The effect of time scale on the determination of water availability in gauged water basins

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Abstract

An increasing number of basins in different latitudes face serious problem of water overexploitation. Establishing the limits until which it is possible to make sustainable use of surface water resources is transcendental both for basins that are starting their development of hydraulic infrastructure and for those that are already developed. It is for this reason that the Mexican Secretariat of the Environment and Natural Resources emitted the Official Mexican Norm NOM-011-CNA-2000, which establishes the procedure to determine the availability of national waters. The objective of this work is to analyze the effect of time scale in the determination of the availability of surface waters in basins through the method established by the Mexican norm. The basin used for the development of this work was the medium-upper basin of the Florido River, in the northern Mexican state of Chihuahua. The basin was divided into Upper Sub-Basin (U-SB1), which lacks infrastructure for water use, and Middle Sub-Basin (M-SB2), in which Irrigation District 103 and its well-developed infrastructure are located. The availability of surface water in both sub-basins was determined at annual and monthly time scales. The downstream flow determined in regulatory or water availability terms for sub-basin U-SB1 was 104 Mm^3 both for the annual and monthly time scales. The downstream flow determined in terms of water availability for sub-basin M-SB2 was 17.7 Mm^3 at the annual scale and 41.3 Mm^3 at the monthly scale. These results differ by 57.14% regarding the monthly scale, and so the chosen time scale is very important in basins with significant water use. The inconsistency between the results obtained at different time scales is due to the fact that the annual time scale does not consider the temporal distribution of water demand throughout the year with respect to the existence of available volumes of surface water. It is then concluded that the availability of surface water in basins must be determined at a monthly temporal time scale, especially in basins that have infrastructure for the use of surface water. The use of an annual time scale in basins that have minimal water use is functional when trying to determine the annual availability of surface water; however, it is not possible to know its distribution throughout the year. For purposes of planning the use of the resource or reordering its distribution among the user sectors, it is recommended that the monthly time scale be used as it produces more reliable results in accordance with the stated purpose.

Keywords

Basin management, hydrological evaluation, natural flows, natural water availability, Water availability.

Introduction

The planning, management and sustainable use of natural resources, especially water, are of incalculable value and urgency for humanity; the fate of future generations depends on them. In order to perform the management of water resources in a hydrological basin, it is necessary to determine their natural availability and occurrence in time and space, but it is also necessary to establish the threshold until which it is possible to make sustainable use of them (Carabias, *et al*., 2005). In many basins with developed water-use infrastructure, as well as in the institutions that manage them, it will be necessary to reform the current water-use schemes in order to guarantee the continuity of their development and growth.

Water availability can have different meanings depending on the focus and timescale to which they refer. Thus, according to the Mexican Secretariat of the Environment and Natural Resources (SEMARNAP, 2000), the mean natural surface water availability of a region is measured in terms of virgin flows (the water carried by the rivers over the course of a year). Availability, however, can also be the amount of water that could be used to satisfy the demands or concessions of a specific time and place in a basin. In congruence with the latter definition, the water available in a dam or basin at the beginning of the agricultural year is that which is distributed among concessionaires in that particular year (CNA, 2000).

In juridical-administrative or regulatory terms, the Official Mexican Norm NOM-011-CNA-2000 of the Mexican Secretariat of the Environment and Natural Resources (SEMARNAT, 2002) establishes that the mean annual surface water availability in a given part of a basin is the amount of water that results from subtracting the volume granted in concessions downstream from the annual mean flow that goes downstream. If there are no concessions in a basin, the water availability (in juridical-administrative or regulatory terms) is the accessible portion of the natural flows minus the volume of these flows that the environment requires. According to this, the concessions that can be authorized in a basin must not surpass it.

In the Texan Water Availability Modeling System, the availability of water in regulatory or permitting terms results from subtracting the total water rights or authorized concessions from the volume of natural flows (TNRCC, 1997 and TNRCC, 1998). In terms of planning, the volume to be deduced can vary from the total of concessions. Flows not assigned o specific sites are the ones that remain uncommitted after all existing water rights have been satisfied both upstream and downstream (TNRCC, 1997 and TNRCC, 1998).

