The Service Level between the Irrigation Department and the Users Associations, Tunuyan System, Mendoza, Argentina

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Abstract

The level of service given by the provincial Irrigation Department (DGI) to the Water Users Associations (UA), and subsequently by the UA's to the related water users, is based on the provincial water law. The intended volume of water being delivered per considered period further depends on the water availability and on the (crop irrigation) water requirements. The Agreed Service Level (ASL) compares the intended water supply with the water supply that would be required to supply the entire irrigable area with sufficient water. As soon as the intended water delivery pattern is set, the measured actual delivery can be assessed against the intention. Several performance indicators are used in this context. Based on the *water delivery performance ratio* and on the *overall consumed ratio* recommendations are made on changes on the monthly water supply from Carrizal reservoir to the Users Associations.

Key words: water management, irrigation performance, Water Users Associations, water delivery, discharge measurements, Argentina.

1 Introduction

The province of Mendoza is situated at the central-western region of Argentina and borders on the Republic of Chile. It extends westward to the mountain range of the Andes and eastward to the last traces of the pampas. The climate is arid and the annual rainfall never exceeds 300 mm. The general impression is that of a desert, apart from the five irrigated areas (350 000 ha). One of these areas is served by the Middle Tunuyan System. This 81200 ha area is partly supplied by surface water and partly by groundwater. Surface water is released from Carrizal storage dam as a function of the water availability and the overall irrigation demand, and is diverted from the Tunuyan river by the Benegas dam. Groundwater is pumped from a confined aquifer by over 6000 wells with a total capacity of 50 m^3/s. The major crops are grapes, stone fruits and olives.

The irrigation system is managed by the Departamento General de Irrigacion (DGI) and by 13 Users Associations (UA's). The DGI is responsible for the water administration and the management of the irrigation system from Carrizal storage dam to the places where the water is handed over to the UA's. The main canal system and the boundaries of the UA's are shown in Figure 1. At the location where the DGI hands over the water to the Users Associations also the responsibility for the water delivery and the maintenance of the canal system and structures is handed over to the Users Associations.

This paper discusses the Agreed Service Level between the Irrigation Department and the UA's. Data were collected by the Departemento General de Irrigacion (DGI) and by Instituto Nacional de Agua y Ambiente (INA-CRA). Additional data were collected through the Research Program on Irrigation Performance (RPIP).

