
Guadalajara
Irapuato
Salamanca
Celaya
Queretaro
Presa Aguamilpa
Pueblos
Pueblos Grandes
Ciudades
10 0 20 40 60
Kilometros

Tabla 4:Poblaciones en La Cuenca Lerma-Chapala-Santiago	
Tipo de Población	**Numero en La Cuneca**
Cuidades	13
Pueblos Grandes	113
Pueblos	393
Pueblitos	3,533
Total	4,052

processing of agricultural products and some light manufacturing. They have a higher potential for environmental impact, but still minimal.

Large towns have a greater population than towns and more urban services. Typically they have a variety of state and local government offices, multiple schools, a wide variety of retail and service providers, considerable light industry and sometimes a few heavy industrial plants. Their environmental impact can be considerable.

Cities are very large concentrations of people with the full range of urban functions: local, state and federal government offices, universities, large numbers of schools, a variety of both light and heavy industry. Cities have the heaviest and most noticeable environmental impact.

These statements about the environmental impact of the different settlement sizes are somewhat gross generalizations. The original plan was to examine in some detail the impacts of the different urban areas, especially the cities. Factors like the types of industry they contain, the waste water treatment facilities, the degree of air pollution, the heavy metals they discharge, and other similar environmental impacts would provide insights into the future of the Presa Aguamilpa. The unfortunate curtailment of the project precludes these investigations.

Nevertheless, the simple location data in maps 6 and 7 provide the basis for some interesting observations. These data are presented in two separate maps for reasons of clarity. The sheer number of villages overwhelms the larger settlements when both maps are combined.

Careful examination of the two maps reveals that both the large settlements, and to a somewhat lesser degree, the villages are concentrated on the eastern and southern sides of the watershed. The north and west sides of the watershed are relatively sparsely populated.

By itself this observation is not particularly significant. When combined with another factor, however, it becomes more interesting. Personal observation, though I have little doubt that it can be documented, leads to the conclusion that virtually no water flows naturally

out of Lake Chapala into the Santiago River. Lake Chapala has been shrinking for at least the last ten years that I have been observing it and probably for longer than that. Other than evaporation, the Guadalajara Aqueduct extracts the only water that is removed from the lake for urban use in that city. This water is, presumably, treated before it is returned to the river. The conclusion is that all of the influences from the human population upstream of Lake Chapala are retained in the lake, and do not continue downstream where they would affect the Presa Aguamilpa.

The significance of this fact is illustrated in Maps 8 and 9 and in Table 5. These maps show the extent of the Rio Lerma-Lake Chapala section of the watershed and the settlements that they contain.

Tabla 5: Poblados en La Cuenca Rio Lerma Chapala			
Tipo de Poblado	**Numero en la Cuenca Lerma-Chapala**	**Numero en Todo La Cuenca**	**Porcentaje**
Cuidades	6	13	46.2%
Pueblos Grandes	56	113	49.6%
Pueblos	219	393	55.7%
Pueblitos	1832	3533	51.9%

Table 5 demonstrates that very nearly half of all the settlements of all sizes in the entire watershed are located in the Lerma-Chapala portion of the watershed. Given that this portion of the watershed should have minimal impact on the Presa Aguamilpa fishery this is very good news indeed. The implication is that the potential influence of human activities in the watershed on the presa is reduced in half. This is not a particularly encouraging fact for the future of Lake Chapala, but that is not our concern here. It does, however, indicate that the cooperative should pay close attention to the efforts that are being made to revitalize Lake Chapala because, in the unlikely event that these efforts should be successful in the near future, the outcome could cause major effects on the Presa Aguamilpa. The cooperative needs to look after its interests in these developments.

Examination of the settlements reveals one final positive indicator regarding the Presa Aguamilpa. Combining the data from the climate map with the settlement maps yields the data also presented in Maps 7 and 8 and in Table 6. These data show the settlements that are located in the dry climate zone. They do not include the settlements discussed above that lie in the Rio Lerma-Lake Chapala watershed, which also contains some area of dry climate, as these settlements have already been removed from consideration.