The availability of water in juridical-administrative or regulatory terms has gained importance in the past years due to the need to establish control in basins with high levels of water use. The general concept can be similar throughout the world, but every country, region and individual basin changes it to its specific problems and legal framework. In Mexico, the Official Mexican Norm NOM-011-CNA-2000 (SEMARNAT, 2002) exists to achieve this very purpose by establishing the procedure to calculate the availability of national waters.

The objective of this document is to analyze the effect of annual and monthly timescales in the determination of surface water availability in hydrological basins, through the procedure established in the Official Mexican Norm NOM-011-CNA-2000. The subject of regulating the use of water resources is an international priority, and so the results of this work can be useful in countries that are in process of developing and implementing regulation mechanisms and because of that are developing local norms like the one analyzed here.

Description of the basin

The Florido River basin is located in the southern region of the State of Chihuahua. This river is a tributary of the Conchos River, that itself is a tributary of the Bravo River. The Bravo River is a territorial limit between the United States and Mexico, and as such its basin is located in both countries and its water resources are shared as established by a bi-national water agreement (CILA, 1944).

The study zone corresponds to the medium-upper basin of the Florido River, from its origin in the State of Durango until its end in ciudad Jiménez, Chih., where it meets the Jiménez Hydrometric Station (Figure 1). It has an area of 7,395 km^2 and contains Irrigation District 103, which has a surface of 8,238 hectares and is irrigated with surface waters from the San Gabriel and Pico de Águila dams (CNA, 1997). The Irrigation Units (IUs), constituted by the farmlands along the river basin, also make use of surface water. Finally, there are some communities that use the river’s water for public supply or for livestock farming.

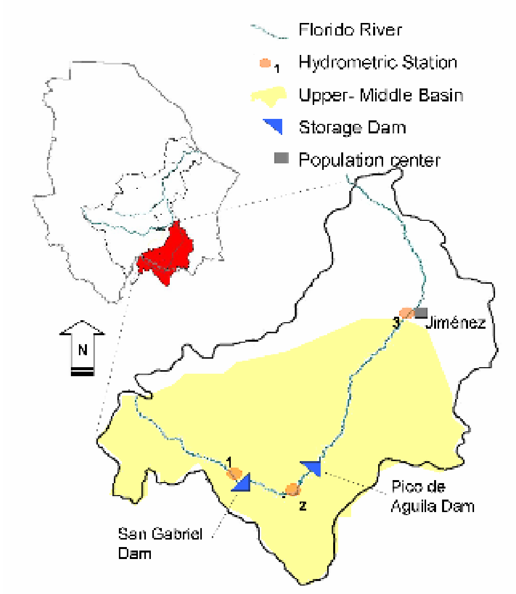

Figure 1. Study area location.

Hydrometry of the basin

According to the National Surface Water Data Bank (IMTA and CNA, 2002), there are three hydrometric stations in the medium-upper basin of the Florido River, located along the main river bed: 1) Puente Ferrocarril (HEPF), 2) San Antonio (HSSA) and 3) Jiménez (HSJ). The HSPF station has records from 1953 to the present day; HSSA, however, stopped operating in 1985 and no records have been made since that year. The HSJ station has records spanning from 1950 to 2006.
Additionally, there are hydrometric records from the San Gabriel and Pico de Águila dams that have been made since they were built in 1980 and 1994, respectively. The HSPF station measures the inflow to the San Gabriel dam, and because of their proximity the records for both are considered to represent a single control point with information spanning from 1953 to 2006.
The HSSA station and Pico de Águila dam are distant from each other, and because of this they were not integrated into a single control point. Since these sites have incomplete records for the required period of time, they were not considered for purposes of the present analysis. As a result of the hydrometric record analysis, the study area was divided into two sub-basins: 1) from the origin of the Florido River to the San Gabriel dam (U-SB1), and 2) from the San Gabriel dam to the Jiménez Hydrometric Station (M-SB2).