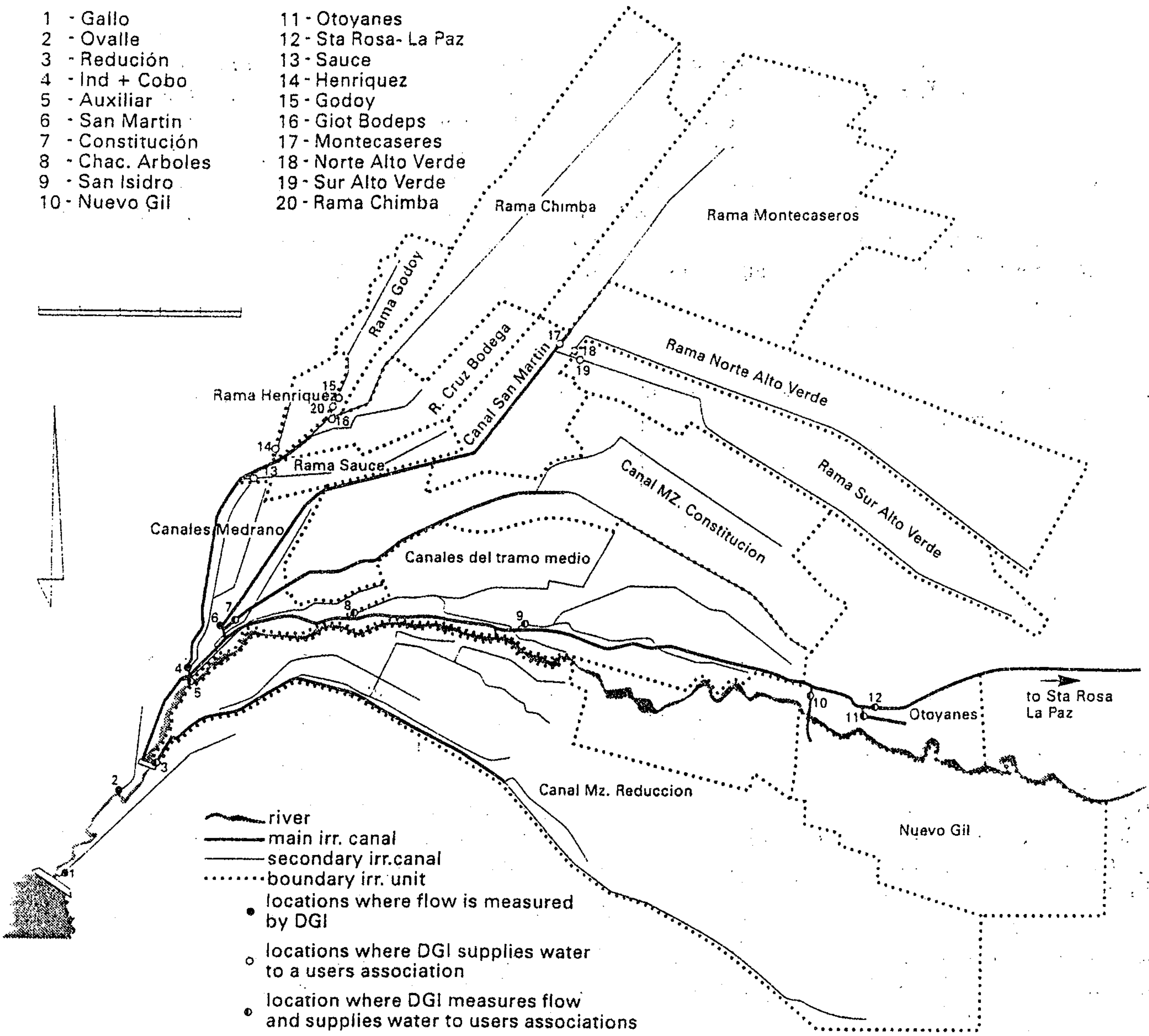


Figure 1 Rio Tunuyan irrigation system: primary and secondary canals and boundaries between the Users Associations

2 The Agreed Service

During earlier work on performance oriented irrigation management (Murray-Rust & Snellen 1993; Bos e.a. 1993) three levels of organization, having different objectives, were distinguished:

- irrigation and drainage **system** level,
- **agency** level,
- and the planning and policy environment at **sector** level.

Despite the differences in objectives in managing each level of organization, a common definition of performance was proposed:

- the degree to which an organization's products and services respond to the needs of their customers or users, and
- the efficiency with which the organization uses the resources at its disposal.

Recognizing that there are different customers or water users, we focus on the service which is intended to be delivered by the Subdelegado of DGI to the 13 Users Associations. The intended service (or product) being delivered by an irrigation organization (DGI) to its customers (the 13 water users organizations)) can be quantified through the 'agreed service level'. The service agreement between an irrigation organization and its customers (water users) specifies (1) the service that is intended to be provided to the users, (2) the payments or other resources that will be contributed by the users in return for these services, (3) the procedures that will be used to check whether services are provided and payments are made as agreed, (5) the authority that will be addressed to settle conflicts, and (6) the procedures that will be used for updating and improving the agreement. General information on items 2 through 6 is given by Agradano de Llanos and Bos (1997). This paper concentrates on the intended and actual delivery of water (item 1).

Performance oriented water management of an irrigation and drainage system is a process of identifying, designing and implementing a water delivery schedule needed for sustained agriculture. This intended water delivery schedule relates to the water requirements as a function of the water

$$\textit{Agreed Service Level} = \frac{\textit{Intended Level of Delivered Resource}}{\textit{Required Level of Considered Resource}}$$

availability. The ratio 'intended' over 'required' has been defined as:
The agreed (or pré-set) service level thus quantifies the intended value of a resource (water in this paper) with respect to a reference (required) level. If the 'intended level of (a) delivered resource' has not be determined, there will be no yardstick against which performance can be measured!

3 Irrigation Water Rights

In the Middle Tunuyan System the origin of the water rights goes back to 1884 when water rights were given to the original 'share holders' according to the 'Ley General de Aguas'. All land that was irrigated at that moment received a permanent right of irrigation water for 100 % of the land. All land that became irrigable after this year received 'eventual rights to water' if the river supply is sufficient. Since the construction of Carrizal Storage Dam, more reliable water became available. Since then land with 'eventual water rights' receive irrigation water for 80% of the irrigable area (Agradano de Llanos and Bos 1997).

Commonly, a command area (also at farm level) contains both; an area with permanent water rights, $A_{permanent}$ and an area with eventual water rights, $A_{eventual}$. The reduced area, $A_{reduced}$, which is used to divide the irrigation water is

$$A_{reduced} = A_{permanent} + 0.8\ A_{eventual}$$

The Subdelegado of DGI has the legal obligation to distribute the available water in proportion to the water rights $A_{reduced}$ in the command areas of the UA's (Table 1).

At farm level this area also is used by the UA to calculate the time that water is delivered to the farm. Depending on the relation between the area of the considered tertiary unit and on the flow rate being delivered, the unit time per hectare varies between 10 and 20 minutes. Small farms (less than about 2 ha) receive water during a longer period; as if they are 2 ha.