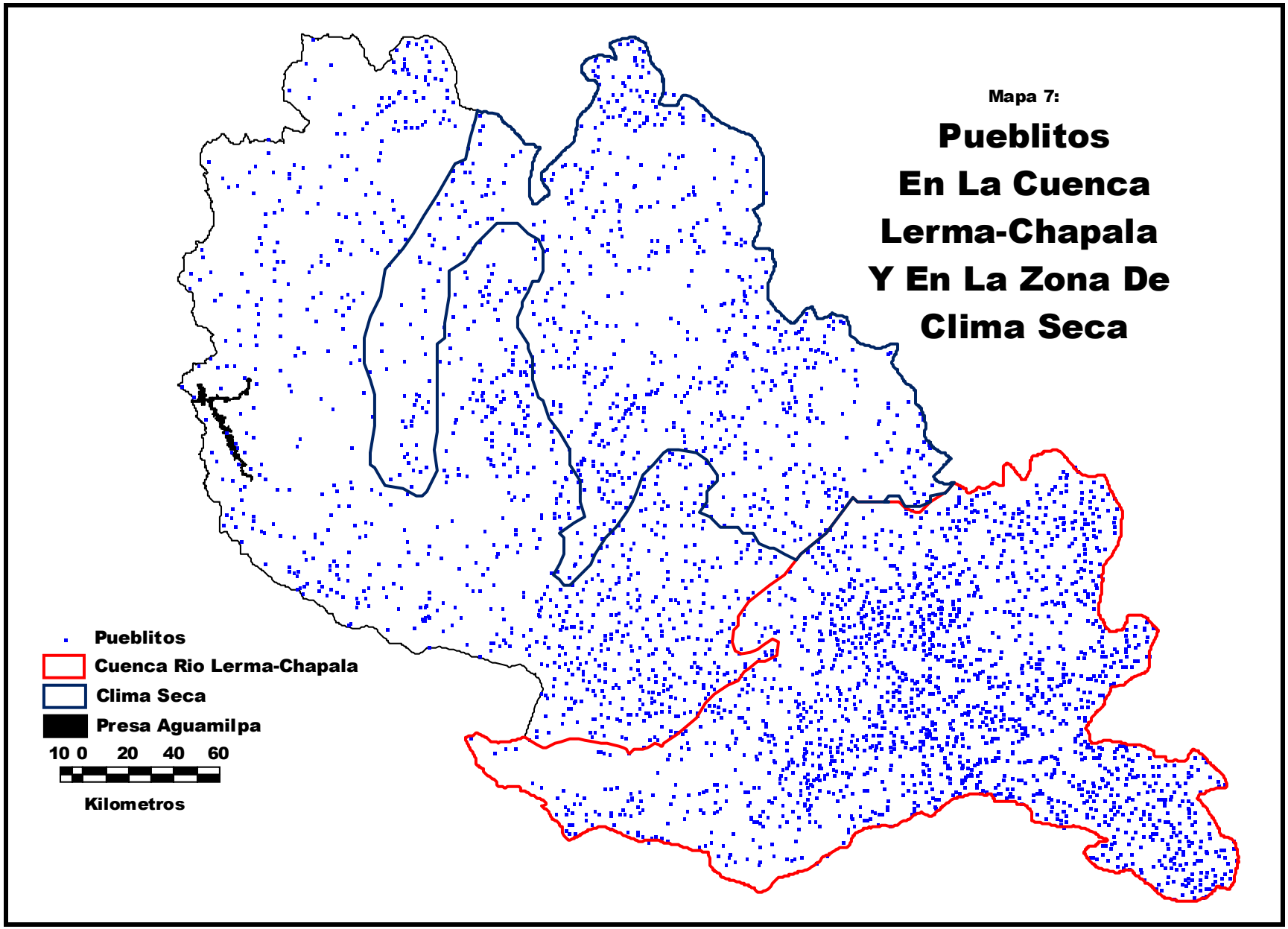
The significance of these data lies in the fact that areas with dry climates produce less runoff than other areas. Settlements located in dry areas will have an impact on a smaller quantity of water than settlements in more humid regions. It is possible that the smaller amount of water will contain the same quantity of contaminants, resulting in higher concentrations of contamination. Even so, it reduces the problem because there is a smaller quantity of water that will require treatment to remove these influences.