Determination of natural flows

According to the Official Mexican Norm NOM-011-CNA-2000, natural flows constitute the volume of water that is naturally captured in a hydrological basin and transforms into surface flow, which is later collected by the basin's own natural draining system (SEMARNAT, 2002). The natural flow (Cp) in gauged basins is determined through the following expression, which incorporates the existence of surface water accumulation in the basin:

$$Cp = V2 + Exb + Ev - V1 + Ex - Im - R + \Delta V$$

Where V1 is the annual gauged volume in the upstream basin, V2 is the annual gauged volume in the downstream basin, Exb is the annual volume granted in concessions, Ev is the annual evaporation, Ex is the annual exported volume, Im is the annual imported volume, R is the annual volume of returns, and ΔV is the change in accumulated water. This equation is derived from the general mass conservation equation, and is also applicable to the monthly time scale.

Surface water availability in the basin

The Mexican norm establishes that the water available in a given place of a basin is the difference between the mean annual flow volume and the current volume (in the specific year in which the study is performed) that has been committed in concessions downstream (SEMARNAT, 2002). If this difference is negative, it represents a deficit. The mean annual availability (D) of surface water in a basin is calculated by the following equation:

$$D = Ab - Rxy$$

Where Rxy is the current annual volume committed downstream. An availability study must be dynamic and periodically updated, the volume of water granted in concessions could change with time (increase or decrease) and with it the current annual volume committed downstream. The NWL rules establish that the study of water availability in a basin must be updated at least every 6 years (CNA, 2004a).

The mean annual flow volume of the downstream basin (Ab) is calculated considering a hypothetical scenario in which the mean annual water use equals the total volume of concessions. The mathematical expression for this is:

$$Ab = Cp + Ar + R + Im - (Extr + Ex + Ev + \Delta V)$$

Where Cp is the mean annual natural flow, Ar is the annual flow gauged in the upstream basin, Extr is the annual surface water extraction volume, Ev is the annual evaporation, Ex is the annual exportation volume, Im is the annual imported volume, R is the annual volume of returns, and ΔV is the change in accumulated water. This equation is also derived from the mass conservation principle and is also applicable to the monthly time scale.

Surface water use in the basin

According to the Public Record of Water Rights (CNA, 2004b), sub-basins U-SB1 and M-SB2 have concessions for 6.5 Mm^3 and 164.45 Mm^3, respectively. For the time period between 1982 and 2000, an annual mean use of 2.275 Mm^3 was estimated for sub-basin U-SB1. Agricultural production in the IUs received 89.04% of the volume, while the remaining 10.96% was destined to livestock farming and urban public use (CNA, 2006). An annual mean use of 108.6 Mm^3 is estimated for sub-basin M-SB2. Irrigation district 103 received 81.56% of the distributed volume, while 18.43% was used in the IUs and only 0.01% was destined to livestock farming and public urban use (CNA, 2006).

Evaporation and changes in accumulated water

From 1982 to 2002, the San Gabriel dam presented a mean annual evaporation of 16.2% of the water volume that entered the dam, while in Pico de Águila this percentage was 6.34% from 1994 to 2002. In the case of the latter dam, the mean accumulation during this period was in the order of 40% of the dam's storage capacity. The accumulation change was determined for the same period of time as the evaporation, both of them from the storage records of both dams (IMTA y CNA, 2000).

Imported and exported water

There are no water exports to other basins from the medium-upper basin of the Florido River; all that leaves the system is included in the mass balance equation within the annual volume gauged in the downstream basin. Also, this part of the basin receives no water imports from adjacent basins.

Return

In the study zone, no return flows were considered from urban public use. This is because the use of surface water for this purpose is limited and the communities in this area are very small. However, agricultural activity using greater volumes of water can generate return flows. This will depend on the efficiency of the hydraulic infrastructure used to conduct and distribute water, as well as on the method by which water is applied to the irrigation lands. Sub-basin U-SB1 has no return flows while M-SB2 does, because of the flows generated by the irrigation district located in the latter. It was determined through the correction of the annual hydrogram of mean monthly natural flow that 30% of the water volume used in irrigation of the basin returned to the river during the period of analysis, as detailed in a work developed by Silva-Hidalgo *et al*. (2008).

Results and Discussion

Annual mean natural flow in sub-basin U-SB1

The annual mean natural flow calculated for the analysis period in sub-basin U-SB1 is shown in Table 1. The natural flow determined using the monthly time scale was 119.9 Mm^3.

