THE 26th CYCLE IN THE WATER TREATY MEXICO-USA, RELATED TO DROUGHT IN THE CONCHOS RIVER BASIN

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ABSTRACT
The Conchos River is one of the most important tributaries of the Río Bravo/Rio Grande (RB/RG), and its runoff constitutes a significant portion of the water flowing to the international dams.

Rainfall evaluation for the 26th cycle of the 1944 International Water Treaty (from October, 1997 to September, 2002, a five-year period), through the isohietal method, and SPI and PDSI drought indices, shows that rain amount has been deficient, and therefore not enough to fulfill the delivery volumes specified in the Treaty.

The valuations in hydrological annual terms, through SPI and PDSI methods, show that on wide areas of the basin, rainfall has been lower than mean long-term conditions, with the consequence of lower surface runoff toward reservoirs, and also lower infiltration into aquifers.

As a result, the hydrological RB/RG region as a whole, including the Conchos River basin, has been severely limited to satisfy water demand; if this condition does not get better in the short term, regional conditions could be harder, and only a deep change in water management will allow to mitigate damages and impacts due to this situation.

Introduction
The river Conchos is the main Mexican tributary of the RB/RG watershed, and as such, its contributions are very significant to cover the annual water quota specified in the International Water Treaty (IWT) between Mexico and the United States signed in 1944.

On the other hand, the same river is the main surface current of the state of Chihuahua and of Northern Mexico (Velasco, 2002; Velasco and Aparicio, 2002), and the reservoirs on it and its tributaries are the sources of water for the irrigated agriculture of the region (Figure 1).

Therefore, this river acquires great significance for the regional economic activities depending on water – agriculture, industry, cattle raising, urban and domestic uses -, and is decisive in order to preserve ecological and landscaping aspects (CNA, 2004). That is why, this basin is highly vulnerable to variations in rainfall and water availability, and when this happens and deficit conditions persist...
in rainfall and runoff, the effects can be devastating for the water dependent activities mentioned above.

In accordance to the IWT, the Mexican part of the basin should to contribute with around 432 million m$^3$/year to the main stem of the RB/RG, and a significant portion of this volume comes from the Conchos River (Velasco et al., 2002). For these effects, the IWT establishes that such volume should be delivered in five-year periods, and that, in case of an extraordinary drought, any undelivered volumes can be covered during the next period.

Rainfall in the 26th five-year period, from September 27, 1997 to September 26, 2002, has been lower than normal, and, as a consequence, insufficient runoff toward the reservoirs and the RB/RG has been produced. For this reason, it has not been possible to deliver the volumes specified by the IWT.

In this work rainfall is analyzed to characterize drought and evaluate the degree to which runoff reductions have been from a natural origin.

**Rainfall on the basin**

Figure 2 shows the isohetal behavior for the period 1970-2003, using rainfall records in 20 meteorological stations inside and in the periphery of the watershed. As can be appreciated, the lowest (Eastern) part in the basin had values below 300 mm, while in the mountain they registered values around 450 mm (CNA, 2004).

Figure 3 compares the values registered in the whole available period (1970-2003) for the same stations with those registered in the period 1998-2002. Here it is shown that almost the entirety of the basin was below 90% of the historical value (80% in absolute terms), and that a smaller significant part below 80%. This is a first symptom that during the 26th cycle, rainfall was lower than expected. The subjective regional perception of lower rainfall in the period acquires a quantitative character with this isohetal analysis.

![Figure 2.- Historical yearly mean rainfall, from 1970 to 2003, in millimeters.](image)

![Figure 3.- Rainfall percentage for the 26th hydrological cycle (1998-2002), related to historical period 1970-2003.](image)
Drought Indices
For space limitation reasons, one of the meteorological stations will be taken as typical or representative, to exemplify the results of obtaining the drought index. This station is Delicias (ID 08027, 28.18°N, 105.50°W, and 1,165 masl), located approximately in the geographic center of the basin.

Table 1. - Conventional dimensionless values of the SPI for any time scale, and of the PDSI (NDMC, 2003; Hayes, 2000).