Table 1: Areas with water rights and actually irrigated area in the Middle Tunuyan per User Association (DGI 1996)

Users Association	Area with Water Rights in ha	Area with Water Rights Percentage Distribution	Actually irrigated area ha	Sustainability of irrigated area
Gallo	619	0 .8	583	0 .94
Ovalle	127	0 .2	104	0 .82
Reduccion	13409	16 .5	10404	0 .78
Medrano	2932	3 .6	1709	0 .58
Los Sauces	2252	2 .8	2565	1 .14
Henriquez	440	0 .5	591	1 .34
Cruz Bodega	962	1 .2	1087	1 .13
Godoy	1582	1 .9	1002	0 .63
Chimbas	4503	5 .5	1963	0 .44
Montecaseros	8581	10 .6	7596	0 .89
Norte Alto Verde	4987	6 .1	3947	0 .79
Sur Alto Verde	3228	4 .0	2051	0 .64
San Martin	2882	3 .5	2107	0 .73
Constitucion	11262	13 .9	8062	0 .72
Tramo Medio	6862	8 .4	3684	0 .54
Lower Tunuyan System	16676	20 .5	10555	0 .63
Total:	81304	100 %	58010	Av. = 0 .71

The actually irrigated area also is sown in Table 2. The last column shows a simple indicator for sustainability, being:

$$\text{Sustainability of Irrigable Area} = \frac{\text{Current Irrigated Area}}{\text{Initial Total Irrigable Area}}$$

The initial area refers to the total irrigable area in the design of the system (being equal to the area with water rights). The annual decrease of the irrigated area varies between 500 and 1000 ha. The reasons for this decrease respectively are; urban and industrial development, salinity and low profitability of agriculture.

4 Irrigation Water Requirements

The crop irrigation water requirement consists of two components: the potential evapo-transpiration, ET_p, minus the effective precipitation, P_e. ET_p is calculated on basis of meteorological data concerning the irrigated area with the Penman-Monteith approach. Data about the cropping pattern of the area are obtained from an unpublished study (Morabito et al 1995). The main irrigated crops are grapes (67%), fruit trees (15%), olives (8%), vegetables (5%), timber (3%) and other crops (2%). The crop irrigation water requirements for the total area are calculated with the program CRIWAR 2.0 and shown in Table 2 (Bos et al 1996).

Because of the above cropping pattern with mostly perennial crops, the crop water requirements vary little from year to year. Other irrigation water requirements (pre-winter irrigation and soil tillage) are shown in Table 2.

Table 2 *Monthly average irrigation water requirements in m^3/s*

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
$Et_p - P_e$	44.6	41.0	25.7	17.8	4.1	3.0	3.5	5.8	20.5	32.4	46.4	47.2
pre-winter irrigation and soil tillage					11.2			11.2				
TOTAL:	44.6	41.0	25.7	17.8	15.3	0*	0*	17.0	20.5	32.4	46.4	47.2

*) winter canal closure period

5 The Intended Water Delivery

The intended water delivery during the next irrigation season depends on a forecast of water availability. This forecast of the total available volume of irrigation is based on the prognosis of the total amount of snow in the Andes mountains (which provide the Tunuyan river with water). Data on snow are measured at 4 locations and transmitted to a main station. Data include; temperature, precipitation and the volume of water contained in the snow. The observations give information on the processes of accumulation and melting of snow in each river basin in the mountains. Average annual meteorological data are used to forecast the melting snow during each month. The standard deviation of the forecast over the previous years was 13 percent. Based on this snow melting forecast, and on the storage in Carrizal reservoir during the forecast (made in October), the intended irrigation water supply for the next irrigation season is quantified. The monthly distribution of surface water is based on:

- The crop irrigation water requirements on the basis of average meteorological data. The cropping pattern consists mostly of perennial crops like vines (67%) and fruit trees (15%). As a result, the forecast of the crop water requirements changes little.
- Water to be stored in the root zone for use by winter crops immediately before the canal closure period. Normally, this equals an extra delivery of 50 mm/ha in May.
- Water delivered to enable farmers to till their land following the canal closure period (extra delivery, also of 50 mm/ha, in August)

Water supply from Carrizal dam is intended to be interrupted during:

- public holidays; Christmas, New Year and Easter.
- the winter canal closure months June and July.

In addition, the DGI intends to interrupt water delivery:

- if one rain shower exceeds 50 mm
- if damage occurs on a canal or a related structure. DGI then closes the canal.

The intended irrigation water supply from Carrizal Dam by DGI to the UA's is published each year in October. For the 1992 through 1996 seasons the average intended flow rates are shown in Table 3.

Table 3: Intended (forecast) monthly irrigation water supply for the 1992 through 1996 irrigation seasons (average monthly flows in m^3/s)

	Intended average water supply in m^3/s			
	1992/93	1993/94	1994/95	1995/96
October	46	40	37	34
November	46	45	45	43
December	50	55	50	48
January	50	55	50	50
February	45	45	45	45
March	40	35	40	40
April	35	30	38	32
May	35	30	43	30
June	0	0	0	0
July	0	0	0	0
August	35	30	38	36
September	40	35	40	31

As mentioned above, the intended delivery of irrigation water is related to the water requirements through the agreed (or pré-set) service level. For the 1992 through 1996 irrigation seasons the (forecast) of the service level is shown in Figure 2. During spring and summer (October through February) the service level is close to 1.0. In fact, during these months too little surface water is available. During the two months before (April and May) and after (August and September) the canal closure period the service ratio exceeds 1.50, being higher than recommended (Bos et al 1991). It is recommended to reduce the service level during these months to 1.5 and allocate the related water to the summer months.