Table 1. Natural flow calculated for sub-basin U-SB1

Subbasin		Cp	Ar	Extr	R	Im	Ex	Ev	Δv	Ab
		Million cubic meter								
U-SB1. Florido river: From its origin to San Gabriel Dam	January	1.7	0.0	0.059	0.0	0.0	0.0	1.153	-1.4	1.889
	February	1.1	0.0	0.166	0.0	0.0	0.0	1.336	-5.7	5.275
	March	1.0	0.0	0.198	0.0	0.0	0.0	1.763	-8.0	6.891
	April	0.9	0.0	0.335	0.0	0.0	0.0	1.892	-13.0	11.522
	May	1.3	0.0	0.450	0.0	0.0	0.0	1.809	-16.5	15.190
	June	2.7	0.0	0.296	0.0	0.0	0.0	1.743	-8.5	8.696
	July	23.4	0.0	0.279	0.0	0.0	0.0	1.545	13.6	7.971
	Agoust	39.0	0.0	0.232	0.0	0.0	0.0	1.521	19.3	18.030
	September	37.1	0.0	0.234	0.0	0.0	0.0	1.559	14.2	21.099
	October	8.8	0.0	0.077	0.0	0.0	0.0	1.537	-1.7	8.865
	November	1.7	0.0	0.022	0.0	0.0	0.0	1.349	-0.8	1.062
	December	1.1	0.0	0.025	0.0	0.0	0.0	1.192	-0.4	0.294
	Annual	119.9	0.0	2.4	0.0	0.0	0.0	18.4	-8.9	106.8

Figure 2 shows the annual hydrogram of monthly mean natural flow as well as the monthly distribution of mean extraction in sub-basin U-SB1 for the period of analysis. It is observed that all extraction was satisfied by natural flows. During no month was the extraction in this sub-basin greater than the natural flows, so practically all natural flow was accumulated in the San Gabriel dam.

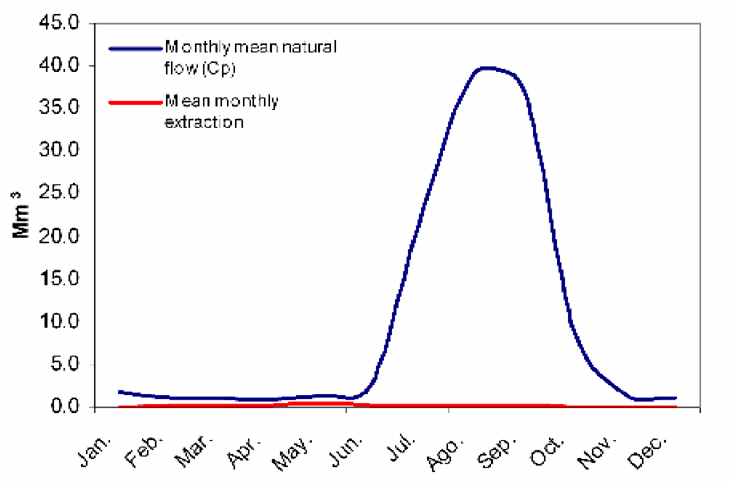

Figure 2. Hydrogram of monthly mean natural flow and mean monthly extraction

Annual mean natural flow in sub-basin M-SB2

The annual mean natural flow calculated for the analysis period is sub-basin M-SB2 is shown in Table 2. The annual mean natural flow determined using the monthly time scale was 59.9 Mm^3, considering that 30% of the volume used in irrigation returns to the river.

