5.3 Farming Committee

This committee is aimed at involving farmer's voice in agricultural development plan, and at the same time it functions to communicate contents of the plan, agreement of the committee, policy of SEA, guidance, etc. to farmers promptly and accurately. The committee is under the guidance and direction of SEA (Refer to Fig. 6.1.1-1). The committee members are representatives of farmers, Banco Agricola, INDRHI, a representative of agro-industry, Horticultural Experiment Station and the officer in charge of SEA-Constanza becomes the chairman. Representatives of farmers and a representative of agro-industry work for 3 years for a term with a small pay. The committee deals with any matter on agriculture in Constanza, and it holds the periodical meeting at least once in three months and the adhoc meeting whenever necessary.

6. Farmers' Organization

There exist farmer's associations in Constanza at present. But each association has small number of members and its activities are limited. In the plan, an agricultural development system is proposed to develop agriculture in Constanza and heighten the productivity as shown in Fig. 6.1.1-1. The aim of the proposal is to cooperate together in the common activities on agriculture such as production, marketing and water management and to improve the production in the whole area. The organization is largely divided into Water Management Division and Agricultural Production Division is under SEA. The existing farmer's associations are reorganized into a block of farmer's association and the whole area can carry out activities systemically.

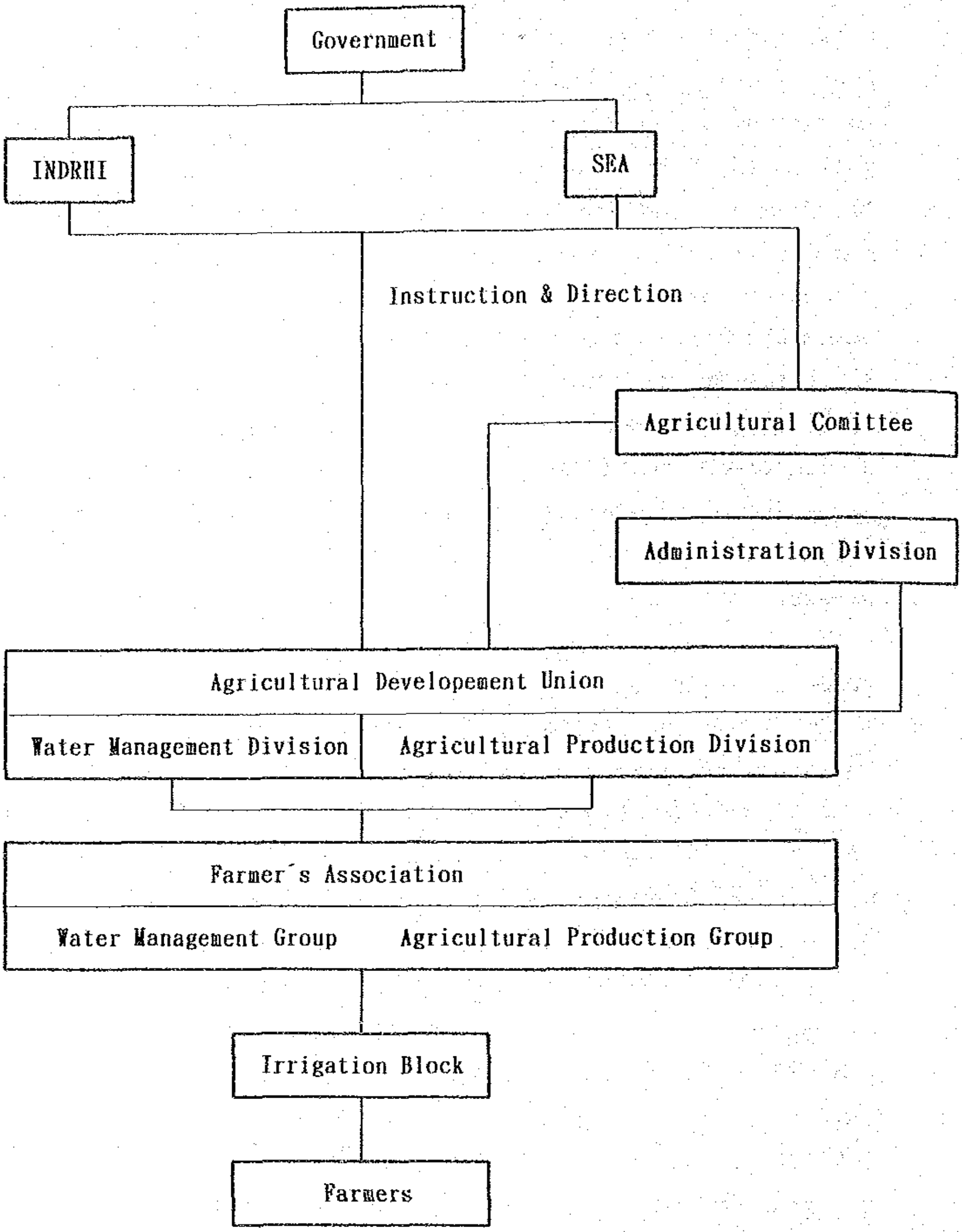


Fig. 6.1.1-1 Organization Chart of Agricultural Development Union in Constanza

ANNEX L : WATER RESOURCES DEVELOPMENT PLAN

ANNEX L: WATER RESOURCES DEVELOPMENT PLAN

LIST OF TABLES

LIST OF FIGURES

ANNEX L: WATER RESOURCES DEVELOPMENT PLAN

1. General

The water resources development plan should focus on the most effective investment plan based on the technical and economical studies.

The basic concept of the plan is to solve the constraints of water resource development and water shortage, examining the existing facility conditions.

Under the present irrigation system, water shortage occurs during December to April. On the other hand, during the other seasons, the excessive water is discharged as ineffective outflow. The effective utilization of the excessive water should be studied and the water resources plan should be designed such that it have no effect on El Salto mini-hydropower station project.

2. Basic Concept of Water Resource Development Plan

The development plan is focused on water resources plan aiming at solving the water shortage condition in the project area.

The following concepts are considered for establishing the development plan.

- The water demand for irrigation varies with respect to irrigated area and irrigation method. In this case, the proposed alternatives should be evaluated based on the following factors:

  1. Irrigated area is 1,510ha which is below 1,240m A.S.L. and can supply water easily.

  2. Sprinkler irrigation system is applied.

  The water resource plan should be studied to satisfy the water demand for irrigation in this area in 5 year return period of rainfall.

- Plans of low economical efficiency should be omitted, although it is possible to obtain large amount of water using these plans.
- The optimum plan should be selected based on the technical and economical studies of available alternative.
- The plan should have no effect on the existing plan (El Salto mini-hydro power station) and the water service facilities.

The flow chart for evaluation of water resources development plans is shown in Fig. 2.1.1-1.

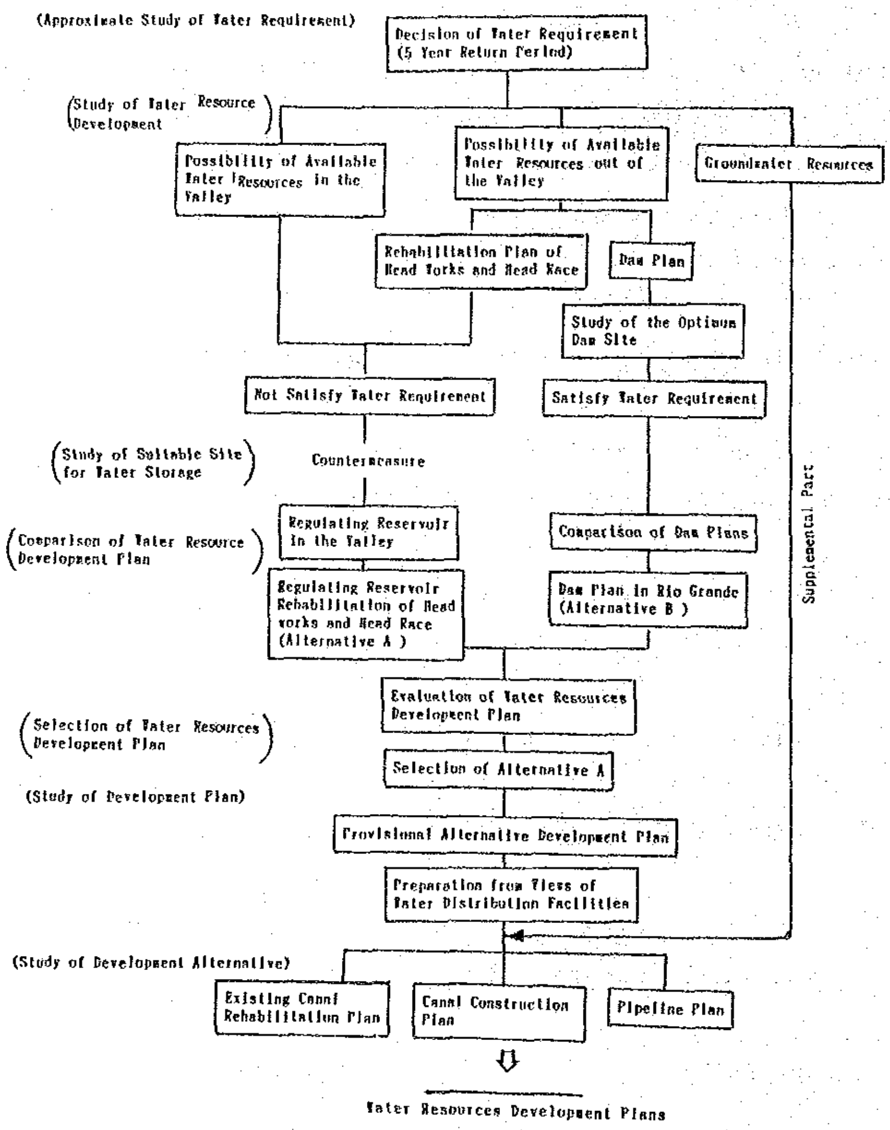


Fig. 2.1.1-1 Flow Chart for Evaluation of Water Resources Development Plans

3. Water Resource Alternative Development Plan

The following three water resources are studied for the water resource development plan in the study area.