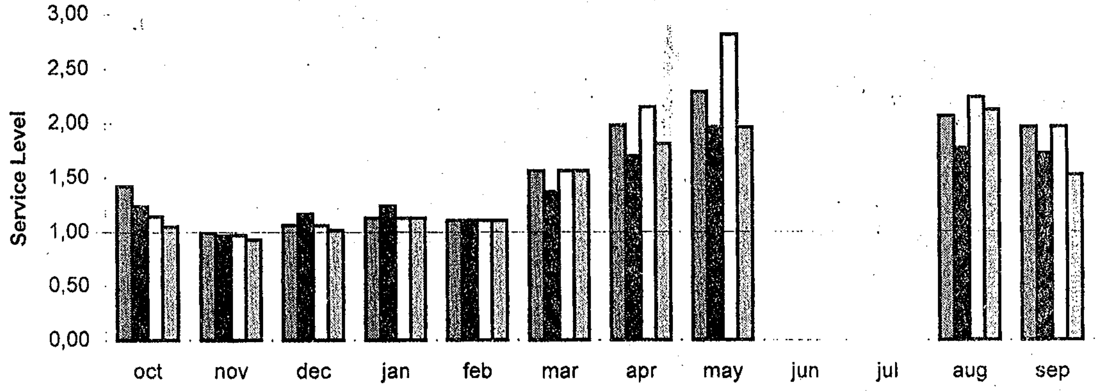
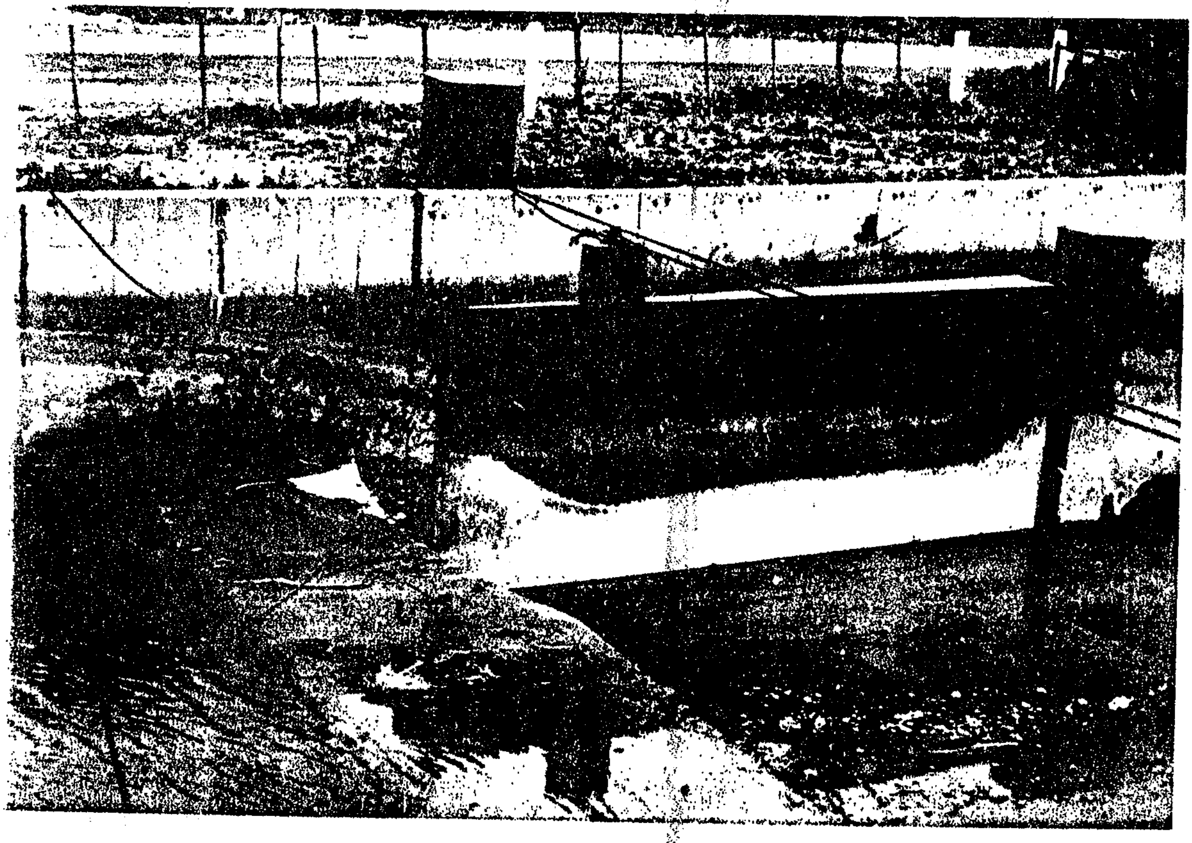


Figure 2 Service level for the 1992 through 1996 irrigation seasons

6 Actual Supplied Flows

As mentioned above, water is released from Carrizal reservoir into the Tunuyan river to meet irrigation water requirements. The Gallo and Ovalle users associations divert water directly from the river; all remaining water (99% of total) is diverted into two canals at the Benegas weir. The right bank canal serves one users association (Reduccion), the left bank canal serves all other UA's. In the upstream part of the system, DGI measures the actually delivered flows by use of broad-crested weirs (main canals) and by rating curves for lined sections of the lateral canals (Figure 1 and 3). More downstream in the system, some short-crested weirs are used to measure flow delivered to users associations. In the lined sections, the flow is measured about once per month by current meter to check the rating curve. Flow division gates are adjusted on the bases of these current meter measurements. Depending on the importance of the measuring site, water levels are measured either by a recorder or by daily staff gauge readings



