Annex 21 - OPERATION AND MAINTENANCE OF IRRIGATION SCHEMES PLAN (O&M)

RECEM VALLES PROJECT

Good management of irrigation schemes is an essential mean to achieve successful irrigated agriculture.

This plan covers the main activities needed for the irrigation scheme (operation and maintenance) that will be considered forthe GCF Project “Upscaling Ecosystem Based Climate Resilience of Vulnerable Rural Communities in the Valles Macro-region of the Plurinational State of Bolivia (RECEM-Valles)”. The plan will be directly linked to a special Agreement subscribed between the MiRiego Program, the municipalities and the Local Irrigation Associations, not only to assure the amount of counterpart to guarantee ownership and sustainability, but also to ensure water flow coming from the MiRiego infrastructure and the adequate operation and maintenance of the climate-proof irrigation systems to be established at farm level. The special Agreement will consider that the end users (the farmers) assume the costs of O&M during and after the implementation of the project, as part of the exit strategy to guarantee the sustainability and effective operability of the project interventions[1].

1. The GCF Project aims to traduce this O&M Plan to Spanish and local dialects and to design the Plan in a friendly communication format with drawings for a better comprehension from the target publics and will also be used as a guide for scaling up to other regions of the country.***OPERATION OF IRRIGATION SCHEMES***

The Operation of irrigation schemes has as its chief objective the timely delivery of the irrigation water necessary to satisfy crop water requirements. The accomplishment of this objective implies the following main activities:

1.1. Planning the Operation (preparation of Irrigation Plans)

The object of this activity is to match supply with demand as closely as possible. The planning exercise may be a complex and laborious undertaking, as is the case when preparing "Irrigation Plans" for large canal systems, or just a simple meeting where farmers are informed of the amount of water available and the times when it will be distributed. The complexity or simplicity of the planning process varies from case to case depending on the scope for manipulating supplies to meet demand, but planning is essential in all cases (and two-way communication with the farmers). As water is a scarce resource in irrigation schemes, the importance of this planning process cannot be overemphasized, but unfortunately there are too many occasions when this process is not carried out even in its most elemental form.

1.1.1. Estimating future water supply

The estimation of the future water supply may be a straightforward calculation or a rather complicated one, depending on several factors such as the characteristics of the dry and wet season, the type of water storage utilized, the reliability of climatic data, or the effective rainfall during the irrigation season.

Simple cases of determination of the water supply are: (a) diversion from a river, with an average flow much greater than the one pumped; (b) pumping from fairly abundant aquifers which has not been disseminated in the valleys macro-region; (b) dam storage where the season for filling the reservoir does not coincide with the irrigation season during which hardly any water contribution can be expected. In all these cases the available water resources are known precisely at the beginning of the irrigation season.

However, there are many other cases in which a certain degree of uncertainty exists about the availability of the water resources. In these, the management of the project should make its projections on the basis of conservative estimates, i.e. using a rainfall probability of 75 or 80 percent. The mathematical modelling technique, based on reliable climatic data, can also be a very useful tool to forecast the water available for different levels of risk. In any case, it is most important in these circumstances to have alternative plans which can be adopted according to changing climatic conditions. In other words, rather than a fixed plan, a dynamic programme is necessary which can be modified according to changes in the weather and changing

[1] The annual cost of O&M is USD 650, i.e. USD 54,16 per month. This monthly cost needs to be divided among the families who are beneficiaries of the system. Considering the average system (72 families), the monthly cost per family is USD 0,75. The average farmers´ monthly income in the Valleys Macroregion is USD 330. Therefore, the percentage of the farmers´ income to the O&M funds is 0.23% monthly.

planting periods that should be articulated with farmers. Technically, this is quite feasible, but the usual bottleneck is the rapid transfer of this information to the farmer, so that he can adjust to the changing conditions.

From a study carried out by Mauricio Villazon, 2021, an analysis was performed to compare the water supply of the Macro-region with the implemented demands. The average water supply in the Amazon region is equivalent to 1230.53 m3/s, the irrigation demand was estimated at 438.80 m3/s and the population demand at 1.50 m3/s, giving a total demand of 440.30 m3/s. Figure 1 shows the monthly distribution, where it can be observed that between the months of August to October the demand exceeds the water supply, generating a deficit of 12.91%.

The average water supply in the La Plata region is equivalent to 253.32 m3/s, the irrigation demand was estimated at 124.49 m3/s and the population demand at 0.57 m3/s, giving a total demand of 125.06 m3/s. Figure 2 shows the monthly distribution, where it can be observed that between the months of June to November the demand exceeds the water supply, generating a deficit of 35.71%.

1.1.2. Estimating water demand

The water demand is basically determined by the expected cropping pattern and the irrigation efficiencies at the farm and project level, considering also that the strategic basins in the Macro-region of the Valleys contribute to the La Plata and Amazon Basins.

m^3/s	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC	ANUAL
Supply	3118.03	2966.08	2000.33	1015.26	716.44	531.13	430.31	335.57	357.18	481.79	926.49	1887.71	1230.53
Demand	207.20	308.77	358.11	467.19	331.75	218.32	284.72	417.02	614.59	824.79	804.71	446.48	440.30
Deficit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	81.45	257.40	343.00	0.00	0.00	56.82

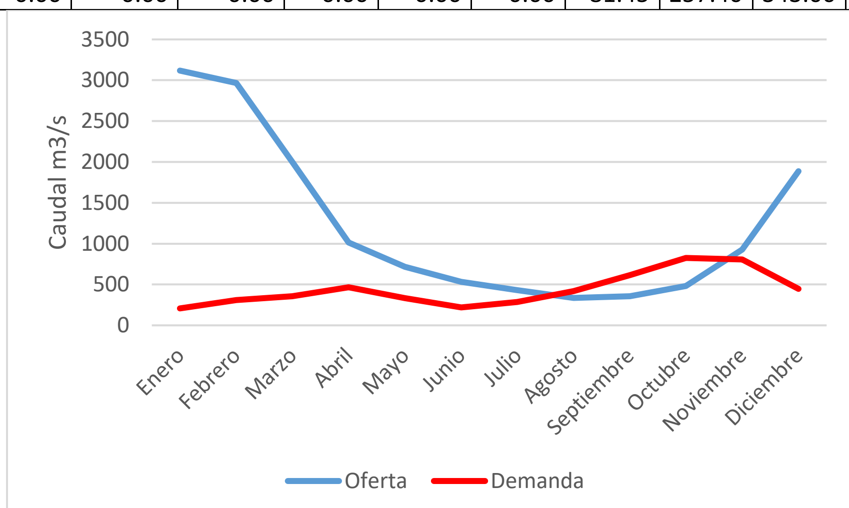

Figure 1. Mass balance Amazon region

m^3/s	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC	ANUAL
Oferta	687.47	791.93	560.15	233.15	96.32	58.17	44.14	39.89	41.45	56.58	122.43	308.10	253.32
Demanda	58.93	87.75	101.74	132.69	94.27	62.09	80.92	118.46	174.51	234.15	228.45	126.82	125.06
Déficit	0.00	0.00	0.00	0.00	0.00	3.92	36.78	78.57	133.06	177.57	106.02	0.00	44.66

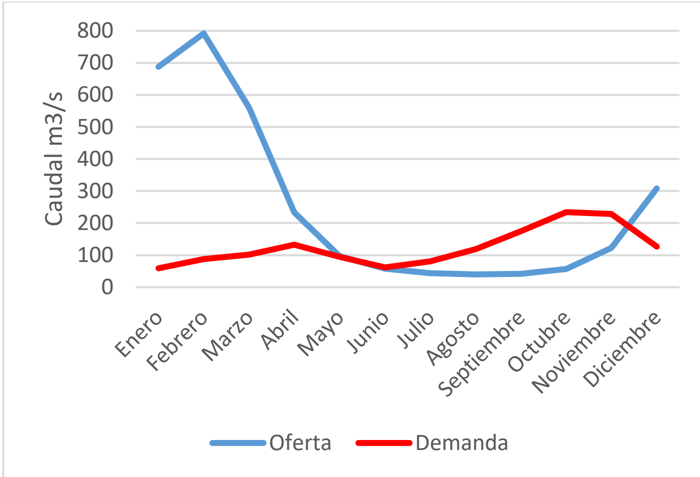

Figure 2. Plata region mass balance

In a 2050 water demand analysis, a combination of climate scenarios, changes in agricultural coverage and population growth have been used.

Population growth has been estimated according to data from the 2012 National Population and Housing Census. To simulate the change in irrigation demand, percentages of growth in coverage are assumed, according to (FAO, 2018) two possible growth scenarios, as shown in Table 1.