<table>
<thead>
<tr>
<th>SPI Value</th>
<th>Condition</th>
<th>PDSI Value</th>
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</thead>
<tbody>
<tr>
<td>+2.00 or more</td>
<td>Exceptionally humid</td>
<td>+5.00 to +6.00</td>
</tr>
<tr>
<td>+1.50 to +2.00</td>
<td>Extremely humid</td>
<td>+4.00 to +5.00</td>
</tr>
<tr>
<td>+1.20 to +1.50</td>
<td>Very humid</td>
<td>+3.00 to +4.00</td>
</tr>
<tr>
<td>+0.80 to +1.20</td>
<td>Moderately humid</td>
<td>+2.00 to +3.00</td>
</tr>
<tr>
<td>+0.50 to +0.80</td>
<td>Incipient humidity</td>
<td>+1.00 to +2.00</td>
</tr>
<tr>
<td>+0.50 to -0.50</td>
<td>normal condition</td>
<td>+1.00 to -1.00</td>
</tr>
<tr>
<td>-0.5 to -0.8</td>
<td>Incipient drought</td>
<td>-1.00 to -2.00</td>
</tr>
<tr>
<td>-0.8 to -1.2</td>
<td>Moderate drought</td>
<td>-2.00 to -3.00</td>
</tr>
<tr>
<td>-1.2 to -1.5</td>
<td>Severe drought</td>
<td>-3.00 to -4.00</td>
</tr>
<tr>
<td>-1.50 to 2.00</td>
<td>Extreme drought</td>
<td>-4.00 to -5.00</td>
</tr>
<tr>
<td>-2.00 or less</td>
<td>Exceptional drought</td>
<td>-5.00 to -6.00</td>
</tr>
</tbody>
</table>

For comparative effects among the two indexes here tested, Table 1 shows conventional values related to each stage or phase of drought.

SPI
This index (McKee et al., 1993; Edwards and McKee, 1997), evaluated for three- and twelve month time scales, is shown in Figure 4. Here, a persistence in negative values can be appreciated. Although they don't reach extreme values, neither they are enough to restore the normal water conditions, because water deficiencies are present since 1993 and there has not been sufficient recovery.

Figure 5 shows the spatial distribution of the index in a three-month scale, for September, 2000; these values reflect what happened in the July-August-September period of 2000, compared with the same period of the whole historical record. It is observed that only in the highest part in the watershed normal water scenarios were present, while in the rest, index values show drought, from incipient to extreme conditions and even exceptional drought.

Figure 4.- SPI for three- and twelve-month scales, from October, 1997 to September, 2002, at Delicias Station.
Figure 6 shows the spatial distribution of SPI in a twelve-month scale, for the period from October, 1999 to September, 2000. For this time scale, although highly negative values are not reached, neither have they indicated conditions of abundant rainfall; this means that deficit conditions persist. Surprisingly, year 2000 as a whole was a dry year, but this is disguised because June was very wet due to abundant rains; nevertheless, this was not enough for the recovery to normality levels (Velasco, 2002).

Similar conditions, with the characteristic variations in time and space for each case, were present in the other analyzed stations, so it can be said that drought evaluation with SPI method for the period showed situations of deficiency, from mild to extreme.

PDSI
The behavior of this index (Palmer, 1965) for the five-year period is shown in Figure 7, for the same station Delicias. It is appreciated that during this period, in spite of the stages of relative abundant humidity, conditions of insufficient water persisted, so as a result, there was not sufficient soil humidity and then drought was present.

In spatial terms, distribution of PDSI in the watershed is as shown in Figure 8; here it is appreciated that, similarly to what is shown in Figure 5, with the exception of small areas of the basin, important water deficiencies were present in the annual period from October, 1999 to September, 2000 despite the abundant rain in June, 2000. Qualitatively, both figures are similar, and they indicate the presence of drought during that year period.
In accordance to the conventional values of Table 1, it is appreciated that, at least in half of the basin, rainfall was insufficient during that period, so PDSI reached values from -2, and even -4, which indicate moderate to extreme drought conditions.