- Development of water resource in the Valley
- Development of water resource out of the Valley
- Development of groundwater resource

3.1 Review of Water Requirement

Irrigation water requirement is the fundamental factor for establishing the water resource development plan. The crop water requirement was estimated based on the following factors.

- Crop evaportranspiration estimated by Penman method
- Crop coefficient in the study area is estimated by the proposed cropping pattern

3.1.1 Crop Water Requirement

Crop water requirement was estimated by Penman method using the meteorological data collected at Constanza Meteorological Station, as shown in Table 3.1.1-1.

Table 3.1.1-1 Mean Monthly Meteorological Data in Constanza

Items	Month	1	2	3	4	5	6	7	8	9	10	11	12
Temperature	(°C)	16.2	16.5	17.4	18.2	18.9	19.2	19.4	19.5	19.5	19.1	18.0	16.9
Sunshine	(hr)	7.2	7.0	7.3	6.4	6.4	6.9	6.8	6.9	6.2	6.2	6.3	7.2
Humidity	(%)	47.5	75.1	72.0	73.3	76.3	74.3	71.6	72.8	74.4	75.6	76.5	76.2
Wind Velocity	(Km/day)	208.2	176.3	250.6	190.9	159.8	208.2	259.2	206.5	167.6	146.0	171.1	196.1

The effective rainfall was estimated by the USDA method by 5 year return period of rainfall (R = 831.7 mm).
Crop water requirement and net water requirement estimated by Penman method are as follows:

Table 3.1.1-2 Crop Water Requirement (ETcrop) and
Net Water Requirement (N.W.R)

Items Month	1	2	3	4	5	6	7	8	9	10	11	12
ETo (mm/month)	77.5	75.6	105.4	99.0	108.5	105.0	117.8	111.6	99.0	93.0	72.0	71.3
Kc	0.68	0.76	0.48	0.26	0.51	0.77	0.68	0.37	0.15	0.32	0.76	0.74
ETcrop(mm/month)	52.7	57.5	50.6	25.7	55.3	80.9	80.1	41.3	14.9	29.8	54.7	52.8
Re (mm/month)	10.5	16.5	17.2	25.3	55.2	55.9	40.8	41.3	14.9	29.8	34.1	25.8
N.W.R (mm/month)	42.4	41.0	33.4	0.4	-	25.0	39.5	-	-	-	20.6	27.0

3.1.2 Selection of Irrigation Method

Irrigation method is the important factor which influences on the economic efficiency of irrigation and the water resources plan.
Although the selection criteria of irrigation method consists of many factors such as the field topographic condition, soil condition, crop items introduced to the project and so on, and in this project the limited water resources potentiality becomes the main criteria of selection.
The irrigation efficiency of the surface irrigation method and the sprinkler method are compared as follows.

Table 3.1.2-1 Irrigation Coefficient Comparison

	Surface Method	Sprinkler Method (1)	Sprinkler Method (2)
Conveyance Efficiency	0.9	0.9	0.9
Field Canal Efficiency	0.8 (Open Canal)	0.9 (Pipeline)	0.8
Application Efficiency	0.5 (Surface)	0.7 (Sprinkler)	0.7
Irrigation Efficiency	0.36	0.57	0.5

note: (1) with pipeline
(2) open canal

The value of irrigation efficiency for the surface method and sprinkler method is estimated as 0.36 and 0.57 respectively. This means that the water demand for the surface method is 1.58 times than that of sprinkler method.

Monthly irrigation water requirement by each irrigation method is shown in Table 3.1.2-2.

Table 3.1.2-2 Monthly Irrigation Water Requirement

Items Month	1	2	3	4	5	6	7	8	9	10	11	12	Year
N.W.R.	42.4	41.0	33.4	0.4	-	25.0	39.5	-	-	-	20.6	27.0	395.6
Surface	117.8	113.9	92.8	1.1	-	69.4	109.7	-	-	-	57.2	75.0	636.9
Sprinkler (1)	74.4	71.9	58.6	0.7	-	43.9	69.3	-	-	-	36.1	47.4	402.3
Sprinkler (2)	84.8	82.0	66.8	0.8	-	50.8	51.2	-	-	-	49.0	52.4	437.8

The irrigation water requirement for irrigating the whole cultivated area are estimated as follows:

1 Sprinkler irrigation (1) V = 608 x 10^4 cu.m

2 Sprinkler irrigation (2) V = 661 x 10^4 cu.m

3 Surface irrigation V = 962 x 10^4 cu.m

Difference 3 - 1 V = 354 x 10^4 cu.m

This means that the surface method requires more storage of 354 x 10^4cu.m against the sprinkler method. It is clearly concluded that the sprinkler irrigation method is more suitable for the project area. Also, the sprinkler method is popular among the farmers in the Valley Considering the sprinkler irrigation method, the gross water demand for the valley is calculated as follows:

Gross Irrigation Water Demand (m^3/s)

	1	2	3	4	5	6	7	8	9	10	11	12
Sprinkler (1)	0.41	0.44	0.33	0.04	-	0.26	0.25	-	-	-	0.27	0.26
Sprinkler (2)	0.47	0.51	0.38	0.05	-	0.30	0.29	-	-	-	0.29	0.30

In the water resources development plan, it is necessary to satisfy this minimum water demand.

3.2 Study of Water Resources Development

The Valley was irrigated by the Arroyo Palero and the Arroyo Pantuflas both of which flow in the Valley and reach the Rio Grande which runs down at the outskirts of the Valley. There are 1,660ha of arable area in the Valley, of which 80% (1,275ha) is irrigated by canals. However, these irrigated areas have chronic problem of water shortage and it is serious at the terminal zone of the canals. Only the area around the upper reach of canals are irrigated sufficiently. In other areas, irrigation water is supplemented by rain water or groundwater. Most of the cultivated areas are not irrigated sufficiently.

The following three countermeasurs are proposed to solve the shortage of irrigation water.

- Development of water resource which is not utilized effectively at present in the Valley

- Development of water resource outside the Valley.

- Development of groundwater resource in the Valley.

Detailed discussion for the above three countermeasures are shown as follows:

3.2.1 Water Resources Development in the Valley

(1) Outline

The basin of the Arroyo Constanza is 57.20sq.km, consisting of 32.40sq.km of mountainous area and 24.80sq.km of plain basin area. In the river networks, there are 2 major perennial sub-basins, one is Pantuflas basin with 10sq.km area and another is Palero basin with 4.8sq.km area. Total basin area of both basins reaches to 14.8sq.km only and the remaining area of 17.6sq.km is not used because of the following reasons:

- Surface flow in the rivers is almost drought through a year because of the river water percolation into the sub-surface

- It is hard to close the site, since the basin is an alluvial fan of unfolded shape.

- The basins have small pocket as a dam because of alluvial fan

- The basins have water high leakage potentiality

Consequently Pantuflas and Palero catchment areas, and lower reach of the Arroyo Constanza remains as the water resources development objects in the Valley. Discharges on 5 year return period of both the catchment areas are as follows:

Pantuflas catchment area	380 x 10^4 cu.m/ yr
Palero catchment area	190 x 10^4 cu.m/ yr

It seems that water is not used effectively since there is no regulating facility such as a dam in the areas.
This proves that the dam construction can modify the present condition.
The Arroyo Constanza gathers river water, irrigation water and drainage water from the field. It seems to have a high potentiality for the water resources development.
There is no facility for regulating discharge along the river. Hence, the flood discharge flows away in vain.
Now, the mini-hydropower station is under construction at El Salto, aiming at utilizing the discharge of the Arroyo Constanza. Its maximum intake capacity is 1 cu.m/sec., which seems to have a vested right of discharge utilization in the Arroyo Constanza.
There is a possibility to develop water resources by regulating the flood discharge with certain regulating facility since the discharge of more than 1cu.m/sec is flown as ineffective outflow.
But the water resources development in the lower reach of the Arroyo Constanza is neglected because of the following constraints:

- There is no suitable dam pocket in the lower reach side. Hence, the earth work volume would be the same as regulation volume.