Table 1. Percentage increase in agricultural coverage

Scenario	Increase
Toward Sustainability / RCP 4.5	4.80 %
Stratified Societies / RCP 8.5	17.60 %

A comparison is made between the water supply of the Macroregion with the demands implemented for the period 2036 - 2065, with the Climate Change scenarios: RCP 4.5 and 8.4 for both the the Amazon regionand the La Plata region.

In the Amazon region, the total demand for the current condition is 440.30 m3/s (Figure 1). For future conditions a population demand of 2.26 m3/s is estimated, the irrigation demand according to the RCP 4.5 increase scenario is 457.76 m3/s and for the RCP 8.5 scenario it is 508.31 m3/s, obtaining a total demand of 460.02 m3/s and 510.57 m3/s respectively. The water supply according to the RCP_4.5 scenario is 947.23 m3/s, Figure 3 shows the monthly distribution, where it is observed that between the months of July to November the demands exceed the water supply, generating a deficit of 21.12% for the RCP 4.5 increase scenario and 24.38% for the RCP 8.5 scenario. The water supply according to the RCP_8.5 scenario is 928.65 m3/s, Figure 4 shows the monthly distribution, where it is observed that between the months of May to October the demands exceed the water supply, generating a deficit of 23.54% for the RCP 4.5 increase scenario and 25.85% for the RCP 8.5 scenario.

In the La Plata region, the total demand for the current condition is 125.06 m3/s (Figure 27). For future conditions a population demand of 1.83 m3/s is estimated, the irrigation demand according to the RCP 4.5 increase scenario is 129.87 m3/s and for the RCP 8.5 scenario it is 144.22 m3/s, obtaining a total demand of 131.70 m3/s and 146.04 m3/s respectively. The water supply according to the RCP_ 8.5 scenario is 250.35 m3/s. Figure 56 shows the monthly distribution, where it can be observed that between the months of May and November the demands exceed the water supply, generating a deficit of 36.13% for the RCP 4.5 increase scenario and 39.08% for the RCP 8.5 scenario. The water supply according to the RCP_4.5 scenario is 226.23 m3/s. Figure 6 shows the monthly distribution, where it can be observed that between the months of May and November the demands exceed the water supply, generating a deficit of 37.02% for the RCP 4.5 increase scenario and 39.89% for the RCP 8.5 scenario.

m^3/s	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC	ANUAL
Supply	2489.27	2441.03	1351.33	662.02	362.61	282.99	231.04	191.18	247.85	400.45	872.99	1834.03	947.23
Demand RCP 4.5	216.84	322.80	374.27	488.07	346.78	228.45	297.71	435.73	641.83	861.12	840.16	466.47	460.02
Demand RCP 8.5	240.54	358.20	415.35	541.71	384.82	253.43	330.34	483.60	712.46	955.96	932.69	517.73	510.57
Deficit RCP 4.5	0.00	0.00	0.00	0.00	0.00	0.00	66.68	244.55	393.98	460.67	0.00	0.00	97.16
Deficit RCP 8.5	0.00	0.00	0.00	0.00	22.21	0.00	99.30	292.42	464.61	555.51	59.70	0.00	124.48

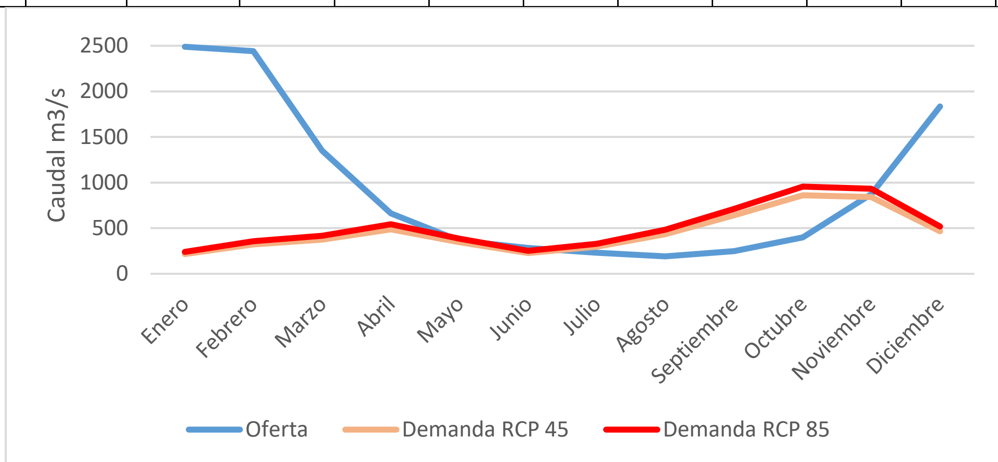

Figure 3. Water balance Amazon region / RCP 4.5 climate scenario, horizon 2036 - 2065.

m^3/s	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC	ANUAL
Supply	2338.24	2258.86	1386.18	638.35	328.20	287.35	210.45	179.23	197.92	367.83	1023.22	1927.92	928.65
Demand RCP 4.5	216.84	322.80	374.27	488.07	346.78	228.45	297.71	435.73	641.83	861.12	840.16	466.47	460.02
Demand RCP 8.5	240.54	358.20	415.35	541.71	384.82	253.43	330.34	483.60	712.46	955.96	932.69	517.73	510.57
Deficit RCP 4.5	0.00	0.00	0.00	0.00	18.58	0.00	87.27	256.51	443.91	493.28	0.00	0.00	108.30
Deficit RCP 8.5	0.00	0.00	0.00	0.00	56.62	0.00	119.89	304.38	514.54	588.13	0.00	0.00	131.96

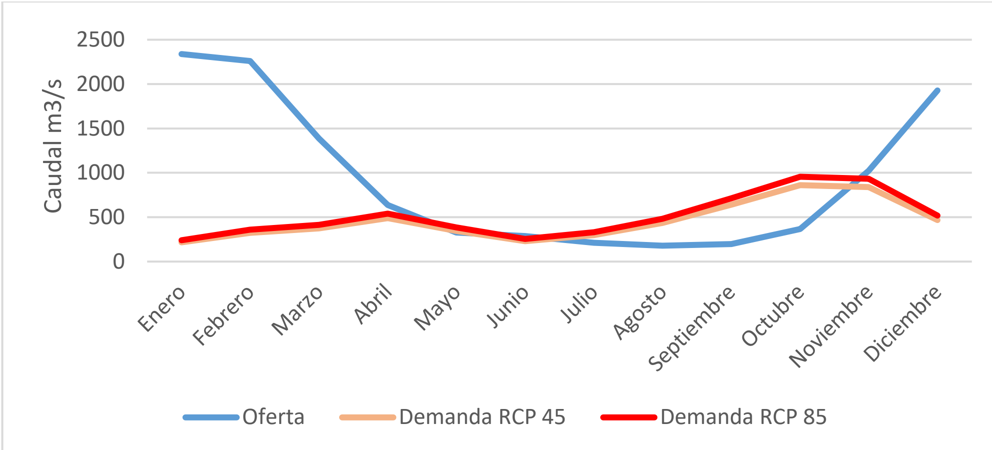

Figure 4. Water balance Amazon region / RCP 8.5 climate scenario, horizon 2036 - 2065.

m^3/s	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC	ANUAL
Oferta	698.24	724.71	459.57	213.50	94.66	55.61	41.56	37.01	39.12	58.57	146.87	434.76	250.35
Demanda RCP 4.5	62.70	92.77	107.37	139.66	99.57	66.00	85.65	124.81	183.28	245.50	239.55	133.53	131.70
Demanda RCP 8.5	69.43	102.81	119.03	154.88	110.36	73.09	94.91	138.39	203.32	272.41	265.80	148.07	146.04
Déficit RCP 4.5	0.00	0.00	0.00	0.00	4.91	10.39	44.09	87.80	144.16	186.92	92.68	0.00	47.58
Déficit RCP 8.5	0.00	0.00	0.00	0.00	15.71	17.48	53.35	101.38	164.20	213.83	118.93	0.00	57.07