Table 2. Natural flow calculated for sub-basin M-SB2

Sub-Basin		Cp	Ar	Extr	R	Im	Ex	Ev	Δv	Ab
		Million cubic meter								
M-SB2. Florido river: From San Gabriel Dam to HSJ.	January	2.7	1.889	4.172	0.4	0.0	0.0	0.206	-0.4	1.292
	February	1.7	5.275	7.437	1.0	0.0	0.0	0.236	-0.2	0.710
	March	0.3	6.891	9.362	1.7	0.0	0.0	0.329	-3.0	0.069
	April	0.4	11.522	13.631	2.6	0.0	0.0	0.336	-1.4	0.042
	May	1.0	15.190	17.002	3.6	0.0	0.0	0.363	-1.6	0.691
	June	3.6	8.696	11.195	2.4	0.0	0.0	0.359	1.1	2.234
	July	10.3	7.971	11.223	2.6	0.0	0.0	0.371	2.5	7.659
	Agoust	14.7	18.030	12.481	3.8	0.0	0.0	0.354	2.6	21.446
	September	12.1	21.099	12.018	2.6	0.0	0.0	0.354	-0.2	23.382
	October	8.0	8.865	5.130	0.6	0.0	0.0	0.321	-0.1	12.677
	November	2.6	1.062	2.740	0.3	0.0	0.0	0.246	0.2	1.052
	December	2.5	0.294	2.210	0.1	0.0	0.0	0.204	0.3	0.521
	Annual	59.9	106.8	108.6	21.7	0.0	0.0	3.7	-0.3	71.8

In sub-basin M-SB2, the monthly mean natural flow was not enough to satisfy the extraction that occurred during the analysis period; the greatest deficit appears between the months of February and June (Figure 3). Thus, the flows coming from sub-basin U-SB1 (the exit flows of the San Gabriel dam) were used to satisfy the demand in M-SB2 during these dry season months. Starting in July, demand is satisfied both by natural flows and the exit flows of the San Gabriel dam, while any excess flow reaches the exit of M-SB2.

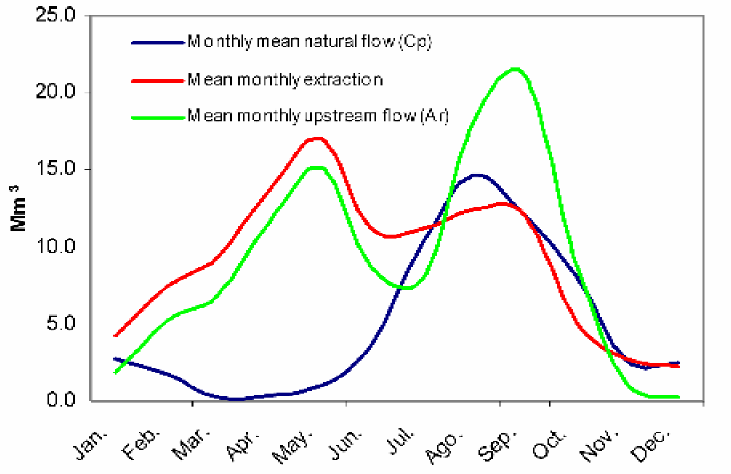

Figure 3. Hydrogram of the monthly mean natural flow, monthly mean demand (concessions) and mean monthly upstream flow for sub-basin M-SB2

Water availability:

Downstream flow in terms of juridical water availability in sub-basins U-SB1 and M-SB2

The term "Rxy" (current annual volume committed downstream) implies knowledge of the degree of dependence that the downstream basins have with respect to the flow generated in the upstream basins. The Florido River is an affluent of the Conchos River, which itself is an affluent of the Bravo River (Kelly, 2001). In order to establish the value of Rxy in U-SB1 and M-SB2, it would be necessary to perform an analysis of the concessions granted for the use of surface water in the Bravo River basin, including what is established in international water agreements between Mexico and the United States (CILA, 1944 and CILA, 1906).

However, water availability in juridical terms (D) depends on the downstream flow (Ab) that is calculated considering a hypothetical use (water extraction) equal to the total volume granted in concessions. Because of this, in order to achieve the initially stated objective, the effect of temporal scale in the determination of this term is analyzed.

a) Annual time scale

Table 3 shows the mean flow (Cp) values previously determined (historical condition) from the other values in the balance equation, as well as the downstream flow (Ab) calculated (hypothetical scenario) using the annual time scale. The mean downstream flow (Ab) calculated for U-SB1 was 104 Mm^3, and that for M-SB2 was 17.7 Mm^3.

Table 3. Downstream flow (Ab) in terms of juridical water availability calculated for sub-basins U-SB1 and M-SB2 at the annual time scale.