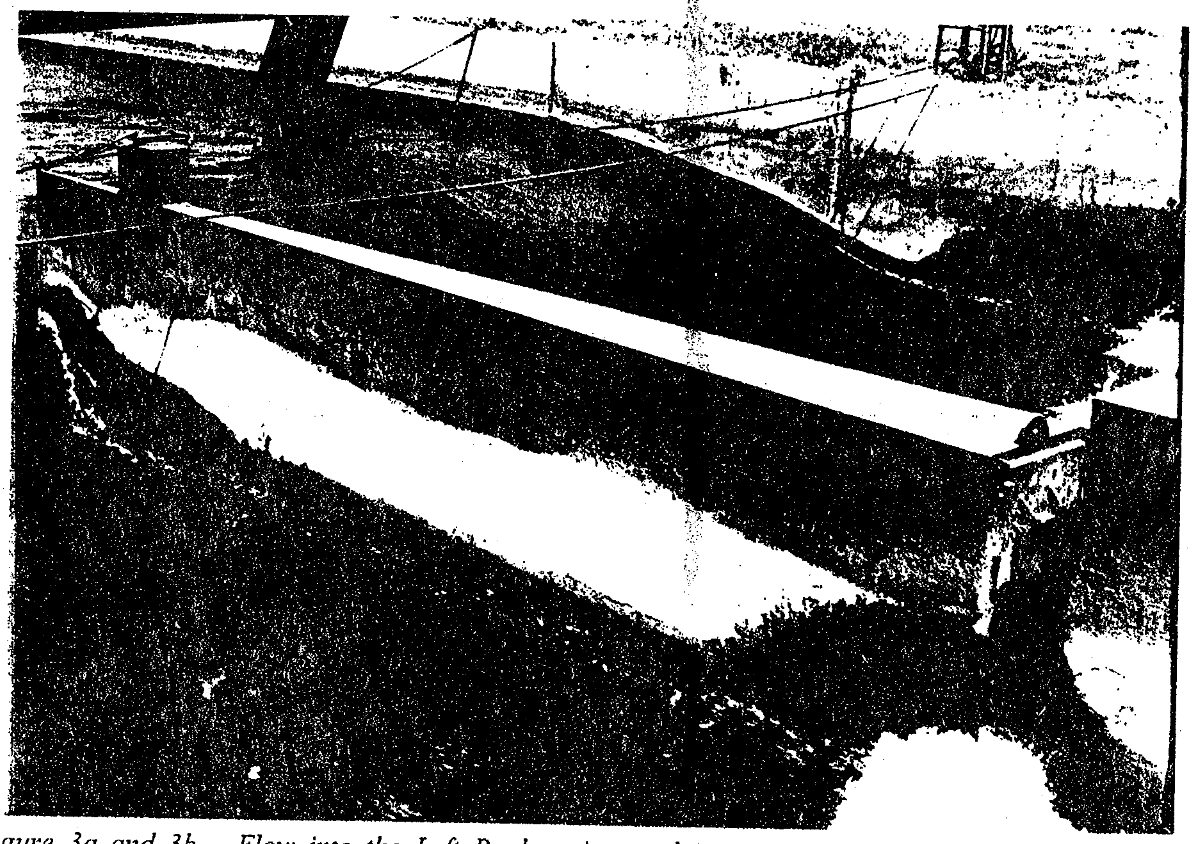


Figure 3a and 3b Flow into the Left Bank main canal is measured with a broad-crested weir upstream of a movable division door.

The actually delivered flow from Carrizal Dam for the 1994-95 through 1996-97 irrigation seasons is shown in Figure 4. As shown, flow is cut several times during public holidays and due to rain. The general pattern of water supply to the irrigated area during the 1994-95 and 1995-96 seasons has similar shapes; the latter being somewhat lower because of lower availability of water. The start of the 1996-97 season follows this same pattern. Following the annual October forecast, however, water supply was reduced by $^1/_3$th while water supply was stopped 3 weeks before the common start of the canal closure period.