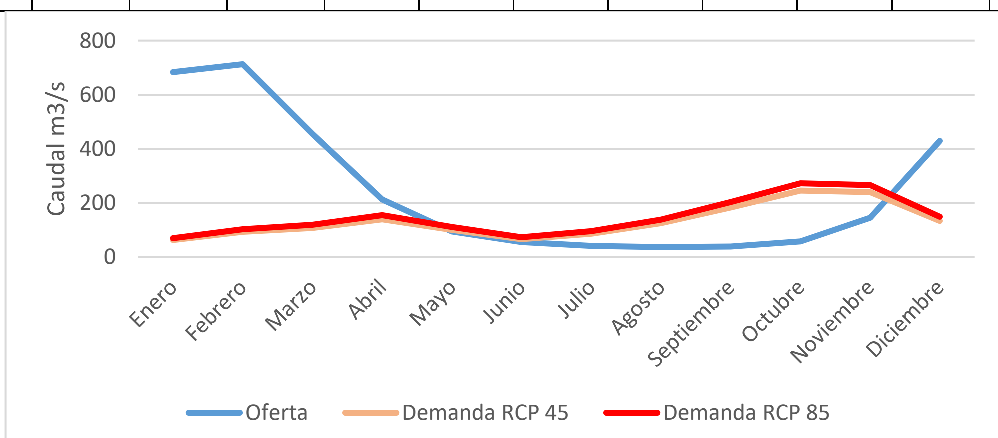

Figure 5. Water Mass balance Plata region / climate scenario RCP 8.5, horizon 2036 - 2065.

m^3/s	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC	ANUAL
Supply	547.53	730.66	428.31	204.58	95.12	55.90	40.92	36.24	37.83	53.26	140.03	344.34	226.23
Demand RCP 4.5	62.70	92.77	107.37	139.66	99.57	66.00	85.65	124.81	183.28	245.50	239.55	133.53	131.70
Demand RCP 8.5	69.43	102.81	119.03	154.88	110.36	73.09	94.91	138.39	203.32	272.41	265.80	148.07	146.04

Deficit RCP 4.5	0.00	0.00	0.00	0.00	4.45	10.10	44.73	88.56	145.46	192.23	99.53	0.00	48.76
Deficit RCP 8.5	0.00	0.00	0.00	0.00	15.25	17.19	53.99	102.15	165.49	219.14	125.78	0.00	58.25

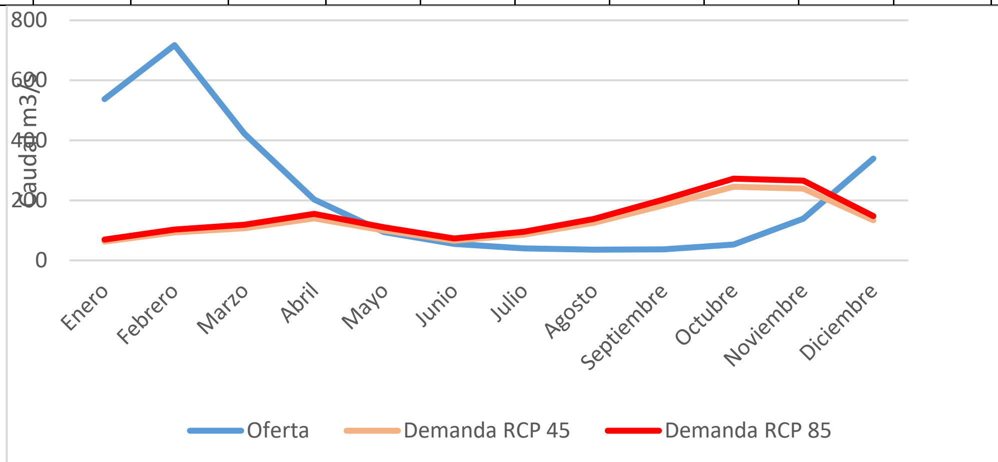

Figure 6. Plata region water balance / RCP 4.5 climate scenario for the 2036 - 2065 horizon

In conclusion, it is observed that the deficit increases under future conditions. In the Amazon region, a current deficit of 12.91% is estimated, for the RCP 4.5 increase scenario it is estimated between 21.12% and 23.45%, while for the RCP 8.5 increase scenario it is estimated between 24.38% and 25.85%. In the La Plata region, the current deficit is estimated at 35.71%, for the RCP 4.5 increment scenario it is estimated between 36.13% and 37.02%, while for the RCP 8.5 increment scenario it is estimated between 39.08% and 39.89%.

i. Cropping pattern

The difficulty of foreseeing the expected cropping pattern on an irrigation scheme varies according to the degree of freedom allowed to farmers in their choice of crops and the timing of their cultivation activities. It is least difficult under conditions of land settlement projects with an integrated management: the government through the operating agency controls the cropping pattern (and, often, the timing of certain cultivation activities, e.g. mechanized land preparation and/or the gradual process of the new model in the area of conservation agriculture which means the incorporation and maintenance of vegetation cover that reduces evapotranspiration and incorporates organic matter to the soil part of conservation agriculture, which is a technological process that goes as far as no-till farming and/or the mandatory incorporation of the necessary quantities of organic matter into the soil to maintain its humidity.). Alternatively, demand can be controlled by means of differential control over the water supply pattern, considering that farmers seek to use large amounts of water that in many cases may not be needed (permitting certain highly water-consuming crops to be grown only in certain designated areas which will be the only ones to receive sufficient water); or legal limits can be placed on the areas to be covered by certain crops (with fines being exacted for contravention of the rules). Or, finally, there can be a free choice of cropping, when response to market demand will be the main determining factor.

In irrigation schemes where the management has recognized authority over the cropping pattern, a good method to keep a balance between the cropping pattern desired by the farmers and the management is the use of approval or rejection forms. The farmer proposes a cropping pattern which is examined and computed by the project management in terms of water requirements. The farmer is informed whether his proposal has been rejected, approved, or slightly modified. In the case of a rejection, the farmer must propose another cropping pattern based also on the local soil conditions. If rejected again, the dispute can be settled by a special committee of appropriate representatives.

On the contrary, in irrigation schemes where the management has no authority over the cropping pattern, information must be gathered from statistical data from previous years and study of the trends in relation to expected prices of different crops, which brings us to the other challenge, that of prices during harvest periods, and crop rotation based on market demand.

According to the Multi-Year Irrigation Plan 2017 - 2020, in order to achieve food sovereignty by 2025, promote the diversification of the country's productive matrix and thus reduce the susceptibility of the Bolivian economy to variations in raw materials, the development strategy of 41 agro-productive regions in the country would give a total increase in the agro-productive area of 1.5 million hectares, a growth of approximately 50% with respect to the area planted in 2012.

Table 2 summarizes the projections for food sovereignty by 2025, in terms of the items in which irrigation is part of the global goals proposed to increase productivity and expand the production area until 2025.

Table 2 Projections of Agricultural Production to 2025 (Patriotic Agenda: Pillar 8)

PRODUCTO	Producción (miles de Tm)				Rendimientos Tm/Ha		Superficie miles Ha		Crecimiento en miles de Ha
	Campaña 2012-2013	Campaña 2024-2025	Crecimiento 2025/base	Crecimiento anual	2013	2025	2013	2025	
Arroz con cascara	360	1.335	270%	11,5%	2,2	4,0	164	334	170 *)***)
Caña de azúcar	8.31	13	56%	3,8%	52,3	65,0	159	200	41
Maíz duro Amarillo	910	2.524	178%	8,9%	2,8	5,0	325	505	180
Trigo	227	1.561	588%	17,4%	1,4	2,2	158	710	552
Quinua	61	300	390%	14,2%	0,5	0,8	131	375	244
Papa	1.149	2.5	118%	6,7%	5,7	7,0	203	357	154 *)
Frutales	1.056	1.896	80%	5,0%			113	160	47 *)**)
Hortalizas	370	891	141%	7,6%			156	253	97 *)**)
						Totales	1409	2894	1485

Source: Elaborated based on data: Presidential Representation for the Patriotic Agenda 2025, Productive Diversification and Food Sovereignty Unit, 2013.

*) Items with a strong implication of irrigation in the expansion of the production area and increase in productivity.

**) Items in which the viability of production in valleys and highlands involves technological innovation, including irrigation technology, fertigation, solar tents, etc.

***) In rice, the proposed production system is under flooding.

According to this vision, a substantial part (one million hectares) of the expansion of the agricultural area must be supported by the expansion of irrigated areas, for two reasons: 1) to guarantee the growth of the production of mass consumption crops in their traditional production areas: potatoes, cereals, legumes, vegetables, fruit trees, and 2) lack of new arable land suitable for sustainable rainfed production. Irrigation also plays a crucial role in reducing production risks caused by increasing climate variability and in controlling the expansion of agriculture through deforestation.

By expanding the area under irrigation, PA2025 seeks to consolidate sustainable and highly productive agriculture, including the plains currently used for rainfed production. This will contribute to the preservation of forests and protected areas in vulnerable life zones, so that the expansion of the irrigated area contributes to the dual purpose of climate change adaptation and mitigation of greenhouse gas emissions, two important pillars of the Framework Law of Mother Earth.