- Storage water level is low and energy will be needed for lifting up water

- The dam will require the large scale area of existing farms

(2) Study of Suitable Site Dam in the Valley.

The more detailed study for the water resources development is carried out about the two catchment areas of the Pantuflas and the Palero. Some sites suitable for water storage are proposed and their effectiveness were studied. Locations of the proposed sites are shown in Fig. 3.2.1-1.

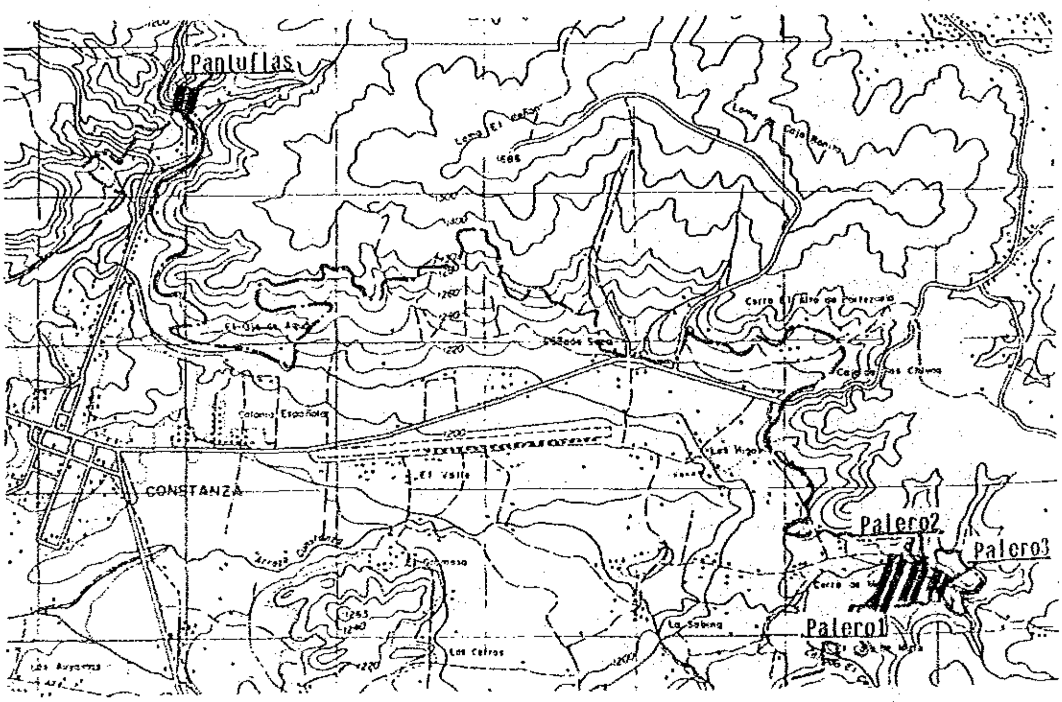


Fig. 3.2.1-1 Location Map of Proposed Dam in the Area

The relation between storage height and storage volume of each site is summarized in Fig. 3.2.1-2.

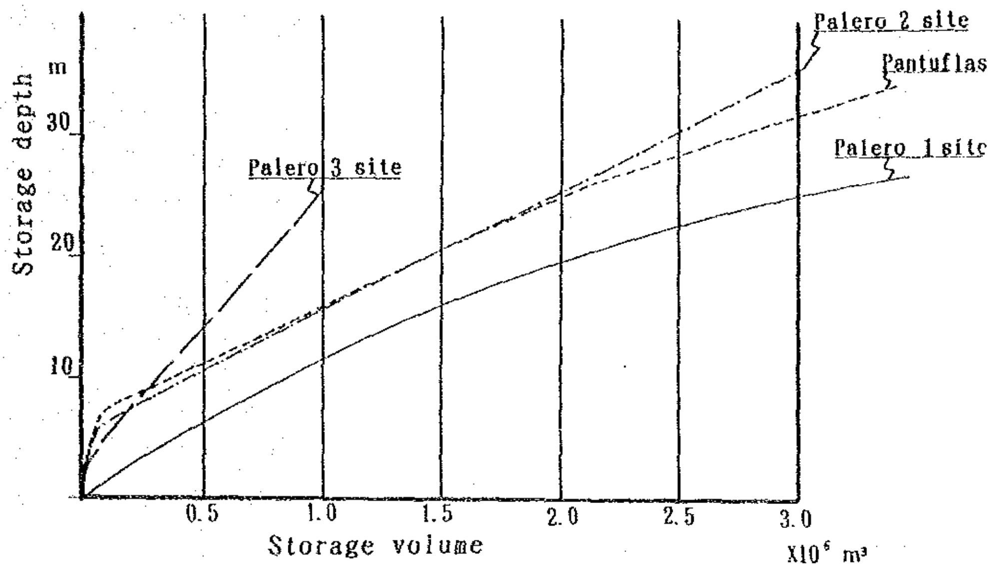


Fig. 3.2.1-2 Dam Mass Storage Curve on Each Site

Palero-3 site has the lowest storage efficiency comparing with other three sites.
Among the three sites, Palero-1 site is the best, followed by Pantuflas site and Palero-2 site. But Pantuflas site seems to be the smallest structure comparing with the others with regard to dam length as follows:

Dam length

Palero-1 site : W=600m
Palero-2 site : W=350m
Pantuflas site : W=100m

Hence, Pantuflas site is proposed as the most suitable site.

3.2.2 Water Resources Development outside the Valley

The following water resources development are proposed outside the project area;

- Using the water from the Arroyo Hondo which flows at the neighboring area of the study area

- Improvement of water use efficiency of the Rio Grande which is used for the existing irrigation system.

(1) Water Resource Development Plan of the Arroyo Hondo

The construction of dam was studied as the water resource development plan in the Arroyo Hondo. Two dam sites viz. upper side of La Culata and lower side of Maldonado are proposed. The following problems are pointed out in these plans;

a. Dam Plan at La Culata

- Vegetables have been cultivated in this area and a lot of farm area will be sacrificed by the dam construction.

- It is necessary to construct 7km of head race for introducing water to the Valley. Furthermore, the construction of head race will be difficult since it passes through the steep slope of mountains.

- The catchment area of the dam is small for it sacrificing much of farm lands.

b. Dam Plan at Maldonado

- The height of the dam will be large because of the steep longitudinal slope of the river.

- The construction of 1.5 km of tunnel will be required for introducing water to the Valley. Its cost will be high.

It is concluded the water resources development plan in the Arroyo Hondo includes several technical and economical problems and is not feasible.

(2) Water Resource Development Plan of Rio Grande

Water in the Rio Grande catchment area is utilized through the head works for irrigation in the Rio Grande and through the intake work for water service of the Valley in the Arroyo Pinar Bonito.

Since the water of the Arroyo Pinar Bonito is used for potable water it is difficult to use it for irrigation.

It is estimated that approximately half of the discharge of the Rio Grande is only introduced to the Valley and the water use efficiency is not high. Therefore, its improvement is an important factor for the water resource development.

Two water resources development schemes can be proposed: one is the dam construction in the Rio Grande Basin and the another is the rehabilitation of existing facilities such as the head works and the head race for effective distribution of water to the Valley.

4 sites are selected as the proposed dam sites as shown in Fig. 3.2.2-1. The evaluation was done about the 4 dam site plans and rehabilitation plan of the existing facilities.

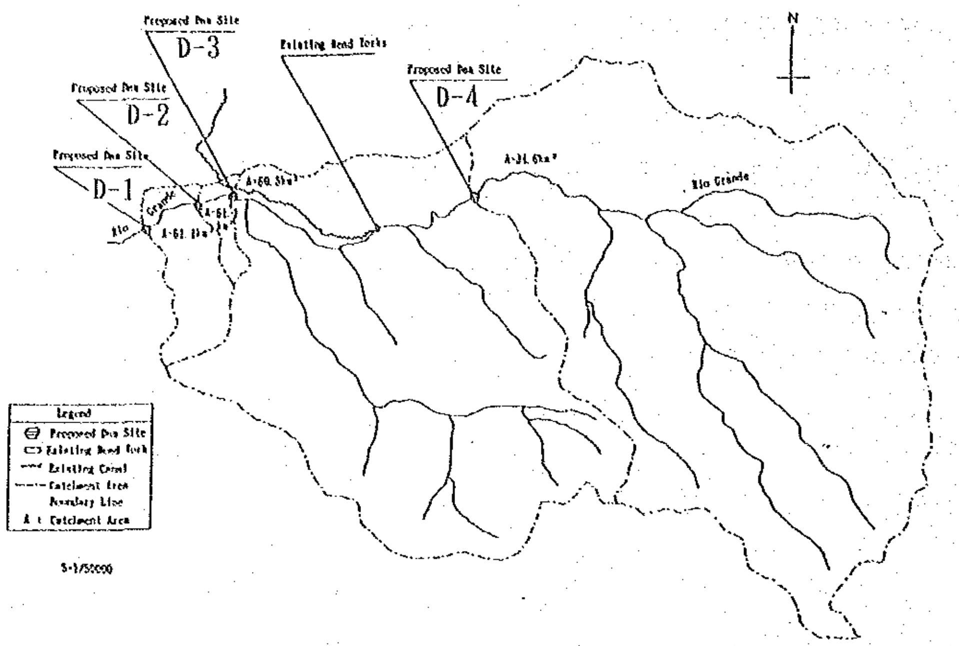


Fig. 3.2.2-1 Location Map of Proposed Dam Sites

Drought water discharge at each site was estimated based on the annual rainfall for 5 year return period (831.7mm/year) as shown below.