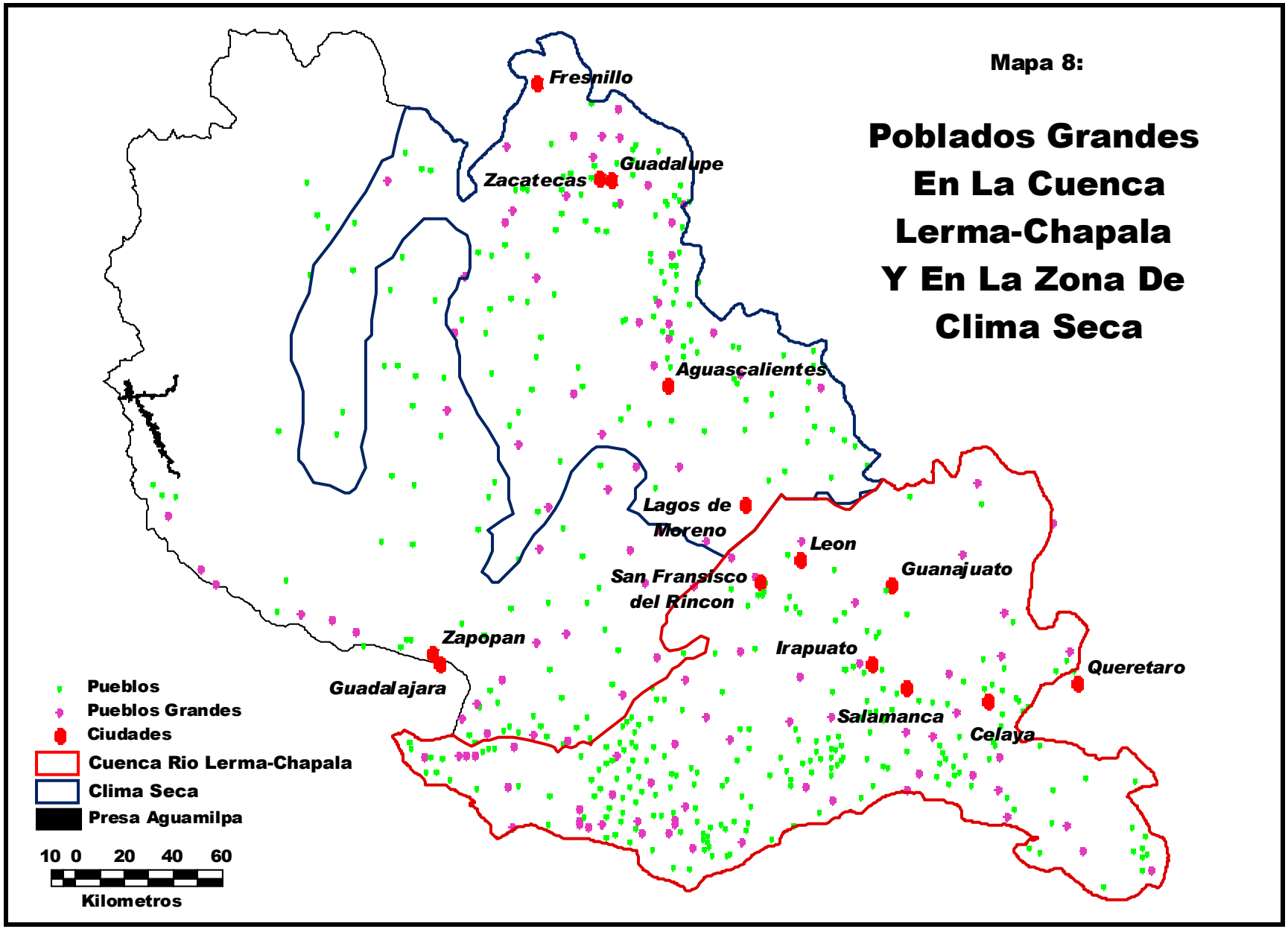
Tabla 6: Poblados en La Zona de Clima Seca			
Tipo de Poblado	**Numero en la Zona Seca**	**Numero en Todo La Cuenca**	**Porcentaje**
Cuidades	5	13	38.5%
Pueblos Grandes	31	113	27.4%
Pueblos	113	393	28.8%
Pueblitos	739	3533	20.9%

Table 6 reveals that approximately one third of the settlements of the watershed, outside the Rio Lerma-Lake Chapala basin, are located in the dry climate region. Combining these settlements with the settlements in the Lerma-Chapala watershed we can conclude that most of the water that arrives at the Presa Aguamilpa comes from areas which contain only about 20% of the settlements.

There is an assumption in this conclusion that direct correlation exists between the number of settlements and the human influences on the water quantity and quality, but it does not seem unreasonable. Given more time it would be desirable to test this assumption with direct data on hydrologic flows and water chemistry. Even without such definitive data there is reason to be optimistic about the properties of the water in the Presa Aguamilpa as the basis for a fishery. Such optimism is enhanced by the current population migration trends towards a net migration from the rural areas into urban areas. Should this continue, and there is every reason to think it will, the picture for the waters of the Presa Aguamilpa will be all the brighter.

Urbanization is by no means the only human influence on the watershed. The original plan also envisioned investigating rural activities such as agricultural practices and mineral exploitation. The unfortunate curtailment of the project has rendered this impossible.


Mapa 7:
Pueblitos
En La Cuenca
Lerma-Chapala
Y En La Zona De
Clima Seca
Pueblitos
Cuenca Rio Lerma-Chapala
Clima Seca
Presa Aguamilpa
10 0 20 40 60
Kilometros


Mapa 8:
Poblados Grandes
En La Cuenca
Lerma-Chapala
Y En La Zona De
Clima Seca
Fresnillo
Zacatecas
Guadalupe
Aguascalientes
Lagos de
Moreno
Leon
Guanajuato
San Fransisco
del Rincon
Zapopan
Guadalajara
Irapuato
Queretaro
Salamanca
Celaya
Pueblos
Pueblos Grandes
Ciudades
Cuenca Rio Lerma-Chapala
Clima Seca
Presa Aguamilpa
10 0 20 40 60
Kilometros