Based on this vision of agro-productive development and taking into account the potentialities and limitations of an expansion of the different types of irrigation in regions with significant potential (see paragraph 3.1.1), irrigation area expansion goals were established until 2025 (see Table 2).

ii. <u>Irrigation efficiencies</u>

To complete the evaluation of the demand, the efficiency of the water distribution system and of application must be known. This is usually the weakest point in estimating the demand, because such evaluations are rarely made in the field as they are time-consuming, and the qualified staff needed to undertake them are frequently not available. This again stresses the need for some specialized unit, that should be implemented by the project as a management model to take care of this important function.

In the absence of reliable field data on efficiencies, empirical data from the abundant literature on the subject can be used.

Table 3. Bolivia - projected expansion of irrigated areas to 2025

Irrigated area expansion strategy	**Incremental irrigated area (Has)**	**Number of Agricultural Production Units (family or business)**	**Estimated investment in millions of US$**	**Cost per incremental irrigated hectare (US$/ha.)**	**Macro-regiones y Regiones**					
					altiplano	**andean headwaters**	**inter-Andean valleys**	**sub-Andean**	**arid and semi-arid lowlands**	**humid and semi-humid lowlands**
Technified irrigation in the plains	200 000	500	300	3 750					x	x
Revitalization of existing irrigation systems (2000 systems)	91 447	125 000[2]	370	9 251	x		x			
New regulated and non-regulated systems	159 535	69 374	1 719	10 777	x	X	x	x	x	
Family multipurpose systems	19 200	36 000	192	10 000		X			x	
Irrigation for flooded rice cultivation	93 000	11 625	558	6 000				x		x
Wastewater reuse systems	18 750	25 000	122	6 500	x		x			
Total:	**581 933**	**267 499**	**3 261**	**5 605**						

Source: Adapted from: Vice Ministry of Water Resources and Irrigation, 2013.

From the projected relationship at the national level and by macro-regions, as well as regions, the RECEM Valles Project will contribute to the implementation of revitalization actions in the Bolivian Valleys**.**In the valley areas, an expansion of the irrigation area will be achieved with the revitalization of old irrigation systems or those built more than two decades ago, estimated at more than four thousand systems with an area of 200 thousand hectares. The irrigation efficiency of these systems is in many cases less than 20%. As water sources in traditional irrigated areas are becoming increasingly scarce, an important option is to improve the efficiency of existing systems. The projection until 2025 is to revitalize half of the old systems, about 2000 systems, including measures to increase efficiency and productivity. The expected overall result is an increase of 100,000 hectares irrigated annually.

For areas with few options for using water sources, especially in the headwaters of Andean basins, the option to meet irrigation demands is through water harvesting systems (atajados) and/or use of small springs for family use.

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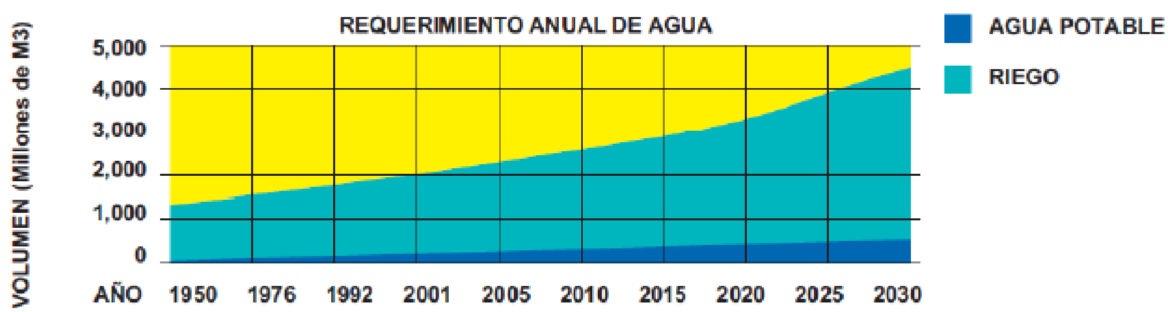
[2] The number of 125,000 families benefited by the revitalization program does not constitute new irrigation families, since the expansion of the irrigation area is used by the same families.

The incremental area to achieve family irrigation systems is 20,000 hectares by 2025, benefiting about 25,000 families in rural areas with the most vulnerable populations.

1.1.3. Matching supply and demand

To the negative climate trends must be added the growing water needs to cover irrigation and drinking water requirements, due to the effects of population growth, economic development and urban growth. The projection of these demands for the irrigation and drinking water sectors for the coming decades foresees an increase of 50% (from 3,000 to 4,500 Hm3) by 2030. The largest increase in needs comes from the irrigation sector from 2,500 to 4,000 Hm3.

Figura 4 Tendencia de Incremento de los Requerimientos Anuales de Agua para uso Doméstico y Riego



Fuente: Proyecciones CAT-PRONAR, 2004.

Once calculations regarding the supply and demand have been completed in the irrigation inventory for the intervention area for the RECEM Valles Project (see activity 2.1.2) the most difficult part of the exercise begins consultation with farmers, which are real problems and demands of a technical nature in the period of irrigation water distribution that the project should respond to, part of the empowerment of farmers in the management of irrigation systems, which guarantees the sustainability of actions in the future when the project is concluded. discussing such practices and measures, it is useful to recall the most common situations that can be found in matching supply and demand. Although the spectrum of possible situations is very large, three main cases can be clearly distinguished:

i. Irrigation schemes where water supply is greater than or equal to the demand.

ii. Irrigation schemes with a moderate water deficit.

iii Irrigation schemes with a large water deficit.

As shown in the figures in previous sections, water supply and demand will depend on certain factors that will obligate to promote different irrigation schemes in order to better use water availability:i. Irrigation schemes where water supply is greater than or equal to the demand.

This is the most favourable situation from the management point of view. Although systems with relatively abundant water are easier to operate, they are likely to be less efficient in terms of returns per unit of water distributed than systems with some degree of scarcity. This kind of situation often corresponds to the construction period of very large irrigation schemes in which, until their completion, demand is considerably lower than supply. It is also typical of incomplete schemes.

In technically well designed schemes, supply and demand should match fairly equally. However, it is not only important to check the seasonal volumes needed but also to check if the demand in the peak month can be met. When the supply is smaller than the peak month demand, the usual corrective measure is to advance the planting dates of some of the crops in order to avoid coincidence of peak demands.

ii. Irrigation schemes with a moderate water deficit

A moderate water deficit (10-20 percent of the water supply available) is often encountered in irrigation schemes. This can either be a periodic situation found only in "dry" years or recurrent every year. In the first case, it is normally an accepted risk in the design of an irrigation scheme, while in the latter it can often be attributed to designs associated more with social factors than technical ones, although other factors (changes in planned cropping pattern, overestimation of the potential water supply, technical deficiencies of the system, etc.) may also have led to this kind of situation. Whichever the case may be, these irrigation systems offer the best potential for maximizing the returns from the water that is available.

Suitable water distribution practices and methods, combined with some of the measures pointed out below, can be extremely useful in matching, as far as possible, supply and demand in these schemes.

iii. Irrigation schemes with a large water deficit

The water deficit is often greater than 50 percent of the available supply. However, these schemes were not designed to irrigate the whole command area at cropping intensities of 100-200 percent. In their case, 'demand' may be fulfilled if 40-60 percent intensities are achieved.

Many of these schemes were designed with the important social objective of benefitting as many people as possible; others were merely the result of an underevaluation of crop water requirements; still others were aimed at maximizing government revenue. Whatever the reason, these projects have frequently yielded less than expected. Production per hectare is low and large areas are sometimes abandoned due to salinity problems. Some of the reasons for such a situation were:

- that although the efficient use of water was essential, the farmers were not assisted in preparing their lands (land levelling, grading) for efficient use when water supplies were limited.
- the same can be said about irrigation practices suitable for salinity control and efficient water use.
- that no preventative measures (drainage system) were taken to prevent build-up of soil salinization.
- that the water distribution network was much longer than it should have been, therefore losses were bound to be greater.

These problems do not only occur in irrigation systems with large water deficits; they can also happen in any of the others. The crux of the matter is that under very limited water supply, these problems are likely to have more damaging effects.

Some of these problems can be corrected a posteriori through the rehabilitation and improvement of the scheme, although this entails greater difficulties and costs than if the project had been suitably designed and operated from the beginning. The point to be made here is that where water supplies are extremely scarce in "socially designed projects", it is possible to obtain high returns from water, provided good management (i.e. ensuring regular and predictable water supplies) is ensured, suitable technical designs are implemented and the farmer is assisted to use water efficiently.