Table 3.2.2-1 Estimated Drought Water Discharge (5 Year Return Period)

Unit: m^3/s

Month	1	2	3	4	5	6	7	8	9	10	11	12
D-1 site	0.43	0.51	0.50	0.68	1.27	0.87	0.70	1.10	1.01	0.88	0.67	0.58
D-2 site	0.41	0.48	0.47	0.64	1.20	0.82	0.66	1.04	0.95	0.83	0.63	0.55
D-3 site	0.41	0.47	0.47	0.64	1.19	0.81	0.65	1.03	0.94	0.82	0.63	0.54
Present intake weir	0.33	0.38	0.38	0.51	0.96	0.66	0.53	0.84	0.77	0.67	0 51	0.44
D-4 site	0.27	0.32	0.31	0.43	0.80	0.55	0.44	0.70	0.64	0.56	0.42	0.37

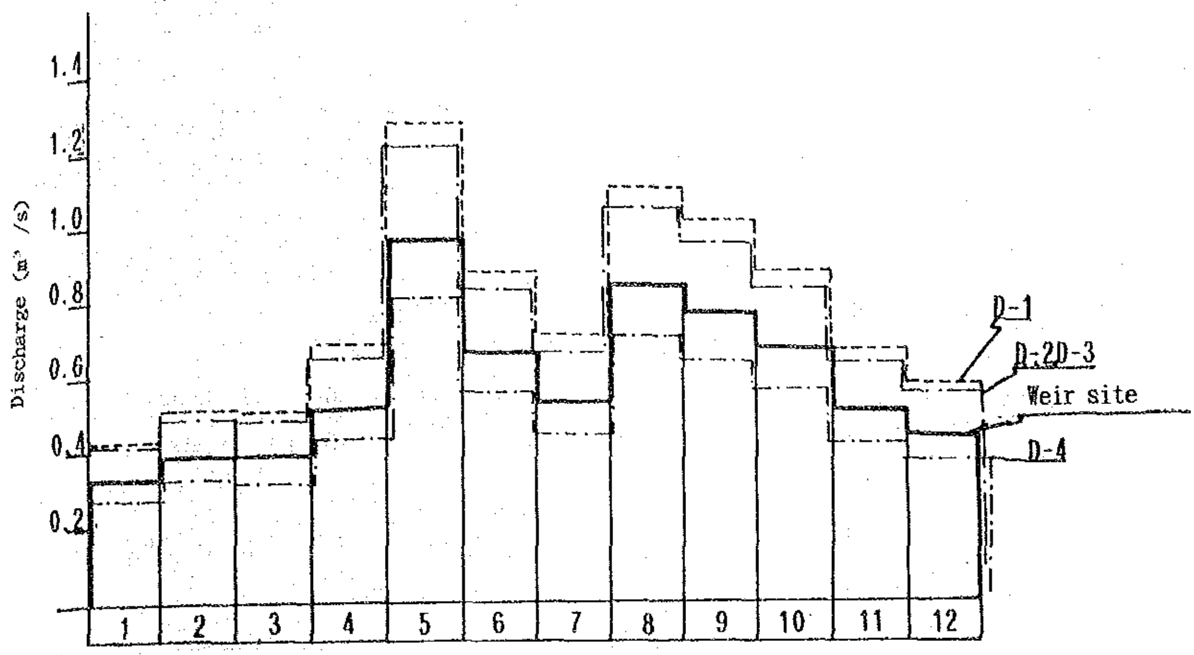


Fig. 3.2.2-2 Estimated Drought Water Discharge (5 Year Return Period)

Available intake water volume of each plan is shown in Fig. 3.2.2-3. In this result the available intake water volume of Plan D-1 is the largest which is followed by Plan D-2, Plan D-3, rehabilitation plan of existing facilities and finally Plan D-4. The available intake water volume of Plan D-4 is smaller than that of the rehabilitation plan of existing facilities.

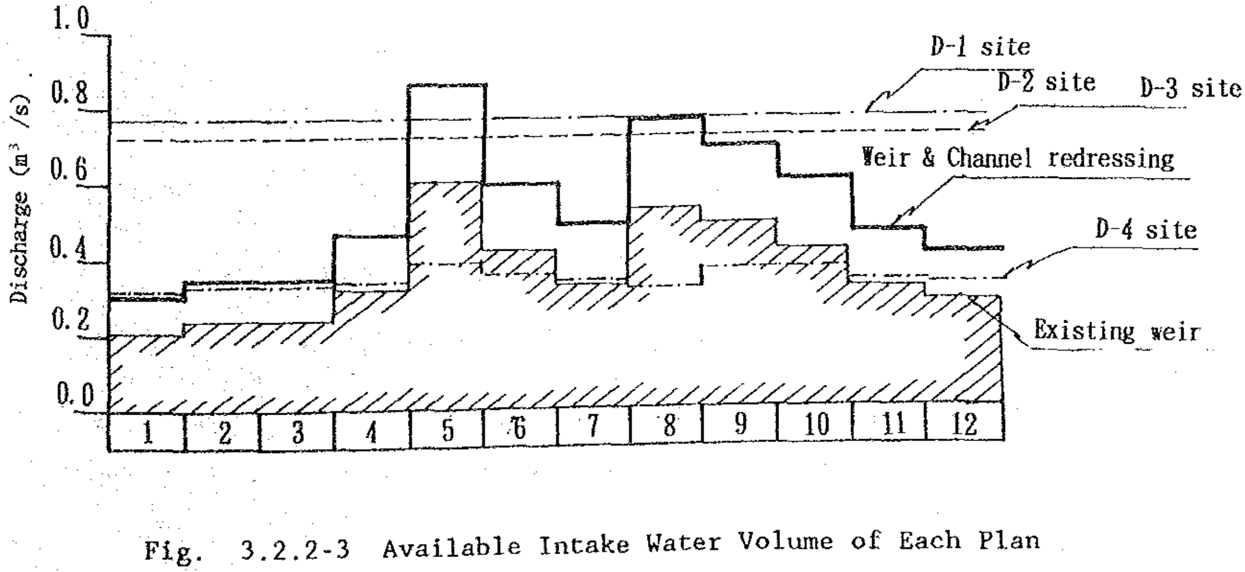


Fig. 3.2.2-3 Available Intake Water Volume of Each Plan

(3) Study of the Optimum Dam Site of the Rio Grande

From the view points of geology, topography and required facilities, the optimum dam site is selected from the plans D-1, D-2 and D-3.

1) Preliminary study of the scale of facilities

The dimensions of dam facilities are studied under the condition that the ground level for the irrigation should be lower than 1,240m A.S.L.
The elevation difference of the river bed and El 1240m at each dam site are as follows;

	Elevation of river bed	Elevation difference
D-1 site	1162 m	-78 m
D-2 site	1205 m	-35 m
D-3 site	1228 m	-12 m

The D-1 dam site is not an appropriate site for the project, since the elevation of the river bed is extremely low for the irrigation of upland in the Valley. For this reason, D-1 site is omitted from the study. The selection of the optimum dam site at the Rio Grande was carried out between D-2 and D-3 sites.

a. D-2 Dam site

The scale of the D-2 dam was determined based on the following conditions.

Effective storage capacity $V = 2,500,000m^3$

Sediment Volume $Vs = 800m^3/km^2 x 61.1km^2 x 100year$

$= 4,888,000m^3$

$= 4,900,000m^3$

Available water level AWL = +1240.0m

The mass storage curve at the proposed site D-2 is shown in Fig. 3.2.2-4 and the profile of proposed dam D-2 is shown in the Fig. 3.2.2-5.