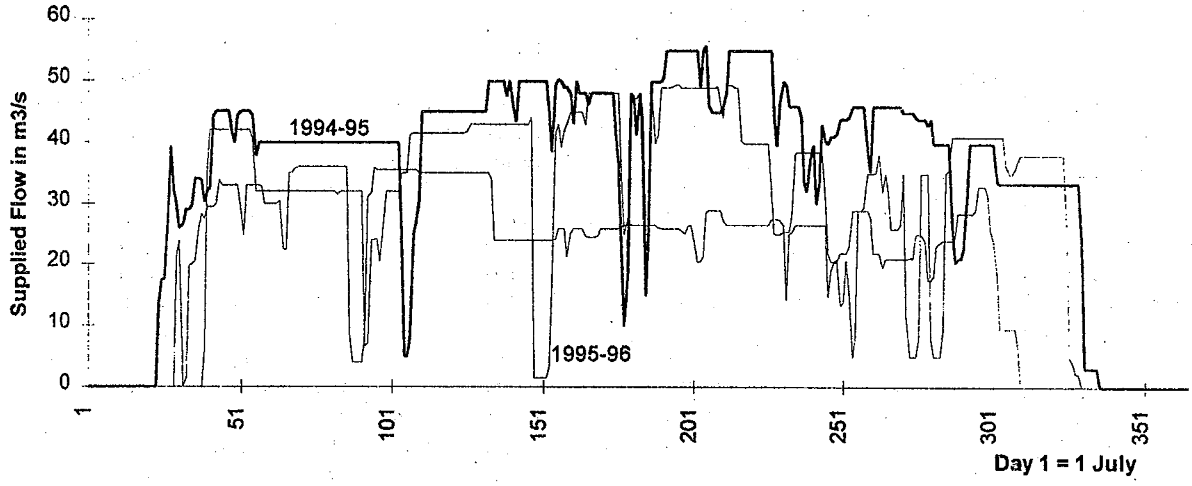


Figure 4 Actual flow delivered from Carrizal during the 1994-95), 1995-96 and 1996-97 irrigation seasons

Up to the 1996-97 irrigation season, DGI measured the flow that supplied water to one or more UA's at selected sites as shown in Figure 1. This actually delivered flow has been compared with the intended flow (see Section 2) through a simple, and yet probably the most important, hydraulic performance indicator, being (Clemmens and Bos 1990; Bos et al. 1991):

$$\textit{Water Delivery Performance} = \frac{\textit{Actually Delivered Volume of Water}}{\textit{Intended Volume of Delivered Water}}$$

This ratio enables a manager to determine the extent to which water is delivered as **intended** during a selected period (month in this paper) and at any location in the system. The primary utility of the Water Delivery Performance ratio is, that it allows for checking of whether the flow at any location in the system is more or less than intended. Tables 3 shows the actual and intended flow volumes (in $m^3 \times 10^6$ per month) for the 1994-95 irrigation seasons (June and July is winter canal closure period). The uniformity of water supply over the irrigation season to each of the measurement locations in the canal system can be quantified by the standard deviation of the monthly *WDP*-values. As shown in the last column of Table 3, the standard deviation of the *WDP* for supply points with relatively small flow volumes (Gallo, 619 ha and Ovalle, 127 ha) is very high ($s > 0.20$). This is due to the rather uncontrolled 'run-of-the-river' nature of these diversion points. The off-take structures are to sensible to variations in river water level. The uniformity at the locations within the actual canal system varies from very good ($s < 0.05$) to good ($s < 0.10$). The used water control structures facilitate accurate water supply (see also Figure 3). The seasonal average values of the *WDP* for each of these supply locations is illustrated in Figure 5. The Otoyanes command area receives only about 65% of the intended flow; all other areas receive the intended volume of water.

Table 3 The ratio (WDP) of Actually (Act) measured flow over the Intended (Int) flow (in $m^3 \times 10^6$) at key locations in the Tunuyan System for the 1994-95 irrigation season