For areas with a large water deficit, the following is proposed, in line with the interventions in the Funding Proposal:

(a) Measures related to cropping patterns, such as optimizing crop calendars and changing the existing crops to crops with lower water requirements e.g. quinoa y sorghum (Alvar-Beltrán, J. et al, 2021);

(b) ensuring irrigation is based on rainwater harvesting

i. Measures related to the cropping pattern

There are three main measures that can be undertaken to reduce water demand: (a) changing the planting time; (b) changing the existing crops for others with lower water requirements; and (c) reducing the irrigation area. Of all the possible measures these are the most effective to reduce water deficit, but they are also the most difficult to implement. They require that the management of the irrigation scheme be invested with the necessary authority to introduce such changes in the cropping pattern. Otherwise, a long dialogue may take place between the management and the farmers to convince them of the necessity for this measure which may not always end with a positive decision.

a. By suitable regulation of the planting time and other cultivation activities large reductions can be attained during the peak demand of an irrigation scheme. Careful planning also allows controlled staggering of cultivation activities between different sections of the same irrigation system leading to a more rational use of available machinery and manpower.

b. Changing the existing crops for others is an effective measure to reduce water demand, e.g., rotation with maize, potato, beans (leguminous), lately oregano has been incorporated in the valleys of Chuquisaca Department for export, in some areas fruit growing in areas, apple production in areas with cold hours and in other areas in the south of the intervention area viticulture etc. However, the condition must be met that the two crops have similar characteristics or end purposes. Otherwise, there is the risk of introducing crops which may have very low water requirements but that are not financially attractive to the farmer, one of the problems faced by farmers is that harvesting in the same period of time causes prices to drop, resulting in oversupply. Therefore, the possibilities for applying this measure are limited.

ii. Measures related to water distribution practices.

Besides the measures described above, there is also the water allocation practice, where water is diverted according to supply and demand.

There are only two measures that can be used to lessen the water deficit:

(a) reducing the water allocation but keeping the same water distribution method, reducing the time of irrigation water use for the productive system that is being irrigated, that is to say, making an efficient use of water resources, satisfying the demand in less time, this can only happen in the framework of the implementation of sprinkler or drip irrigation systes

(b) changing the water distribution method to a more efficient one, changing from irrigation channels to the plot for irrigation by precipitation or flooding, to drip or sprinkler irrigation systems using flat hose: single-layer and double-layer hose, for agricultural use and water conduction to the crop.

a. Reducing the water allocation can be affected in different ways:

- Acuerdos territoriales y comunitarios para adecuación de la administración concertada del agua para riego acorde a la necesidad del Sistema productivo y al volumen de agua disponible.
- : This is common where high value crops (fruit trees, nursery produce, vegetables) are grown near to less valuable ones. In such cases, the regulation is sometimes established that the valuable crops must receive their necessary allocation and

whatever is left can be utilized for the other crops.. This kind of measure is easy to implement provided that the interests of the farmers and the management are the same, which is generally the case.

- Decreasing the amount of water given per irrigation: This can be done in a manner proportional to the deficit with no regard to the possible effects on the crop yield or, on the contrary, by trying to decrease the amounts in such a way that the effect on crop production is minimized. The first alternative is the most commonly adopted because of its simplicity, but the second one offers much better possibilities, where it can be applied. This method can be extremely effective in irrigation schemes concerned with one single crop, but its effectiveness decreases with the number of crops grown because the intervals that fit one crop well may not necessarily do so for others.

  With measures like these, the reduction that can be expected in the water demand is moderate. Large reductions in flow in canals will often hamper their operation, e.g. the canals of northern India are designed to run above 75 percent capacity and will not distribute water proportionally if run below this figure.

- Extending the interval between irrigations is the measure most commonly used to cope with water deficits. For example, if in one given year the system is able to provide 8 irrigations but the following year the supply is only half this amount, the system will deliver 4 irrigations at double intervals of time. Although this measure is most common, there is, however, as in other cases, also the possibility of giving the 4 irrigations at times when the crop can make best use of the water. As in the previous case, using the same principles of crop yield response to water. Similarly, the effectiveness of the method is reduced by an increase in the number of crops grown in the scheme. This leads to the gradual implementation of technified irrigation.

b. Changing the water distribution method: Among the different water distribution methods described in detail in the next section, it is to be expected that some will be more efficient (assuming comparable situations of management and technical design the irrigation systems in the area are not technified, it is necessary to incorporate either drip or sprinkler irrigation gradually) than others. The possibilities of changing the water distribution method are very limited since a certain method is normally linked with a specific technical design.

In most cases, changing the method also means changing the physical system to some extent. However, even in cases where there is no need to alter the physical system, a switch is difficult to introduce because farmers have been used to a particular system for many years. When such changes are intended, it is advisable to try them out in a pilot area and later extend them to the rest of the system when the positive attributes of the new method have been demonstrated.

This policy changed later because of a reduction in cotton prices on the international market and an increase in the water supply to the scheme.

1.2. iii. General guidelines for integrated and sustainable water management

According to their uses and customs, as well as communal or irrigation association regulations, the distribution of water may have different characteristics depending on the water distribution method utilized. The main water distribution methods are:

- On-demand: Water is available to the farmer any time when the intake or hydrant is opened. Therefore the amounts to be used are not limited but water consumption, unusual in the area and very harmful because it weakens organized actions among farmers for the rational use of water.

- Semi-demand: Water is made available to the farmer within a few days (generally 2-7 days) of his request. The amount is often limited to a certain volume per hectare.

- Canal rotation and free demand: Secondary canals receive water by turns, for example every 7 days, and once the canal has water, farmers can take the amount they need at the time they wish.

- Rotational system: Secondary canals receive water by turns and the individual farmers within a given canal area receive the water at a pre-set time and generally in a limited quantity.

- Continuous flow: Throughout the irrigation season, the farmer receives a small but continuous flow that compensates the daily crop evapotranspiration.

As stated earlier, the water distribution method is normally linked to the design of the conveyance system - although there are exceptions; therefore, once a water distribution method has been selected there is little possibility to change it. The selection of the water distribution method is thus an important matter where social, technical, and economic characteristics must be taken into consideration. Each of the methods has its own characteristics which may, or may not, suit local conditions.

1.2.1. On-demand

On-demand irrigation systems are generally designed with high-level technology. The degree of human intervention is minimal since they operate on automatic principles, i.e., when the water level or pressure drops in a canal or pipe due to the opening of an inlet, the level or pressure is immediately reinstated by an automatic device which calls for a greater supply, provided by automatic gates or valves. The efficiency of these systems is very high (up to 90 percent) particularly when using pipes for the distribution.

There is very little actual operation in these systems and that is limited to some overall control of the automatic system, which is usually done through remote control panels located at the management office. Although the manpower requirements are small, the people must be highly qualified.

The great advantage of this method is that it allows the farmer to use the water when it is most necessary for the crops. The main disadvantages are high costs and the need for a high-level technology in the construction and maintenance of the systems. Thus, the systems are more suitable for developed countries than developing ones and rather unsuitable for the least developed countries.

The success of on-demand systems in developing countries depends on many factors but, in any case, the closed system (pipes) has better possibilities than the open canal system. The reason for this is that in the latter the automatic gates are susceptible to blockage by vegetation or misuse by human intervention and once the automatic regime of the canal is disrupted the chances of overtopping are great, with subsequent damage. On the contrary, pipe systems have the important advantage that they cannot be manipulated by anyone, and thus operational and social problems (e.g. stealing of water, etc.) are reduced.

1.2.2. Semi-demand

This is perhaps the most common system of water distribution due to its simplicity. A farmer requests the water from the water guard, who passes the information up to the water master. He makes the necessary calculation to accommodate it with the demands of the other farmers within the limited capacity of the canal. If the demand can be met, the information is passed back through the water guard to the farmer with an indication of the exact time of his turn. In irrigation systems where the canals have been designed with a certain flexibility, the request is usually met within a short time (2-3 days), although sometimes 6-7 days can elapse in the case of canals with little flexibility and high demand, depends on water availability related to increasingly erratic rainfall distribution due to climate change.

The amount to be supplied to the farmer is usually fixed in relation to the number of hectares. A known amount of water is an indispensable requirement for such a system, otherwise the water master cannot calculate the time and flow needed for each request in order to prepare the water distribution programme.

This form of distribution requires a well-designed and constructed irrigation system since the flows delivered by the canals should be well-known, and the intakes should also be capable of delivering the requested flow.

The water guard has a crucial role, and he must be a man trusted and respected by the farmers. It is preferable that he lives among the farmers of the canal in order to facilitate communications, and he must be able to undertake elemental calculations to adjust demand and supply.