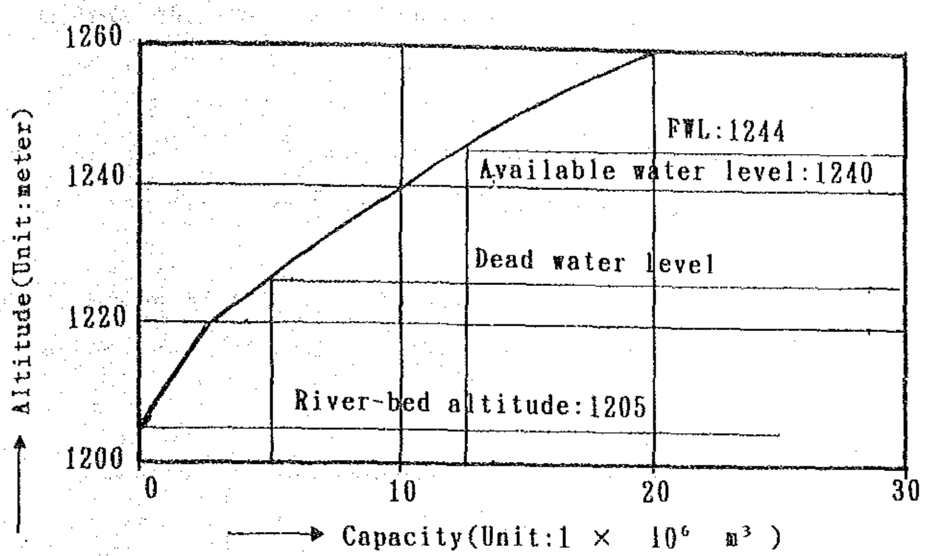


Fig. 3.2.2-4 Mass Storage Curve at Proposed D-2 Site

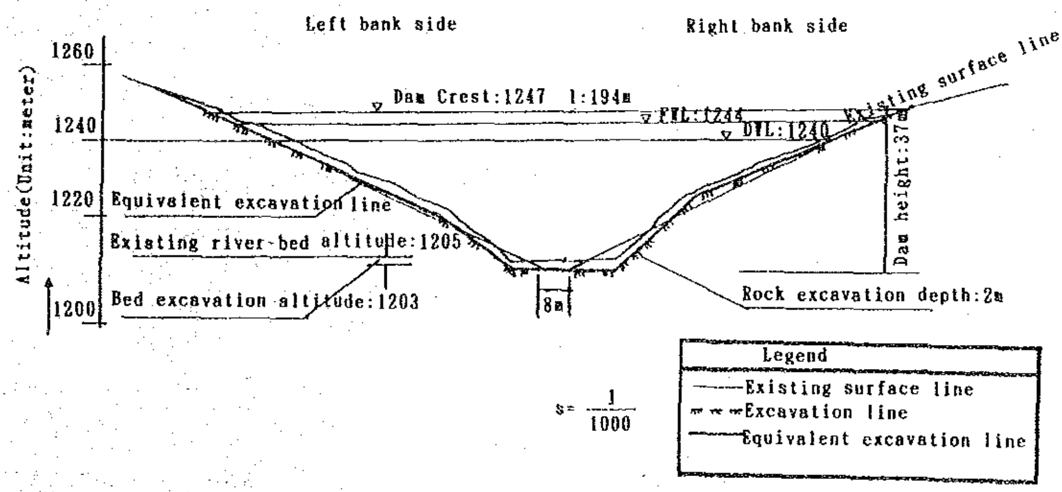


Fig. 3.2.2-5 Profile of Proposed Dam Site D-2 on Rio Grande

b. D-3 dam site

The scale of the D-3 dam was determined based on the following conditions.

Effective storage capacity Vc = 2,500,000m^3

Sediment Volume Vs = 800m^3/km^2x60.5km^2x100year = 4,840,000m^3

The mass storage curve at proposed site D-3 is shown in the Fig. 3.2.2-6 and the profile of proposed dam D-3 is shown in the Fig. 3.2.2-7.

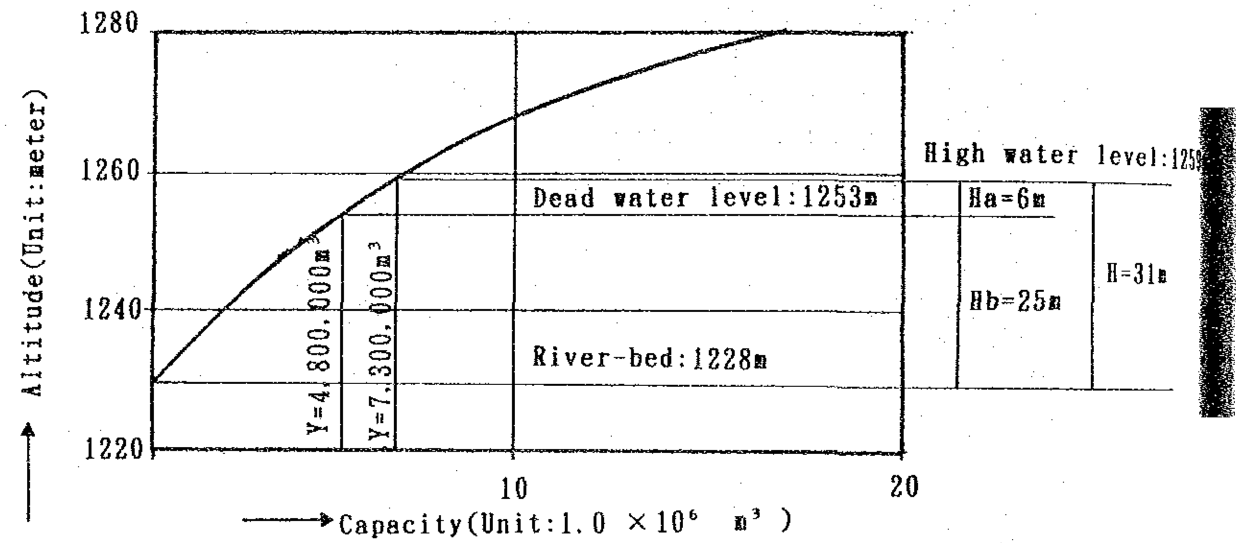


Fig. 3.2.2-6 Mass Storage Curve at Proposed D-3 Site

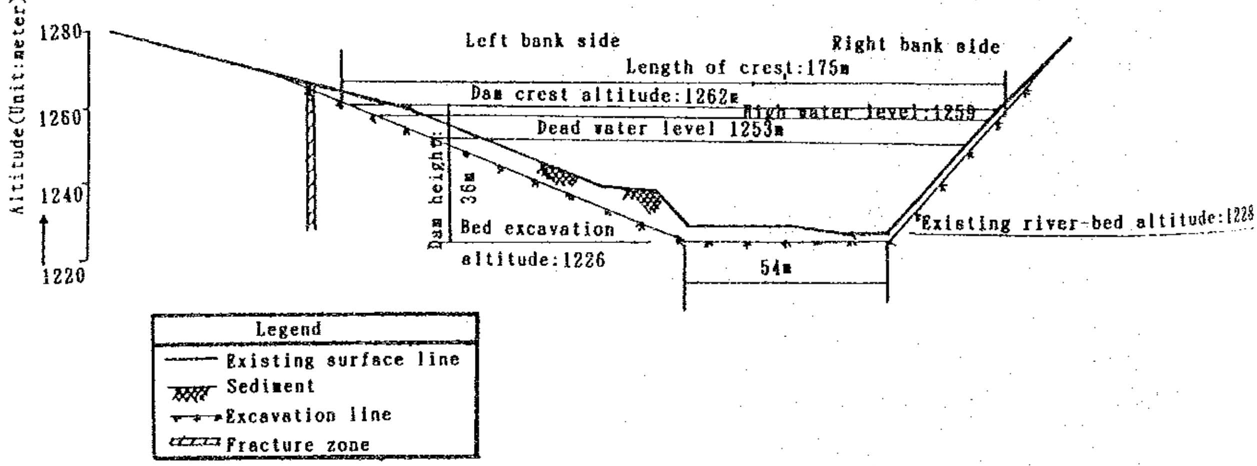


Fig. 3.2.2-7 Profile of Proposed Dam Site D-3 on Rio Grande

2) Scale of Facilities

The dimensions of dam facilities are studied, considering the distribution of water to the upland in the Valley (1,240m A.S.L.). The result is shown in Table 3.2.2-2.

Table 3.2.2-2 Dimensions of Dam Facilities

Items		D-2	D-3
River Bed Elevation	(m.a.s.l)	1,205	1,228
H.W.L.	(m.a.s.l)	1,244	1,259
Dead Water Level	(m.a.s.l)	1,240	1,253
Dam Elevation	(m.a.s.l)	1,247	1,262
Dam Height	(m)	42	36
Dam Length	(m)	200	175
River Width	(m)	40	54
Dam Volume	(cu.m)	490,000	380,000
Tunnel Length	(m)	500	400
Others	Rebuilding of drinking water facility is required.		

(2) The Optimum Dam Site

Considering the available intake water volume and dam volume, it can be understood that Plan D-3 is advantageous and the optimum among the three plans.

3.2.3 Possibility of Groundwater Resources Development

Groundwater is used mainly in the surrounding area outside the Canal Constanza in the Valley. Especially, many wells are constructed in the northern part of the Valley. On the other hand, a few wells are used inside the Canal Constanza.

Groundwater of center area collects the fostered groundwater from surrounding area of the Valley and flows down. It is estimated that available water volume per one well in the center area would be more than that in the surrounding area.

Two groundwater development plans can be considered; one is the development of the artesian aquifer and the other is the development of the sub-surface groundwater.

It is expected that the development of the artesian aquifer would be difficult, considering the estimated groundwater discharge ($Q=0.01m^3/s$) which is too small to use for irrigation.

A high amount of subsurface groundwater flows out to the lower stream of the Arroyo Constanza. In case that the development of subsurface groundwater is carried out, the water discharge of the Arroyo Constanza will be reduced.

Problems of the groundwater development are summarized as follows.

- A lot of wells are installed in the northern part of Constanza Valley and water from these wells is used for irrigation. In case that new wells are installed for irrigation in this area, fall of groundwater level or drying up of groundwater is anticipated due to their mutual influence.