CANAL ↓		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	St. Dv. of WDP
Gallo	Act	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803	
	Int	0.747	0.828	0.705	0.991	0.862	0.977	0.843	0.992	0.719	0.450	
	WDP	1.07	0.97	1.14	0.81	0.93	0.82	0.95	0.81	1.12	1.78	0.288
Ovalle	Act	0.159	0.171	0.147	0.206	0.182	0.18	0.188	0.338	0.158	0.092	
	Int	0.154	0.170	0.145	0.204	0.177	0.201	0.173	0.204	0.148	0.093	
	WDP	1.03	1.00	1.01	1.01	1.03	0.90	1.08	1.66	1.07	0.99	0.209
Reducción	Act	14.505	17.936	17.137	21.517	19.656	19.753	16.803	22.948	16.584	9.754	
	Int	16.091	17.832	15.196	21.351	18.569	21.054	18.155	21.362	15.486	9.703	
	WDP	0.90	1.01	1.13	1.01	1.06	0.94	0.93	1.07	1.07	1.01	0.073.
Ind+Cobo	Act	12.429	14.455	12.325	17.14	15.191	17.494	15.109	16.75	11.444	7.709	
	Int	12.844	14.233	12.129	17.042	14.822	16.805	14.491	17.051	12.361	7.745	
	WDP	0.97	1.02	1.02	1.01	1.02	1.04	1.04	0.98	0.93	1.00	0.035
Auxiliar	Act	2.284	2.461	2.271	2.948	2.612	2.812	2.692	2.816	2.271	1.328	
	Int	2.205	2.443	2.082	2.925	2.544	2.884	2.487	2.927	2.122	1.329	
	WDP	1.04	1.01	1.09	1.01	1.03	0.97	1.08	0.96	1.07	1.00	0.044
San Martin	Act	25.84	27.741	21.382	33.311	27.486	32.848	29.383	29.754	21.382	14.968	
	Int	24.955	27.655	23.567	33.113	28.798	32.652	28.156	33.129	24.016	15.049	
	WDP	1.04	1.00	0.91	1.01	0.95	1.01	1.04	0.90	0.89	0.99	0.057
Constitución	Act	13.538	14.587	11.696	17.475	15.513	17.272	13.7	18.913	13.495	7.868	
	Int	13.105	14.522	12.376	17.388	15.123	17.146	14.786	17.397	12.612	7.902	
	WDP	1.03	1.00	0.95	1.00	1.03	1.01	0.93	1.09	1.07	1.00	0.049
Chac-Arboles	Act	3.308	3.499	2.963	4.15	3.394	4.209	3.905	3.615	3.292	1.922	
	Int	3.199	3.545	3.021	4.244	3.691	4.185	3.609	4.246	3.078	1.929	
	WDP	1.03	0.99	0.98	0.98	0.92	1.01	1.08	0.85	1.07	1.00	0.068
San Isidro	Act	4.247	4.418	3.796	5.174	4.35	5.401	5.011	5.508	4.218	2.473	
	Int	4.108	4.553	3.880	5.451	4.741	5.375	4.635	5.454	3.954	2.477	
	WDP	1.03	0.97	0.98	0.95	0.92	1.00	1.08	1.01	1.07	1.00	0.051
Nuevo Gil	Act	2.5	2.68	2.4	3.23	2.85	3.29	2.74	3.77	2.49	1.45	
	Int	2.416	2.677	2.282	3.206	2.788	3.161	2.726	3.207	2.325	1.457	
	WDP	1.03	1.00	1.05	1.01	1.02	1.04	1.01	1.18	1.07	1.00	0.053
Otoyanes	Act	0.53	0.56	0.51	0.92	0.6	0.69	0.58	0.85	0.52	0.3	
	Int	0.868	0.962	0.820	1.152	1.002	1.136	0.979	1.152	0.835	0.523	
	WDP	0.61	0.58	0.62	0.80	0.60	0.61	0.59	0.74	0.62	0.57	0.074
Santa Rosa	Act	14.11	15.14	13.58	18.19	16.13	18.57	15.43	19.06	14.05	8.17	
and La Paz	Int	13.563	15.030	12.808	17.996	15.651	17.745	15.302	18.005	13.052	8.179	
	WDP	1.04	1.01	1.06	1.01	1.03	1.05	1.01	1.06	1.08	1.00	0.027
Total		94.253	104.451	89.01	125.064	108.767	123.322	106.344	125.125	90.707	56.837	
Average WDP		0.99	0.96	0.99	0.97	0.96	0.95	0.99	1.03	1.01	1.03	

As mentioned above, DGI did not measure the flow as supplied to each individual Users Association. Since 1985, however, the many small UA's merged. Currently there are 157 UA's in Mendoza Province ranging in size between 300 and 13000 ha (Chambouleyron 1989). DGI has designed broad-crested weirs to measure the flow to each of these UA's. In the Tunuyan system these structures were constructed during the 1997 canal closure period. On the one hand, the use of these weirs will allow DGI to supply the intended flow to the UA more accurately. On the other hand, the UA will be able to check if their water supply is correct. Experience with the use of these flow data in other irrigated areas in Mendoza province has reduces the uncertainty with the system managers in supplying water and has led to a more business-like (less emotional) communication between the Subdelegado of DGI and the UA's.

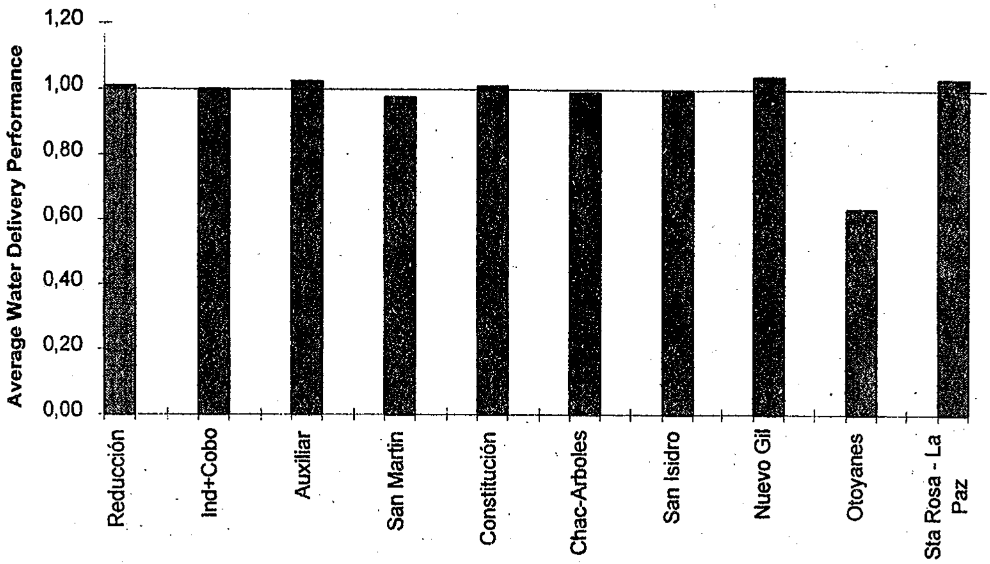


Figure 5 Average WDP values for the 1994-95 irrigation season for the Tunuyan canal system.