To avoid possible excess in water use by the farmers some restrictions may be imposed, such as: the number of irrigation per year is limited, or a certain time (7-10 days) must elapse between two requests for water, or those who in a given month have already received water have a lower priority than those who have not, etc.

Another advantage of this system is that when the need arises (peak month) or during exceptionally dry years, it can also function on a fixed rotation.

The only disadvantage of this distribution system is its low efficiency at times of low demand because the opening and closing of canals for a few farmers could imply considerable losses. However, the problem is mitigated since at times of low demand water losses are not so relevant.

1.2.3. Canal rotation and free demand

This system is adopted particularly where there is mixed control of management. The public administration undertakes the operation of the main and secondary canals, and the farmers either take the water freely from those canals or distribute it themselves from a smaller canal.

All those classified A receive water for seven days, and are then closed for seven days, while the B canals receive water when the A are closed. These turns may be changed during the irrigation season and vary from region to region.

The duration of the turns is generally the result of experience in the area. When the number of crops grown in the irrigation project or region is fairly large, there is not much opportunity for rationalizing the duration of the turns. However, where the number of crops is limited or some crops clearly prevail, the duration of the turns can be determined in a rational way. Annex II gives an example of a generalized procedure for the determination of the minimum irrigation turns.

When it is their turn, the farmers take the water from canals on free demand, or they may eventually establish some kind of rotation among themselves. In the first case, which is the more frequent, the canal must be designed to cope with a concentration of demand at any time.

This type of distribution can be handled easily by public organizations, but it implies large operational losses. The low efficiency of the system is mainly due to the fact that demand and supply are disassociated: canals are filled every turn irrespective of the demand. Some adjustments can be made in the canal water levels according to the demand pattern, but still operational water losses are bound to be high. The system can easily be improved by properly organizing the farmers along the watercourses and regulating the flows according to the requests received from the groups of farmers on each watercourse. Under this hypothesis the system could be much more effective.

1.2.4. Rotational system

In this system all canals receive water by turns and farmers on the tertiary canals or watercourses receive water at a pre-set time and in the allowed quantity. This system is an improvement on the previous one where the rotation is not only of the main canals receiving water but also of the farms. It is a highly efficient system from the operational point of view and socially fair since it gives an equal chance to everyone.

There are several ways in which a rotational system can be implemented:

i. The water is distributed by turns of equal duration throughout the irrigation season. The farmer receives the water on a fixed day for an amount of time that is always constant, regardless of the crops that he may plant.

ii. The water is distributed by turns of different duration, longer at the beginning and end of the irrigation season and shorter in the middle, according to crop demand. The order of distribution within each turn is always the same and the amount delivered is constant throughout the season.

iii. The water is distributed by turns of different durations and the amount delivered also changes throughout the season. The amount delivered is calculated according to the actual crop water requirements.

The degree of technicality increases from (i) to (iii) and this not only refers to the actual calculation of the amounts of water to be delivered but also to the design of the irrigation network. For instance, method (i) can only be applied if the irrigation network has water measuring devices for each farm.

Method (i) is the simplest of the three and perhaps the most widely used. Socially speaking, it is a fair method, since it gives every user an amount of water proportional to the amount of land. If water is extremely scarce, the method is still quite efficient as the farmer must adapt his cropping pattern to the fixed turns. Calculations for the water delivery are simple and can be made easily.

Method (ii) requires a little more technical knowledge as the intervals must be adapted more to the actual needs of the crops. This can be very effective when the scheme is concerned with monoculture but the more diversified the production, the less effective will it be.

Method (iii) technically offers the best opportunity to meet crop water requirements and achieve greater water efficiency. However, it is difficult to implement. First of all, water measuring devices are needed at the farm level in order to measure the amount of water that must be delivered. Secondly, the management must have an excellent communication system in order to inform the farmers well in advance about their turns. Thirdly, since the calculations for the amounts of water to be delivered are made by the management and change from one irrigation to the next, the system is very vulnerable to malpractice. Fourthly, the calculation procedures are quite complicated and lengthy, needing qualified staff for their execution. As a result of all these requirements, this method is rarely used, despite its theoretical advantages.

2. MAINTENANCE OF IRRIGATION SCHEMES

The Maintenance Service is entrusted with the overall responsibility for keeping the irrigation and drainage systems working in a satisfactory manner.

The GCF Project will promote an Agreement for O&M, signed between the program MiRiego, the municipalities and the irrigation committees, to ensure in principle a counterpart amount that guarantees the sustainability and effective application of the O&M Plan.

The main functions to be undertaken under Maintenance are:

A) planning the maintenance activities.

- make an inventory of all the works that require maintenance.
- determine the volume of maintenance activities to be undertaken annually.
- establish the optimum cycle of maintenance for each type of work.
- determine the machinery and manpower requirements to undertake the maintenance.
- budgeting and establishing the maintenance priorities.

B) implementing the maintenance activities planned and those unforeseen.

The implementation of maintenance activities is highly site specific in nature, but some general management principles can be applied, the most relevant of which are as follows:

- Good planning is particularly important in maintenance work since the time and resources available for its execution are limited. The use of planning techniques such as critical path methods and bar diagrams, is helpful, though rarely put into practice.
- Monitoring the output productivity is essential, not only to feed back the planning process with realistic data but also to control the progress of the work planned.
- Farmers' participation in maintenance work should be encouraged. In some irrigation schemes the contribution of a number of man days per farmer is spelled out in the by-laws of the scheme. In other cases, the responsibility may be for specific studies of irrigation ditches. The Maintenance Service should provide technical guidance, organize and control the work.
- Maintenance work on a voluntary basis is customary in some old irrigation associations but it is difficult to obtain in public irrigation schemes, however, it is mandatory because of its own benefit.
- Whenever unskilled labour is required, use should be made of the human resources of the farming community of the project.

C) monitoring the above-mentioned activities:

- Requires data for good planning which can be obtained by regular monitoring.
- Without reliable data on costs for the different units of work and on productivity no realistic planning can be done.
- Later in this text, productivity data are given for machinery and manpower engaged in maintenance operations in coordination with the municipalities.
- They will be helpful when planning and costing activities if no better data are available, but a project should endeavour to have its own data based on the specific conditions of the area.

All of the mentioned aspects will be part of the Agreement signed between MiRiego, the municipalities and the Irrigation Associations, not only considering an amount as a counterpart, but also for the adequate O & M.

In a complementary manner, operation and maintenance plans will be prepared by irrigation associations or communities organized according to their customs and traditions.

2.1. Types of maintenance

There are three main types of maintenance, namely:

- routine or normal maintenance which includes all work necessary to keep the irrigation system functioning satisfactorily and is normally done annually.

- special maintenance including repairs of damage caused by major disasters common in the area, such as torrential rains which causes flash floods. The unforeseeable nature of such natural phenomena makes it very difficult to take specific preventive action, although general safeguards can be installed in particularly prone areas, e.g. large drainage dykes in flood areas. In irrigation schemes located in places subject to these hazards, a "special reserve fund" or budget allocation should be established for repair work.

- deferred maintenance including any work necessary to regain the lost flow capacity in canals, reservoirs and structures when compared to the original design. It often includes large modifications to the canal system and structures arising from important changes (cropping patterns, drainage problems, etc.) that have occurred in an irrigation scheme. In practice, it is difficult to differentiate between so-called 'deferred maintenance' and a 'rehabilitation programme'. The difference is mainly of a financial nature, because 'deferred maintenance' is normally undertaken with funds from the national budget allocated to operation and maintenance while rehabilitation programmes are considered as an investment and the funds come from a different source one of these could be the Multiannual Integrated Watershed Management Program under the Ministry of Environment and Water.

2.2. Maintenance activities

The maintenance activities for which the Maintenance Service is responsible should be clearly spelled out in the by-laws of the irrigation scheme. While some activities are clearly a responsibility of the Service (silt removal in canals, weed clearing, etc.), there are others not so precisely defined, for instance, rural roads, ancillary works, buildings, the cleaning of the drainage system. Nevertheless, it has 'been decided to include in the text all potential activities that could be the object of maintenance with a brief description of their characteristics and relative importance.

The maintenance activities have been grouped according to the major elements of an irrigation system; they are: (i) dam and reservoir; (ii) irrigation network; (iii) drainage network; (iv) pump stations; and (v) ancillary works. They are described below.

2.2.1. Dam and reservoir

Maintenance activities in a reservoir itself comprise:

- surveying the solid deposition in the natural drainage systems that feed irrigation systems, soil sediments are common, from runoff and soil erosion in the upper reaches of the basins.