Sub-Basin	Cp	Ar	Extr	R	Im	Ex	Ev	Δv	Ab	Ab (+)
	Million cubic meter									
U-SB1. Florido river: From its origin to San Gabriel Dam	119.9	0.0	6.5	0.0	0.0	0.0	18.4	-8.9	104.0	104.0
M-SB2. Florido river: From San Gabriel Dam to HSJ	59.9	104.0	164.4	21.7	0.0	0.0	3.7	-0.3	17.7	17.7

When a positive quantity is determined in column Ab (next to last) of Table 3, the same value is given to column Ab+ (last); all negative values are changed to zero. A negative value represents a water deficit with respect to the demanded (conceded) volume.

b) Monthly time scale.

Table 4 shows the monthly mean flow values (Cp) previously determined (historical condition) from the other values in the balance equation, as well as the downstream flow (Ab) calculated (hypothetical scenario) using the monthly time scale. The mean downstream flow (Ab) calculated for U-SB1 was 104 Mm^3, and that for M-SB2 was 41.3 Mm^3. Negative downstream (Ab) flow values were obtained for sub-basin M-SB2 from January to June.

Table 4. Downstream flow (Ab) in terms of juridical water availability calculated for sub-basins U-SB1 and M-SB2 at the monthly time scale

Sub-Basin		Cp	Ar	Extr	R	Im	Ex	Ev	Δv	Ab	Ab (+)
		Million cubic meter									
U-SB1. Florido river: From its origin to San Gabriel Dam	January	1.7	0.0	0.2	0.0	0.0	0.0	1.2	-1.4	1.8	1.8
	February	1.1	0.0	0.5	0.0	0.0	0.0	1.3	-5.7	5.0	5.0
	March	1.0	0.0	0.5	0.0	0.0	0.0	1.8	-8.0	6.8	6.8
	April	0.9	0.0	0.9	0.0	0.0	0.0	1.9	-13.0	11.1	11.1
	May	1.3	0.0	1.2	0.0	0.0	0.0	1.8	-16.5	14.8	14.8
	June	2.7	0.0	0.8	0.0	0.0	0.0	1.7	-8.5	8.6	8.6
	July	23.4	0.0	0.8	0.0	0.0	0.0	1.5	13.6	7.5	7.5
	Agoust	39.0	0.0	0.6	0.0	0.0	0.0	1.5	19.3	17.6	17.6
	September	37.1	0.0	0.6	0.0	0.0	0.0	1.6	14.2	20.7	20.7
	October	8.8	0.0	0.2	0.0	0.0	0.0	1.5	-1.7	8.7	8.7
	November	1.7	0.0	0.1	0.0	0.0	0.0	1.3	-0.8	1.0	1.0
	December	1.1	0.0	0.1	0.0	0.0	0.0	1.2	-0.4	0.3	0.3
	Annual	119.9	0.0	6.5	0.0	0.0	0.0	18.4	-8.9	104.0	104.0

Sub-Basin		Cp	Ar	Extr	R	Im	Ex	Ev	Δv	Ab	Ab (+)
		Million cubic meter									
M-SB2. Florido river: From San Gabriel Dam to HSJ.	January	2.7	1.8	6.3	0.4	0.0	0.0	0.2	-0.4	-1.2	0.0
	February	1.7	5.0	11.3	1.0	0.0	0.0	0.2	-0.2	-3.6	0.0
	March	0.3	6.8	14.2	1.7	0.0	0.0	0.3	-3.0	-2.8	0.0
	April	0.4	11.1	20.6	2.6	0.0	0.0	0.3	-1.4	-5.4	0.0
	May	1.0	14.8	25.7	3.6	0.0	0.0	0.4	-1.6	-5.2	0.0
	June	3.6	8.6	17.0	2.4	0.0	0.0	0.4	1.1	-3.9	0.0
	July	10.3	7.5	17.0	2.6	0.0	0.0	0.4	2.5	0.6	0.6
	Agoust	14.7	17.6	18.9	3.8	0.0	0.0	0.4	2.6	14.3	14.3
	September	12.1	20.7	18.2	2.6	0.0	0.0	0.4	-0.2	17.1	17.1
	October	8.0	8.7	7.8	0.6	0.0	0.0	0.3	-0.1	9.4	9.4
	November	2.6	1.0	4.1	0.3	0.0	0.0	0.2	0.2	-0.7	0.0
	December	2.5	0.3	3.3	0.1	0.0	0.0	0.2	0.3	-0.9	0.0
	Annual	59.9	104.0	164.4	21.7	0.0	0.0	3.7	-0.3	17.7	41.3

In sub-basin U-SB1, the same downstream flow in juridical terms was obtained for the annual and monthly time scales. This indicates that the mean monthly demand that comes from the existing surface water use concessions never exceeds the mean monthly natural flow generated by the basin [Figure 4(a)].