Seemingly, according to the graphs in Figures 4 and 7, and the maps in Figures 6 and 8, PDSI shows more severe values than SPI. It is probable that PDSI overvalues conditions of water inadequacy, because this index was designed for other environment conditions, where rainfall is enough to sustain the agricultural activity without the artificial water application. In general, these conditions don't happen in the basin of the Conchos River, except for small areas in the mountainous highlands (where rainfall is less than 400 mm/year), so it can be said that, without artificial irrigation, crops wouldn’t prosper. Certainly, natural vegetation exists, but it is adapted to the prevailing conditions of scarce precipitation, and it persists even in the most severe periods of humidity.

**Effect of drought conditions in runoff toward RB/RG main stem**

Table 2 shows a summary of runoff and water contributions to the main stem of RB/RG, accounted for IWT effects (CILA, 2004; CNA, 2004).

According to available information, hydrological year 2000 was contrasting: as a whole, it seems a humid year, but drought analysis shows that rainy season was below expected values; explanation can be because June was wetter than normal, and this fact masks the results; nevertheless, rain and runoff were so that water contribution from the Conchos River to the total of the IWT for RB/RG was 32%, while during 1999 contribution was up to 57% (less dry year) and in year 2001 contribution was just 26%, a drier year, according to Figures 4 and 7.

In spite of the two years (2000 and 2001) which were wetter than others within the cycle, and made possible to fulfill the annual water quota, for the whole five-year period, accumulated deficit was 376 millions m³. Of
the total volume that Mexico contributed to the main stem of the RB/RG during the five year period, the Conchos River watershed contributed with 35%.

Table 2. – Water volumes contributed during the 26th five-year cycle, in the Mexican part of the RB/RG basin, which includes the Conchos River (CNA, 2004; CILA, 2004).

<table>
<thead>
<tr>
<th>YEAR IN CYCLE</th>
<th>YEAR (from October to September)</th>
<th>RIO BRAVO/RIO GRANDE BASIN, MEXICAN PART</th>
<th>CONCHOS RIVER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VOLUME TO TRANSFER ACCORDING TO IWT</td>
<td>ANNUAL DELIVERED VOLUME</td>
<td>ACCUMULATED DELIVERED VOLUME</td>
</tr>
<tr>
<td>1</td>
<td>97-98</td>
<td>431.7</td>
<td>148</td>
</tr>
<tr>
<td>2</td>
<td>98-99</td>
<td>431.7</td>
<td>204</td>
</tr>
<tr>
<td>3</td>
<td>99-00</td>
<td>431.7</td>
<td>619</td>
</tr>
<tr>
<td>4</td>
<td>00-01</td>
<td>431.7</td>
<td>588</td>
</tr>
<tr>
<td>5</td>
<td>01-02</td>
<td>431.7</td>
<td>224</td>
</tr>
<tr>
<td>SUM OR AVERAGE</td>
<td></td>
<td>2158.5</td>
<td>357</td>
</tr>
</tbody>
</table>

This is an important proportion, if it is considered that inside the basin there were severe restrictions for all uses, especially for agriculture, limiting sensitively crop surfaces and assigned volumes.

Conclusion
The five-year period comprehended from October, 1997 to September, 2002, equivalent to cycle 26 of the IWT, in strictly meteorological sense, expressed in rainfall values and mean monthly temperature, was a period with deficiencies of water, quantified so much in the “efficiency” of rain, evaluated through SPI, as in relation to the soil humidity necessary to satisfy water crops requirements and the environment (temperature, radiation, etc.), evaluated through PDSI.

For both indices, drought evaluation shows periods and geographical areas with deficiencies from mild and moderate to extremely dry. The consequence of these persistent conditions was the decrease of runoff in surface currents, insufficient to fulfill the capacity of the basin reservoirs and to fulfill the water volumes specified in the IWT. That is why water demand also overcame the offer for the diverse uses, and that contributed decisively to the impossibility of completing the quota committed according to the Treaty on the whole five-year period. It can be concluded that the persistent and recurrent natural conditions of drought, beyond other artificial considerations, have been the basic reasons for the lack of enough water for the local and regional necessities, as well as for the international commitments.

References