- removing large debris e.g. rocks, tree trunks trailed or floating in the water that may damage hydraulic works,

- monitoring the water quality: not only from the salt content point of view but also from a biological standpoint in order to detect possible sources of pollution,

The most common problem in the area it is by soil sediments which are common, from runoff and soil erosion in the upper reaches of the basins. The problem of water shortages that can cause the reduction of water availability in the lower part of the basins, running the risk of reduced water availability in irrigation systems, is an integral problem that must be addressed in the integrated management of watersheds, under participatory planning with farmers.

Another frequent problem is eutrophication (over-abundance of nutrients in the water bodies) resulting in high production of blue-green algae and the associated phenomenon of lack of dissolved oxygen in the water. This problem, which is very serious if the water is used for urban water supplies, is less important when the water is used for irrigation, the main consequence of the latter being an increase of vegetation in the irrigation canals and greater weed infestation. Injecting compressed air into reservoir water has proved to be a satisfactory solution on several occasions but there are other techniques that can be applied.

The main maintenance activities for an irrigation dam are: lubrication of gates, anti-corrosion treatment, cleaning of debris, control of filters, and some other minor work. Earth dams require greater maintenance, especially the upstream slope where weed control is necessary once or twice a year. The electro-mechanical system of a dam must also receive proper maintenance, particularly electric engines, head gates, and the lighting system. The maintenance of these elements is rather specialized and the manufacturers of the equipment usually provide detailed instructions.

2.2.2. Irrigation network

The canals in irrigation networks are generally either of earth or concrete-lined and their maintenance characteristics are quite different.

i. Concrete - lined canals

Concrete-lined canals should require little maintenance provided, , that they have been properly constructed and any potential problems studied (subpressure, gypsum soils, swelling clays, etc.) and adequate technical solutions provided. One of the main reasons for constructing concrete-lined canals is precisely to reduce maintenance operations, however, must be cleaned constantly specially of rocks and stones.

The routine activities include replacement of joints, replacement of damaged concrete slabs, weed control in joints and on the surface of concrete slabs, control and treatment of filters, control and removal of silt. In the case of concrete flumes, chemical sterilization is also needed around the supporting structures.

Under normal conditions, the silting in concrete-lined canals is not an important problem since water velocity is high and sand traps and silting basins are often provided to reduce the solid content of the water. Heavy rain may cause deposition of solid materials if the berms are not properly formed. Drifting sand may be a serious problem in schemes surrounded by desert or bare land and subjected to strong winds. The most effective way of preventing this type of silting is to install windbreaks or barriers where sand accumulates before reaching the canal.

Removal of silt from concrete-lined canals is an expensive operation because it is mainly manual. Mechanical equipment can be used when specially adapted to avoid damaging the lining. In some irrigation schemes, the technique of flushing "quick water" through the canal is used to remove silt from one place and concentrate it in another where it can be more easily removed or disposed of. For this purpose, the canal should be run at its maximum capacity to reach the highest possible velocity.

Weed control should not be a major problem in lined canals, although aquatic weeds must be periodically removed. Later in the text, guidelines are given for weed control in both lined and earth canals.

The main problem in concrete - lined canals is cracking of the lining and eventual eruption of concrete slabs due to subpressure. Apart from repairing the damaged lining, corrective action must be taken. Usually the installation of subpressure valves is enough to relieve the pressure, but this involves major work. An alternative measure can be the construction of a subsurface drainage system to lower the water level.

ii. Earth canals

There are four main problems in earth canals requiring maintenance attention and, although they are closely interrelated, they will be treated separately.

a. Silting

Excessive sedimentation is perhaps the most common problem affecting the performance of earth canals. Malik (1978) identifies the following causes for canal siltation:

1. excessive silt entry at the main canal intake.
2. disproportionate withdrawal by branches.

3. prolonged heading up at control points.
4. drifting sand.
5. inadequate transport capacity of channels.
6. re-entry of excavated material by rain and wind action.
7. malfunctioning of intakes.
8. haphazard sediment excavation.
9. excessive weed growth.
10. wrong channel regulation.

Causes 1 to 5 indicate defective design, 6 to 9 inefficient maintenance, while 10 denotes improper channel operation. Corrective measures for defective design are difficult to implement since they require major physical changes which imply heavy investments. However, the effects of defective design can be reduced by proper maintenance. For example, an erroneous angle between the parent branch and canal may induce the formation of a sand shoal which, if allowed to develop, will accelerate the silting process, thus compounding the consequences. Incorrect operation is also a major cause of silting. Canals carrying a heavy load of material in suspension should not be allowed to run at less than three quarters of their capacity since at lower capacities the velocity decreases inducing silting.

Abrupt shutting of gates, causing rapid changes in flow velocity, may induce bank erosion near the gates.

b. Water infiltration

Water leaks through canal banks can be caused by overflow of sediments, stones, rocks, or by rotting plants and roots which were not removed from the canal bank seat during construction. Ants are also known to be a problem even in concrete-lined canals. These leaks can be repaired by following the path of the leak through the bank either by hand digging or hydraulic backhoe if available and once the path has been found, the trench must be carefully backfilled and compacted. Canal leaks, if not repaired in time, can result in major breaches in banks causing far greater inconvenience and most costly repairs.

Water seepage through porous soils may also be a major concern. Seepage through banks can be considerably reduced by trenching them and burying a plastic membrane or thick slurry made from the excavated material. The trench is backfilled with sand after the barrier has been interred.

d. Erosion of banks

Canal banks can be eroded by heavy rainfall, slopes or wind, improper canal operation, stock grazing or passage by drinking animals, and the transit of vehicles. Heavy rainfall, slopes or wind can cause serious damage to unprotected banks. Seeding of grasses in the unwetted part of the canal is a cheap and effective protective measure. Short growing varieties (e.g., Agropyron riparium (streambank wheatgrass), Festuca sativa (sheep fescue) and Phleum bertolonii (dwarf timothy)) give good results.

Rapid and abrupt closure of canal water may also contribute to bank erosion. The practice of leaving a canal empty during the rainy season will contribute considerably to erosion of canal slopes.

Cattle and sheep damage the channel banks in different ways. Cattle tend to push the moist bank material at the waterline into the waterway when they drink. Sheep, however, graze the banks bare thereby allowing wind and rain to wash away the bank material.

Erosion of canals can be repaired by mechanical means or manually by re-building the worn canal banks. However, care should be taken to construct a proper join between the old and the new part, otherwise the canal will deteriorate at the same place.

The most effective measures are of a preventive nature: such as seeding grass mentioned earlier, fencing the canals, and constructing special places for animal watering and bathing.

2.2.3. Drainage network

The retention in good working order of open drains includes the following operations:

- light deforestation.
- weed control in the canal section.
- seeding grass in the canal section.
- maintenance of flow gauges and other measuring devices.
- removal of silt.
- maintenance of pumping stations where water cannot be evacuated by gravity.

For practical purposes, the maintenance of open drains is very similar to that of earth irrigation canals. However, all too often drainage networks receive much less attention than the irrigation ones. The result is that during heavy rain, when they are much needed, they do not work as they should.

Drainage maintenance should always be programmed from downstream to upstream, and as far as possible completed within an irrigation season. The intervals in regular maintenance should not exceed periods of 2-3 years between two consecutive cleanings.

Tile drains are subject to two main problems: (a) obstruction due to silting and plant roots, and (b) mineral deposits. The most common is the first. Mineral deposits of iron and manganese occur quite frequently in some irrigation schemes and the time necessary for such depositions varies widely from a few months to 30-40 years, depending on the mineral composition of the soil.

2.2.4. Pump stations

Pumping stations for irrigation schemes may be:

a. main irrigation lift-pump stations (surface water or groundwater);
b. booster-pump stations for additional lifts in the main or branch canals;
c. drainage-pump stations.

The first two are usually of medium to high lift, required to pump forecasted quantities of water for long continuous periods. The last is usually for low lift with much larger quantities of water and required to operate intermittently. The irrigation pumps are usually manually controlled whereas the drainage station is frequently float controlled to ensure automatic starting once drainage levels in the scheme begin to rise above a pre-set level. A manual operator should also be on call even with an automatic control.

Operation and maintenance tasks for electric pump stations powered by solar energy panels are comparatively simple. The operators must be given clear instructions on safety measures, on the methods of starting the pump motors and the way in which they must be brought into full operation. Electric motors powered by solar energy panels, sometimes require to be stepped up in speed manually at a strictly controlled rate. Also, canals may be damaged if all pumps come rapidly into full operation.