- There are only a few wells in the middle and western area of the Valley. It means that there is much possibility to construct new wells for irrigation in those areas. However, it seems to be difficult to expect much water per one well considering the result of boring tests.

- There is possibility that too much development of groundwater for irrigation will influence on reducing the groundwater level which lead to percolation of surface water in small streams. And it is expected that the water discharge of the Arroyo Constanza will be reduced and mini-hydropower station which under construction now will be influenced.

It is judged that the groundwater resources should be developed in the area where it is difficult to distribute irrigation water because of its topographic condition. Especially, it is quite difficult to convey the irrigation water to the area of over 1,240m A.S.L. The development of groundwater for irrigation should be considered in such areas.

Shallow well and deep well were studied for the development of groundwater. Only 60-150m^3/day/well of discharge is expected in deep wells. On the other hand, it is possible to get large amount of water from shallow well in case that the diameter of the well is large enough. Depending on the diameter of the well, about 1-5ha of farm land can be irrigated by one shallow well. Therefore, considering the water discharge for one well, shallow well is more effective than deep well.

The water discharge from wells in the Valley are estimated as shown in Table 3.2.3-1.

Table 3.2.3-1 Estimated Water Discharge from the Wells

Unit : cu.m/day

		Western Area	Eastern Area
Deep Well		66	167
Shallow Well	(r = 1 m)	78	198
	(r = 2 m)	155	397
	(r = 3 m)	311	794
	(r = 6 m)	466	1,192

3.2.4 Conclusion of Development Potentiality of Water Resources

Both of the Pantuflas and Palero basins have high potentiality for the water resources development in the Valley. Especially there is a suitable pocket as a dam site at Arroyo Arriba in the Pantuflas basin to store sufficient water in order to solve the water shortage during December to March.

The lower reach of the Arroyo Constanza has high potentiality of water dicharge. However, the development potentiality is low because of its topological constrains.

Both of the Arroyo Hondo and the Rio Grande are proposed as the water resources outside the Valley.

In case of the Arroyo Hondo, it becomes clear that the conveyance canal construction cost will be too high to apply it for the project.

In case of the Rio Grande basin development, the following two plans are proposed.

a. Dam construction plan
b. Intake facilities rehabilitation plan

Although 4 dam site alternatives in the Rio Grande are proposed and evaluated, it is clear that Plan D-3 which is located near the Arroyo Pinar Bonito is considered to be the optimum plan.

Groundwater development potentiality is judged to be low considering the thin aquifer thickness.

Table 3.2.4-1 Summary of Water Resources Development Potentiality

Water Resources	Water Resources Capacity	Suitability	Definite Proposed Plan	Plan Selection
(Valley Interior)				
Arroyo Constanza	Good	Poor	-	-
Arroyo Pantuflas	Good	Fine	. Dam	Good
Arroyo Palero	Good	Fine	. Dam	-
(Valley Exterior)				
Arroyo Hondo	Good	Poor	-	-
Rio Grande	Good	Fine	. Dam-1	-
			. Dam-2	-
			. Dam-3	Good
			. Dam-4	-
			. Redressing Facilities	Good
(Groundwater)				
Wells in Valley	Poor		. Wells	Supplementary

3.3 Water Resources Development Alternatives

On the basis of the water resources development study and the study of the optimum dam site, two alternative water resources development plans were considered in order to select the appropriate plan.

Alternative A: Pantuflas dam + rehabilitation of the head works and the head race.

Alternative B: Dam at the Rio Grande (the Pinar Bonito)

Alternative A is to construct the dam at the Arroyo Pantuflas in order to supplement the insufficient water during December to April.

Alternative B is to construct the dam at D-3 site of the Rio Grande which was selected as the optimum dam site and to irrigate the arable area lower than 1,240m A.S.L.

The water resource facilities are only evaluated for comparison of water resources alternatives on the premise of the followings.

- Each alternative satisfy the water demand
- Farm facilities are under same conditions
- Sprinkler irrigation is applied

The mean monthly irrigation water demand used in this comparison study are as follows.

Irrigation Water Demand (m^3/s)

Month	1	2	3	4	5	6	7	8	9	10	11	12
Water demand	0.47	0.51	0.38	0.05	-	0.30	0.29	-	-	-	0.29	0.30

3.3.1 Dimension of the facilities

(1) Alternative A (Pantuflas dam + rehabilitation of the intake facilities)

By the rehabilitation of the intake facilities, it is expected that the conveyance efficiency will be improved. The dam should have the capacity to supplement the inefficient water demand of the Rio Grande water resources.

The irrigation water demand, available water discharge from the Rio Grande and inefficient water discharge are shown in Table 3.3.1-1.

Table 3.3.1-1 Water Demand, Available Water Discharge and Shortage Water Discharge

Month	1	2	3	4	5	6	7	8	9	10	11	12
Water demand (m^3/s)	0.47	0.51	0.38	0.05	-	0.30	0.29	-	-	-	0.29	0.30
Available water discharge (m^3/s)	0.30	0.34	0.34	0.46	0.86	0.57	0.48	0.76	0.69	0.60	0.46	0.40
Shortage discharge	0.17	0.17	0.04	-	-	-	-	-	-	-	-	-

In this alternative, the dam should have the capacity to reserve a volume of $980{,}000m^3$.

The storage capacity of the dam was determined as follows:

Effective storage capacity	$V = 980{,}000m^3$
Sediment volume	$Vs = 100m^3/km^2 x 6.7km^2 x 100year$
	$= 67{,}000m^3$
	$= 70{,}000m^3$
Total storage capacity	$V = 1{,}050{,}000m^3$

The dimensions of the dam was determined as follows:

Type	:	Center Core Rockfill Dam
Dam Volume	:	22,000 m^3
Height of Dam	:	30 m
Length of Crest	:	162 m
Available Water Level	:	1,236 m
Full Water Level	:	1,261 m

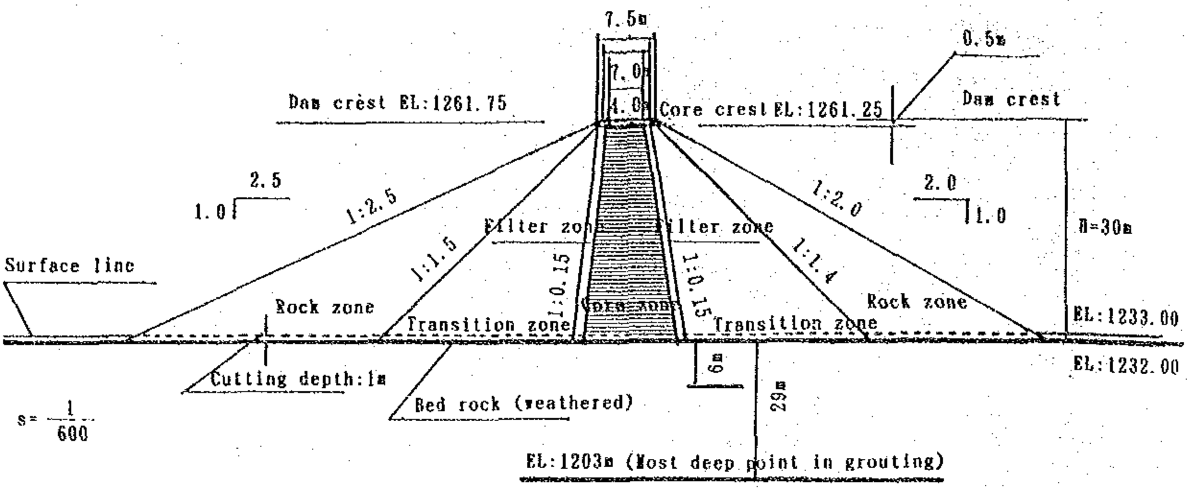


Fig. 3.3.1-1 Standard Section of Pantuflas Dam

(2) Alternative B-Dam at the Rio Grande (the Pinar Bonito)

In this alternative, the dam have to satisfy the water demand. The irrigation water demand, river discharge and shortage discharge are shown in the Table 3.3.1-2.