7 The Overall Consumed Ratio

The overall (or project) consumed ratio. R_p. quantifies the fraction of irrigation water evapo-transpired by the crops in the water balance of the irrigated area (Bos and Nugteren 1974; Bos 1997) Assuming negligible non-irrigation water deliveries. it is defined as

$$\textit{Overall Consumed Ratio} = \frac{ET_p - P_e}{V_c}$$

V_c is the volume of irrigation water diverted from the river or reservoir (see Figure 4). The irrigation water requirement, ET_p - P_e, for the average cropping pattern is shown in Table 2. As mentioned before, the cropping pattern varies little from year to year.

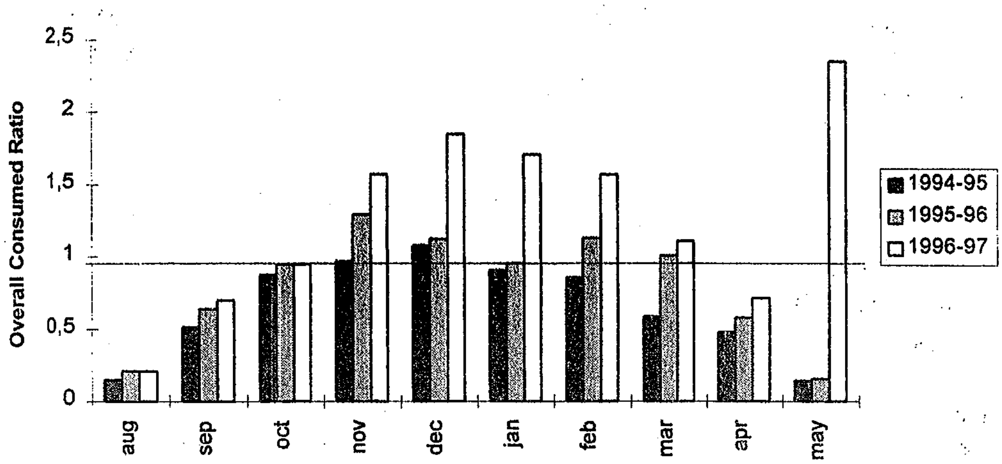


Figure 6 The overall consumed ratio as a function of time for three irrigation seasons

Figure 6 quantifies the effect of a number of water management practices. As will be mentioned, some of these practices have undesirable side effect.

- During a season with sufficient water supply (1994-95), the overall consumed ratio varies from very low (< 0.2) at the start and end of the irrigation season, to a ratio above 1.0 during the peak month(s). During periods with low ratios, the non consumed fraction of the water will cause the groundwater table to rise while during periods with a ratio above 0.6 groundwater must be pumped to avoid water shortage (Bos et al 1991). To alleviate these effects, it is recommended to reduce the flow from Carrizal reservoir during the off-peak months so that the overall consumed ratio becomes 0.5. This ratio allows sufficient leaching while more water becomes available during the peak months (less energy needed for pumping).
- With less water becoming available (1995-96), the number of months with a ratio over 1.0 increase. If the ratio would vary between 0.5 and 0.6 during the off-peak months, the period with water shortage can be shortened considerably.
- During the very dry 1996-97 season, the DGI changed the water supply to the UA's from continuous supply to a two-weeks-on-one week-off rotational schedule. This change was decided upon following the October forecast. Early May the canals had to be closed because Carrizal reservoir was empty. The negative effects of such a dry year on crop yield can be alleviated by the proper use of the aquifer; being the third (and only multi-year) storage reservoir. A positive side effect of such a dry year is the drop of the groundwater table and the related reduction of salinity in the root zone.

8 Conclusions and Recommendations

The service level between the General Department of Irrigation (DGI) and the Users Associations in Mendoza province is based on the framework as laid down in the provincial water law (Aradano de Llanos & Bos 1997). According to this law, DGI intends to supply surface water to Users Associations in proportion of the accumulated water rights of all users within each association. A comparison of the actual water supply with this intention through the *Water Delivery Performance* ratio shows a very uniform water supply; both in terms of different command areas and in terms of time.

The actual monthly water supply from Carrizal reservoir depends on the availability of water in spring (October). A forecast of the monthly supply of water during the irrigation season is made each October based on the volume of snow in the Andes mountains and the water volume in Carrizal reservoir. The available water in the third reservoir (the aquifer under the irrigated area) is not managed by DGI. Groundwater is pumped by individual users. The conjunctive management of surface water and groundwater is recommended.

The *Overall Consumed Ratio* is (as) low (as) 0.2 during the first and the last months of the irrigation season. The non-consumed fraction of the surface water causes the groundwater table to rise into the root zone. To revert this negative environmental effect (and the related salinity) we recommend to reduce the flow from Carrizal to such an extend the ratio varies between 0.5 and 0.6. The non-released water can be used to reduce the ratio during the peak months.

To improve the accountability of the DGI versus the UA's (and vice versa) we recommended the construction of broad-crested weirs at the location where water is supplied by DGI to each individual UA. We are pleased to note that these structures were constructed during the 1997 canal closure period.

9 Acknowledgments

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