They must also be given a programme of irrigation quantities to be pumped i.e. 1, 2 or 3 etc. pumps to be operating. Where 24-hour pumping is not provided, account must be taken of the rate of rise and fall of canal levels in the irrigated area. It is of little use with a 12-hour pumping schedule if canals do not fill up until late in the morning and still remain full long after dark.

In case of an emergency, there must be some system for easy communication between the pump house operator and the officer in charge - either telephone or signal or runner.

2.2.5. Ancillary works

The hydraulic structures in an irrigation scheme include gates, inlets, spillways, outlets, dividers, siphons, jumps, check dams and other minor structures. Maintenance of such items, when they are constructed in concrete, is restricted to the removal of silt and obstructions. The mechanical elements require periodic greasing. Iron elements require antirust treatment. The same applies to structures in drainage networks (culverts, drainage outlets) and those in road networks (bridges, culverts, crossings, etc.).

Administrative buildings and some other special installations (stores, workshops) require a certain amount of upkeep and should not be overlooked.

2.3. Planning maintenance activities

In order to be able to formulate a maintenance programme, the following steps must be taken:

i. make an inventory of all the works that require maintenance.

ii. determine the volume of maintenance activities to be undertaken annually.

iii. establish the optimum cycle of maintenance for each type of work.

iv. determine the machinery and manpower requirements to undertake the maintenance.

v. budget and establish the maintenance priorities.

2.4. Implementation of the maintenance programme

The implementation of maintenance activities is highly site specific in nature, but some general management principles can be applied, the most relevant of which are as follows:

a. Good planning is particularly important in maintenance work since the time and resources available for its execution are limited. The use of planning techniques such as critical path methods and bar diagrams, is helpful, though rarely put into practice. should consider actions in the upper parts of the basin and its conservation.

b. Monitoring the output productivity is essential, not only to feed back the planning process with realistic data but also to control the progress of the work planned.

c. Farmers' participation in maintenance work should be encouraged. In some irrigation schemes the contribution of a number of mandays per farmer is spelled out in the by-laws of the scheme. In other cases, the responsibility may be for specific studies of irrigation ditches. The Maintenance Service should provide technical guidance, organize and control the work.

d. Maintenance work on a voluntary basis is customary in some old irrigation associations but it is difficult to obtain in public irrigation schemes. In this latter case, the use of incentives such as food and transportation, is advisable and work should be restricted to special repairs that need unexpected large human resources.

e. Whenever unskilled labour is required, use should be made of the human resources of the farming community of the project.

f. Subcontracting part of the maintenance work may be advisable in certain circumstances and should be more frequently adopted. It reduces the number of permanent staff in a maintenance unit and is a system that can be adapted to maintenance conditions that change from one year to another. It is highly suitable for specialized jobs such as maintenance of electro-mechanical equipment of gates and remote control devices, placing and removing deep well pumps, etc. Irrigation schemes having few vehicles and machines should also consider the possibility of subcontracting their maintenance rather than having a poorly equipped workshop where maintenance may be of low standard.

3. *ORGANIZATION FOR THE OPERATIONS AND MAINTENANCE OF WATER SCHEMES*

In order for the operations and maintenance of irrigation systems to be carried out efficiently, the organizational structure involves the contributions of the national government through its Program Mi Riego, municipalities, cooperation projects / programs / NGOs and family farmers, basin level management is a priority.

A water management organization can be broadly defined as a social organization aiming at an appropriate use of water for irrigation purposes among the farmers of a community, has to be considered , that has to articulate with communities in the upper part of the basin for its conservation and/or land use planning in the upper parts of the basin, especially for livestock, avoiding overgrazing or the development of plots in both cases, as mentioned above, causing sediment dragging that reduces water availability in the lower parts of the basin. On that sense, at the local level, the structure and organization of farmers is prioritized at level of micro basin where complementary actions is necessary. These organizations have the opportunity to be legally formalized constituting also an Irrigation Associations through which they will be able to access public financial resources in such a way as to ensure their sustainability over time.

i. The structure of the Water management Organization has the following executive bodies:

a. The Assembly composed of all the farmers of the association. It is the highest authority. Its main function is to select their representatives and to approve or disapprove the management plans.

b. The Board of Representatives: This is the highest executive body. Its main function is to supervise and direct the execution of the work approved by the assembly and to prepare management plans annually.

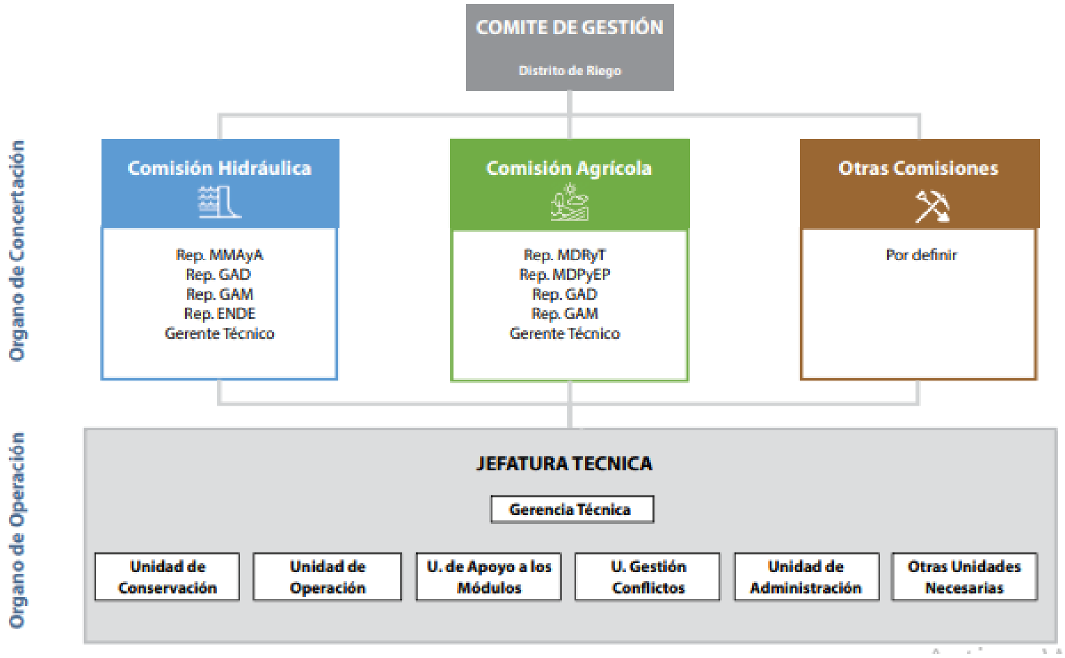
c. The Manager: Is directly responsible for the execution of the mandate giver by the Board of Representatives and for day-to-day work.

d. The Irrigation Juries: Some of these associations - especially the traditional ones - have their own juries to punish faults against the set rules and regulations. The jury is generally selected from distinguished members of the Board.

Irrigation Associations secure farmers' participation in decision-making for the irrigation schemes. The democratic process of selecting farmers' representatives guarantees such participation.

In this connection it may be opportune to raise the issue of the non-political nature of these associations.
According to the Diagnosis and Identification of Dam Projects with Multipurpose Potential in Bolivia, 17 projects with very high potential have been identified; In this sense, for the implementation of the proposed projects, it is essential to prepare a regulation that allows designing the management of irrigation infrastructure, in order to establish the aspects of operation and maintenance of these systems, which undoubtedly constitutes a management model for irrigation projects, articulated to multipurpose dams, which will be implemented in Bolivian territory, all within the framework of the General Regulation for the Management of >Irrigation infrastructure.

The Management Committee is a coordinating body for the Collegiate Management of Irrigation infrastructure, made up of representatives of Bolivian State entities at different levels (National, Departmental and Municipal) and companies related to dam management (Empresa Nacional de Electricidad, ENDE). It is responsible for the management, regulation and supervision, ensuring efficient water management, improving agricultural production, and the proper management of its infrastructure, as well as the operation, conservation, maintenance and administration of the major network infrastructure. This committee is organized into two commissions: Hydraulic Commission and Agricultural Commission, it also has a Technical Head.
In this sense, those in charge of the maintenance of the irrigation systems are the governments, municipalities, national level entities, as appropriate the MMAyA, MDRyT, among others. In a complementary manner, the users also maintain their irrigation systems as appropriate, pending the generation of investments to implement technified irrigation systems with resources from credits and donations established by the State at the plot or small family agrarian property or family communal unit level.



Organizational structure of the management of the Irrigation infrastructure, MMAyA, 2018.

NOTE. - This material will be traduced in Spanish and Bolivian dialects and will be accompanied by drawings and other communication technics in order to make this more understandable for local population.