Table 3.3.1-2 Irrigation Water Demand, River Discharge and Shortage Water Discharge

Month	1	2	3	4	5	6	7	8	9	10	11	12
Water demand (m^3/s)	0.47	0.51	0.38	0.05	-	0.30	0.29	-	-	-	0.29	0.30
River discharge (m^3/s)	0.38	0.44	0.44	0.60	1.11	0.76	0.61	0.97	0.89	0.77	0.59	0.51
Shortage discharge (m^3/s)	0.09	0.07	-	-	-	-	-	-	-	-	-	-

In this alternative, the dam should have a reserve capacity of 410,000m^3. Considering the sedimentation volume, the storage capacity of this dam is determined as follows:

Effective reservoir capacity V = 410,000m^3

Sediment volume Vs = 800m^3/km^2x60.5km^2x100year = 4,840,000m^3

Dam capacity V = 5,250,000m^3

The dimensions of the dam at the Rio Grande are as follows:

Type	:	Rockfill Dam
Dam Volume	:	380,000 m^3
Height of Dam	:	36 m
Length of Crest	:	175 m
Available Water Level	:	1,253 m
Full Water Level	:	1,254 m
Length of Canal Tunnel	:	400 m

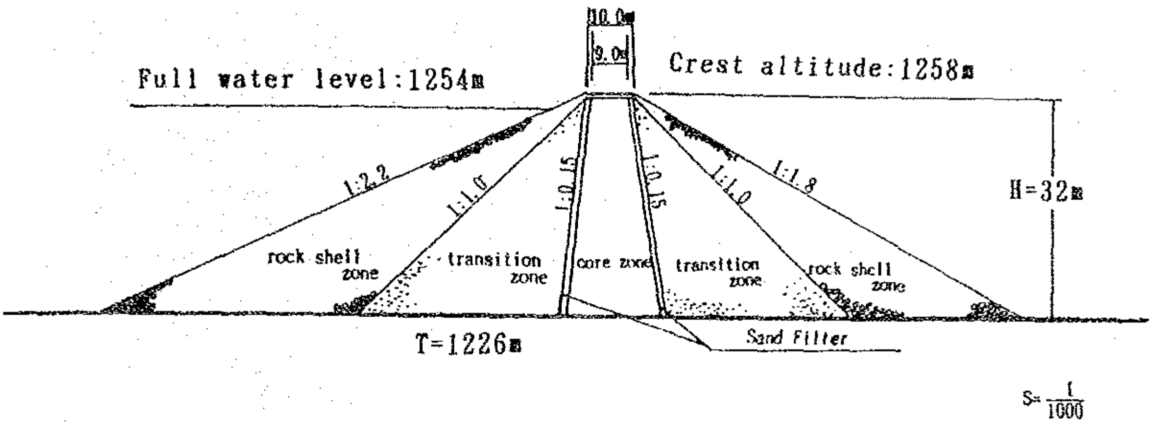


Fig. 3.3.1-2 Standard Section of the Dam at the Rio Grande

3.3.2 Comparative Study of the Alternatives

The result of the comparative study of the alternatives is shown in Table 3.3.2-1.

Table 3.3.2-1 Comparison of the Water Resources Alternative Plan

	Alternative - A (Pantuflas Dam)	Alternative - B (Dam at the Rio Grande)
Dimension of the Facility		
Type	Rockfill Dam	Rockfill Dam
Dam Volume	220,000 m^3	380,000 m^3
Height of Dam	30 m	36 m
Length of Dam	162 m	175 m
Available water level	1,236 m	1,253 m
Full water level	1,261 m	1,254 m
Available storage capacity	98 x 10^4 m^3	41 x 10^4 m^3
Other facilities	Flood sluice (A =6.7 km^2) Rehabilitation of head works and head race	Canal tunnel l=400m Flood sluice (A =62km^2) Curtain Grouting
Benefited Area	less than EL 1,240 m	less than EL 1,240 m
Water shortage problem	No	No
Construction Cost (RD$)	35,900,000	101,300,000
Technical problem of construction	No	Canal tunnel
Geological problem	No	Fault in the right bank
Problem for potable water	No	Transfer of the existing water line
Problem for the El Salto hydropower station	No	Advantageous
Evaluation	○	△

As a result of the comparison study, the advantage of the Alternative A was justified since the construction volume of Alternative A is small. Further study of the alternative development plan will be carried out on the basis of the determined water resources alternatives.

4. Water Resources Development Plan

The water resources development plan is carried out on the basis of Alternative A (Pantuflas dam + Rehabilitation of the intake facilities), which was selected in the comparison study of the water resources. The water demand and available water resources is calculated considering 5 years return period of rainfall.

The water resources plan for the open canal rehabilitation plan, which was selected as an appropriate development plan, is carried out on the basis of the determined water resources alternative (Pantuflas dam + rehabilitation of the intake facilities).
The basic countermeasure of the water resources development plan are as follows;

- Main water resources of the project is the Rio Grande

- Construction of the head works and rehabilitation of the head race will be carried out to improve the conveyance efficiency.

- Pantuflas dam will be constructed in order to supplement the irrigation water in the dry season.

- Irrigation in the wet season will be carried out by the water resources of the Rio Grande.

- Discharge of the small river (the Arroyo Palero etc.) will be taken by the intake works for the irrigation, but these water resources will not be included for the calculation of the water resources development plan, since these discharge are insignificant for the project.

- Groundwater resources will not be included for the plan.

4.1 Rio Grande Water Resources Development Plan

This water resources will be developed by the construction of the head works and the rehabilitation of the head race in order to improve the conveyance efficiency. At present, the conveyance efficiency is low due to the deterioration of the Canal Constanza and the water is not conveyed efficiently to the Valley. In the planning, the rehabilitation of the head works and the head race will be carried out.

Actual conveyance efficiency was estimated approximately 62%. In the planning, the efficiency will be improved to 90%.

The available discharge, the conveyed discharge and the conveyed water discharge after improving the conveyance efficiency are shown in Table 4.1.1-1.

Table 4.1.1-1 Available Discharge, Conveyed Discharge and Improved Intake Discharge of the Rio Grande

Month	1	2	3	4	5	6	7	8	9	10	11	12
Available Discharge (m^3/s)	0.33	0.38	0.38	0.51	0.96	0.66	0.53	0.84	0.77	0.67	0.51	0.41
Conveyed Discharge (m^3/s)	0.21	0.24	0.24	0.32	0.60	0.42	0.33	0.53	0.49	0.42	0.32	0.28
Improved Intake Discharge (m^3/s)	0.30	0.34	0.34	0.46	0.86	0.57	0.48	0.76	0.69	0.60	0.46	0.37

It is very important that the structure of the head works should have the capacity to take the available discharge efficiently, especially in the dry season.

4.2 Pantuflas Dam Plan

The Pantuflas dam will be constructed at Arroyo Arriba site which is selected by the optimum dam site study, in order to supplement the irrigation water in dry season. The required storage volume is calculated as follows.

Shortage water volume	V =	980,000m^3
Sedimentation volume	V =	70,000m^3
Total storage volume	V =	1,050,000m^3

The Pantuflas dam will supplement irrigation water to the following area of arable land in the dry season.

Junuary	A = 550ha
February	A = 510ha
March	A = 160ha

In January and February, the water of the Pantuflas dam will be alimented to the Canal Constanza in order to supplement the shortage volume of the Canal Constanza. The irrigation to the Canal Pantuflas will be realized during January to March. The Pantuflas dam will store the discharge of the Arroyo Pantuflas. The total annual runoff of the dam site is approximately 250 x $10^4 m^3$/year. The storage volume of the Pantuflas dam is equivalent to 41% of the annual runoff.

The structure of the Pantuflas dam will be described in the Annex: Facilities Plan.

4.3 Other Countermeasures

The rehabilitation of the existing small water gate and construction of the water gate will be realized for efficient utilization of the water resources of the arroyos in the Valley. The countermeasures to be followed in the project are as follows.

- Rehabilitation of the intake works at the Arroyo Pantuflas for efficient utilization of the water resources. This intake works aliment to the Canal Pantuflas.

- Rehabilitation of the intake works at the Arroyo Palero in order to aliment to the Canal Nueva Constanza.

- Rehabilitation of the intake works at the Canal Abud in order to aliment the Canal Abud and to catch the drained water.

- Construction of two water gates.

ANNEX M : IRRIGATION PLAN

ANNEX M: IRRIGATION PLAN

Page

LIST OF TABLES

LIST OF FIGURES

ANNEX M: IRRIGATION PLAN

1. General

1.1 Resource of Irrigation Water

Water for irrigation in the study area will be obtained from the following resources:

- The Rio Grande
- Mountainous small rivers in the study area
- Groundwater in the study area

After evaluation of these resources, the Rio Grande water resource has been selected as the principal water resource. The Pantuflas dam will be constructed to supplement irrigation water in dry season. The water resource of the mountainous small rivers may be the supplementary water resource.

1.1.1 Available Water Discharge

The available water discharge at 5 year return period is shown in Table 1.1.1-1.

Table 1.1.1-1 Available Water Discharge

Unit: m³/s

Month	1	2	3	4	5	6	7	8	9	10	11	12
Arroyo Pantuflas	0.05	0.06	0.06	0.09	0.17	0.11	0.09	0.15	0.14	0.12	0.09	0.07
Arroyo Palero	0.03	0.04	0.04	0.05	0.10	0.07	0.05	0.09	0.08	0.07	0.05	0.04
Rio Grande	0.33	0.38	0.38	0.51	0.96	0.66	0.53	0.84	0.77	0.67	0.51	0.41
Total	0.41	0.48	0.48	0.65	1.23	0.84	0.67	1.08	0.99	0.86	0.65	0.52

In the planning, the efficient utilization of these resources will be considered.

At present, the following discharge are conveyed to the Valley through the existing canals.