Sub-basin M-SB2 shows significant differences in the downstream (Ab) flow in juridical terms obtained at the annual and monthly scales. The former scale produced an annual mean of 17.7 Mm^3, while the latter generated a mean of 41.3 Mm^3. The difference is 23.6 Mm^3 and originates from the fact that the annual analysis does not consider the temporal distribution of the parameters that intervene in the mass conservation equation throughout the year. The greatest demand appears during the dry season and progressively decreases from the beginning of the wet season. Thus, only a fraction of the natural flow volume generated during the rainy months is demanded during those months, and the unclaimed volume flows downstream as the monthly analysis verifies.

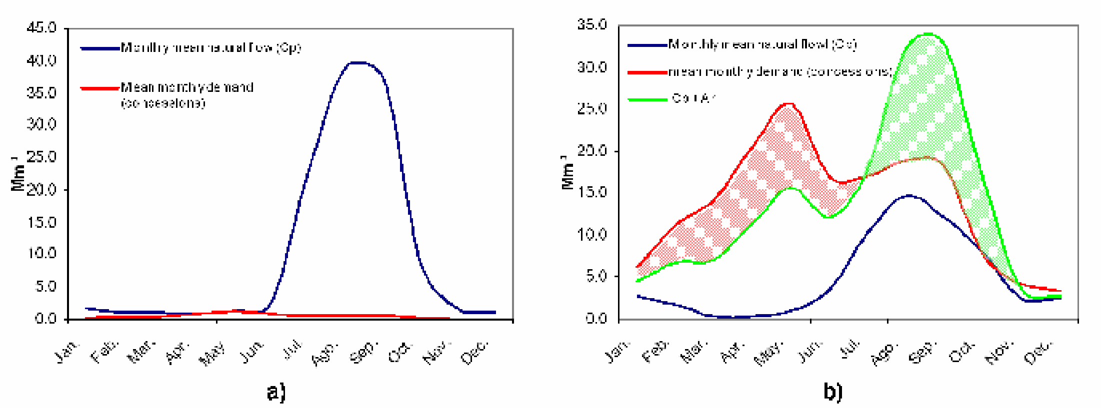

Figure 4. Monthly mean natural flow hydrogram, mean monthly demand (concessions) and upstream flow (Ar) plus monthly mean natural flow (Cp), for sub-basins a) U-SB1 and b) M-SB2

Through annual analysis it is not possible to compare the distribution of demand with respect the available volume, and so the volume generated during the wet months (July to September) is quantified as if it were usable during the dry season (February to June). This is graphically observed in Figure 4(b); the dry months show the juridical water deficit in red, while the water surplus that arrives during the rainy season and flows downstream is shown in green. In an analysis performed at the annual time scale, the surplus is quantified as if it were available to satisfy the deficit, which is not true. If a value of zero had not been given to column Ab+ (the last one in Table 4), the downstream flow (Ab) calculated at the annual and monthly time scales would be equal. However, this is incorrect because it considers the deficit to be satisfied by the surplus, which is not possible as there is no overlap in time.

This flaw in analysis performed at the annual scale appears in basins that have significant water use. Evidence of this can be found in the availability results at the annual time scale for sub-basin M-SB2. These results say that during the period from 1982 to 2002 it would have been possible to satisfy the mean annual concession volume of 164.4 Mm^3 and still have an annual mean of 17.7 Mm^3 flowing downstream. However, in reality it was only possible to use an annual mean of 108.6 Mm^3 and the mean annual downstream flow was 71.8 Mm^3.

Conclusions

The juridical availability of surface water is a control measure for the granting of concessions or permits for surface water use in a hydrological basin. Natural availability is a measure of the amount of the resource that exists in a basin, but not all of this volume can actually be used.

The concept of water availability in juridical terms has gained more importance in modern times. Due to the increase in water use in the economic activities of humanity, including food production, it is necessary to establish and instrument limits to the water volume that can be used in a basin, considering the spatial and temporal distribution of water along the basin. In this sense, Mexico has an important advantage because it has a National Water Law that incorporates this concept into the national water policy. It even has an Official Mexican Norm as a guide to the determination of the surface water availability.

In basins that have little or no development in the use of surface water, the monthly and annual time scales produce the same results, and which one is chosen has no effect on the determination of juridical water availability. In basins with a significant development of their surface water use, the analysis of water availability at the annual time scale can produce incorrect results. This is due to the fact that the annual time scale does not consider the temporal distribution throughout the year of the parameters that intervene in the mass conservation equation. In this sense, it is advisable that the Mexican norm incorporate some explanation of the temporal scale with which the analysis of each case must be performed.

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References

Carabias, J., Landa, R., Collado, J. y Martínez, P., (2005), Agua, Medio Ambiente y Sociedad, Capítulo 10. Estructura Institucional y Descentralización, pp 127-137.

Comisión Internacional del Límites y Aguas, Sección Mexicana (CILA), (1944), Tratado Sobre la Distribución de Aguas Internacionales entre Los Estados Unidos Mexicanos y Los Estados Unidos de América (Tratado de Aguas), México.

Comisión Nacional del Agua (CNA), (1997), Programa Hidráulico de Gran Visión del Estado de Chihuahua, Contrato: SGC-GRN-CHIH-96-82A, México. D. F.

Comisión Nacional del Agua (CNA), (2000), Reglamento del Distrito de Riego 005, Delicias, Gerencia Estatal Chihuahua, Chihuahua, Chih.

Comisión Nacional del Agua (CNA), (2004a), Ley Federal de Aguas Nacionales y su reglamento, México, D. F.

Comisión Nacional del Agua (CNA), (2004b), Base de datos del Registro Publico de Derechos de Agua en la Cuenca del Río Bravo, Monterrey, N.L., México.

Comisión Nacional del Agua (CNA), (2006), Base de datos hidrométricos consignados en el Estudio de Disponibilidad de Aguas Superficiales en la Cuenca del Río Conchos, Monterrey, N.L., México.

Instituto Mexicano de Tecnología del Agua (IMTA) y Comisión Nacional del Agua (CNA), (2000), Banco nacional de Datos de Aguas Superficiales (BANDAS), CD, Volumen 7. Jiutepec, Mor. México.

Kelly, M.E., (2001) The Río Conchos: A Preliminary Overview, Texas Center for Water Policy Studies, Austin, TX.

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), (2002), NOM-011-CNA-2000 Conservación del Recurso Agua - Que establece las especificaciones y el Método para determinar la disponibilidad media anual de las aguas nacionales, Diario Oficial de la Federación, miércoles 17 de abril, pp. 2-18 (Primera Sección), México D. F.

Secretaría de Medio Ambiente, Recursos Naturales y Pesca SEMARNAP. (2000), La Gestión Ambiental en México, Disponibilidad de agua en México, México.

Silva-Hidalgo, H.; Martín-Domínguez, I.R.; Alarcón-Herrera, M.T. and Granados-Olivas, A. (2008). Natural flows determination in gauged hydrological basins. Part I: Alternative method for irrigation return flows estimation. Submited to the XXXIII World Water Congress. 1-4 September. Montpellier, France.

Texas Natural Resource Conservation Commission (TNRCC), (1997), Evaluation of Naturalized Streamflow Methodologies, Technical Paper #1, 21 pages.

Texas Natural Resources Conservation Commission (TNRCC), (1998), Evaluation of existing water availability models, Technical Paper #2.

Wurbs, R. (2005b), Texas Water Availability Modeling system, *Journal of Water Resources Planning and Management*, ASCE, **131**(4): 270-279.

Yoshitani, J. and Tianqi, A., (2007), Development of natural flow hydrological database for PUB studies (Proceedings of the Kick-off meeting held in Brasilia 20-22 November 2002), IAHS Publ. **309**: 201-207.

Jothiprakash, V., (2003), Water Balance Model to Assess the Water Loss/Gain in a River System, *IE(I) Journal-CV* (84):196-200.

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