Table 1.1.1-2 Actual Conveyed Discharge

(Unit: m³/s)

Month	1	2	3	4	5	6	7	8	9	10	11	12
Canal Pantuflas	0.05	0.05	0.05	0.08	0.15	0.10	0.08	0.14	0.13	0.11	0.08	0.05
Canal Palero	0.02	0.03	0.03	0.04	0.08	0.06	0.04	0.07	0.06	0.06	0.04	0.03
Canal Constanza	0.21	0.24	0.24	0.32	0.60	0.42	0.33	0.53	0.49	0.42	0.32	0.28
Total	0.28	0.32	0.32	0.44	0.83	0.58	0.45	0.74	0.68	0.59	0.44	0.36

In the water resources development plan, the improvement of the conveyance efficiencies of the canals are planned.
The water discharge after improvement of the conveyance efficiency is shown in Table 1.1.1-3.

Table 1.1.1-3 Water Discharge after Improvement of the Conveyance Efficiency

Unit : m³/s

Month	1	2	3	4	5	6	7	8	9	10	11	12
Canal Pantuflas	0.05	0.05	0.05	0.08	0.15	0.10	0.18	0.14	0.13	0.11	0.08	0.05
Canal Palero	0.02	0.03	0.03	0.04	0.08	0.06	0.04	0.07	0.06	0.06	0.04	0.03
Canal Constanza	0.30	0.34	0.34	0.46	0.86	0.57	0.48	0.76	0.69	0.60	0.46	0.40
Total	0.37	0.42	0.42	0.58	1.09	0.73	0.60	0.97	0.88	0.77	0.58	0.48

Considering efficient utilization of these resources, the Canal Constanza is designed to improve the conveyance efficiency.
The designed available discharge is shown in Table 1.1.1-4.

Table 1.1.1-4 Designed Available Discharge for the Irrigation Plan

Month	1	2	3	4	5	6	7	8	9	10	11	12
Discharge	0.30	0.34	0.34	0.46	0.86	0.57	0.48	0.76	0.69	0.60	0.46	0.40

1.2 Benefited Area and Proposed Rate of Cropping

The cropping pattern and cultivation area of main crops in 1,510ha of the benefited area are discussed in Annex K. The basic concept of the irrigation plan is to avoid injury of continuous cropping by introducing gramineous crops, and to increase cropping of highly profitable vegetables. As a result of the proposed irrigation plan, local labor will be utilized effectively.

The proposed rate of cropping is performed based on the hearing survey of farmer's intention, past records of representative farmers in the Constanza Valley, opinions of the agriculture extension adviser, etc. The basic rate of cropping is determined as shown below through several trial calculations.

Table 1.2.1-1 *Proposed Cropping Area*

Class	Area	Crops	Cropping Area
1	296 ha	Graminae + Vegetables	888 ha
2	296	Onion + Vegetables + Potato	888
3	296	Kidney beans + Garlic	592
4	296	Vegetable + Green manure crops + Garlic	888
5	296	Potato + Garlic	592
	30	Flowers	
Total	1510		3878
Cropp-ing rate	(100)		(257)

2. Net Irrigation Requirements

2.1 Related Crop Evapotranspiration, ETo

Related crop evapotranspiration has been computed by applying the Penman Method. Climatic data for this purpose are collected at the Constanza Station which is located adjacent to the study area and provides more reliable data.

The form of the equation used in this method is:

$$ETo = c.[\underbrace{W.Rn}_{\text{radiation term}} + \underbrace{(1-W).f(u).(ea-ed)}_{\text{aerodynamic term}}]$$

where,
- ETo : related crop evapotranspiration in mm/day
- W : temperature-related weighting factor
- Rn : net radiation in equivalent to evaporation in mm/day
- f(u) : wind-related function
- (ea-ed): difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar
- c : adjustment factor to compensate for the effect of day and night weather conditions

ETo computation is summarized in Table 2.1.1-1.

Table 2.1.1-1 Format for Calculation of Penman Method

Item	1	2	3	4	5	6	7	8	9	10	11	12
T mean℃	16.2	16.5	17.4	18.2	18.9	19.2	19.4	19.5	19.5	19.1	18.0	16.9
W	0.67	0.67	0.68	0.70	0.70	0.71	0.71	0.71	0.71	0.71	0.69	0.68
n	7.16	6.98	7.31	6.37	6.37	6.94	6.81	6.91	6.24	6.17	6.34	7.21
N	11.08	11.53	12.0	12.57	13.02	13.22	13.12	12.75	12.27	11.73	11.25	11.98
n/N	0.65	0.61	0.61	0.51	0.49	0.52	0.52	0.54	0.51	0.53	0.56	0.60
Ra	11.42	12.87	14.51	15.60	16.19	16.24	16.19	15.85	14.86	13.47	11.82	10.92
Rs=(0.25+0.5n/N)Ra	6.57	7.14	8.05	7.88	8.01	8.28	8.26	8.24	7.50	6.94	6.26	6.01
Rns=(1-α)Rs	4.93	5.36	6.04	5.91	6.01	6.21	6.20	6.18	5.63	5.21	4.70	4.51
f(T)	13.84	13.90	14.3	14.2	14.38	14.4	14.4	14.5	14.5	14.4	14.2	13.98
ea	18.4	18.7	19.7	20.7	21.7	22.2	22.4	22.7	22.7	22.1	20.6	19.1
RH	74.5	75.1	72.0	73.3	76.3	74.3	71.6	72.8	74.4	75.6	76.5	76.2
ed:ea ×RHmean/100	13.7	14.1	14.2	15.2	16.6	16.5	16.1	16.5	16.9	16.7	15.8	14.6
ea-ed	4.7	4.6	5.5	5.5	5.1	5.7	6.3	6.2	5.8	5.4	4.8	4.5
f(ed)=0.34-0.044$\sqrt{ed}$	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17
f(n/N)=0.1+0.9n/N	0.68	0.67	0.67	0.56	0.54	0.57	0.57	0.59	0.56	0.58	0.60	0.64
Rne=f(T)・f(ed)・f(n/N)	0.61	1.53	1.63	1.35	1.24	1.31	1.31	1.37	1.30	1.34	1.45	1.52
Rn=Rns-Rne	3.32	3.83	4.41	4.56	4.77	4.9	4.89	4.81	4.33	3.87	3.25	2.99
W・Rn	2.22	2.57	3.00	3.19	3.34	3.48	3.47	3.42	3.07	2.75	2.24	2.03
1-W	0.33	0.33	0.32	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.31	0.32
U km/day	208.2	176.3	250.6	190.9	159.8	208.2	257.2	206.5	167.6	146.0	171.1	196.1
U_2 km/day	177.0	149.9	213.0	162.3	135.8	177.1	220.3	175.5	142.5	124.1	145.4	166.7
f(u)=0.27(1+ U_2 /100)	0.75	0.67	0.85	0.71	0.64	0.75	0.86	0.74	0.65	0.61	0.66	0.72
(1-W).f(u).(ea-ed)	1.16	1.02	1.50	1.17	0.98	1.24	1.57	1.33	1.09	0.76	0.98	1.04
W.Rn+(1-W).f(u).(ea-eb)	3.38	3.59	4.50	4.36	4.32	4.72	5.04	4.75	4.16	3.71	3.22	3.07
C	0.75	0.75	0.75	0.75	0.80	0.75	0.75	0.75	0.8	0.8	0.75	0.75
ETo	2.5	2.7	3.4	3.3	3.5	3.5	3.8	3.6	3.3	3.0	2.4	2.3
Monthly ETo	77.5	75.6	105.4	99.0	108.5	105.0	117.8	111.6	99.0	93.0	72.0	71.3

Where:

T mean ℃ : monthly average temperature

W : temperature-related weighting factor

n : actual sunshine hour

N : maximum possible sunshine hours

ea : mean saturation vapour pressure

RH : Relative Humidity

U : wind speed

2.2 Crop Water Requirements, ETcrop

Crop water requirements have been estimated by the equation as follows:

$$ETcrop = Kc \times ETo$$

where, Kc : crop coefficient

ETo : related crop evapotranspiration

The crop coefficients, which have been obtained according to FAO's guideline, are as follows:

Table 2.2.1-1 Crop Coefficient of Each Growing Stage

Crop	Growing period Total(1st/2nd/3rd/4th)	Crop coefficient (1st/2nd/3rd/4th)
Garlic(seeded in Oct.)	120(25/55/25/15)	0.58/0.77/0.95/0.95
Garlic(seeded in Nov.)	120(25/55/25/15)	0.63/0.79/0.95/0.95
Onion	60(15/30/10/5)	0.54/0.75/0.95/0.95
Kidney bean	105(15/25/45/20)	0.54/0.77/1.0/0.45
Graminae	120(30/35/35/20)	0.56/0.81/1.05/0.95
Vegetable 1, 3	75(15/25/20/15)	0.58/0.79/1.0/0.9
Vegetable 2	75(15/25/20/15)	0.62/0.81/1.0/0.9
Vegetable 4	90(20/25/25/20)	0.56/0.78/1.0/0.7
Green manure crop	45(30/15)	0.56/0.81
Potato(seeded in Apr.)	90(20/25/25/20)	0.56/0.81/1.05/0.7
Potato(seeded in Jan.)	90(20/25/25/20)	0.62/0.84/1.05/0.7
Flower	-	1.0

Monthly crop coefficient calculated based on the cropping pattern is shown in Fig. 2.2.1-1 and Table 2.2.1-1.

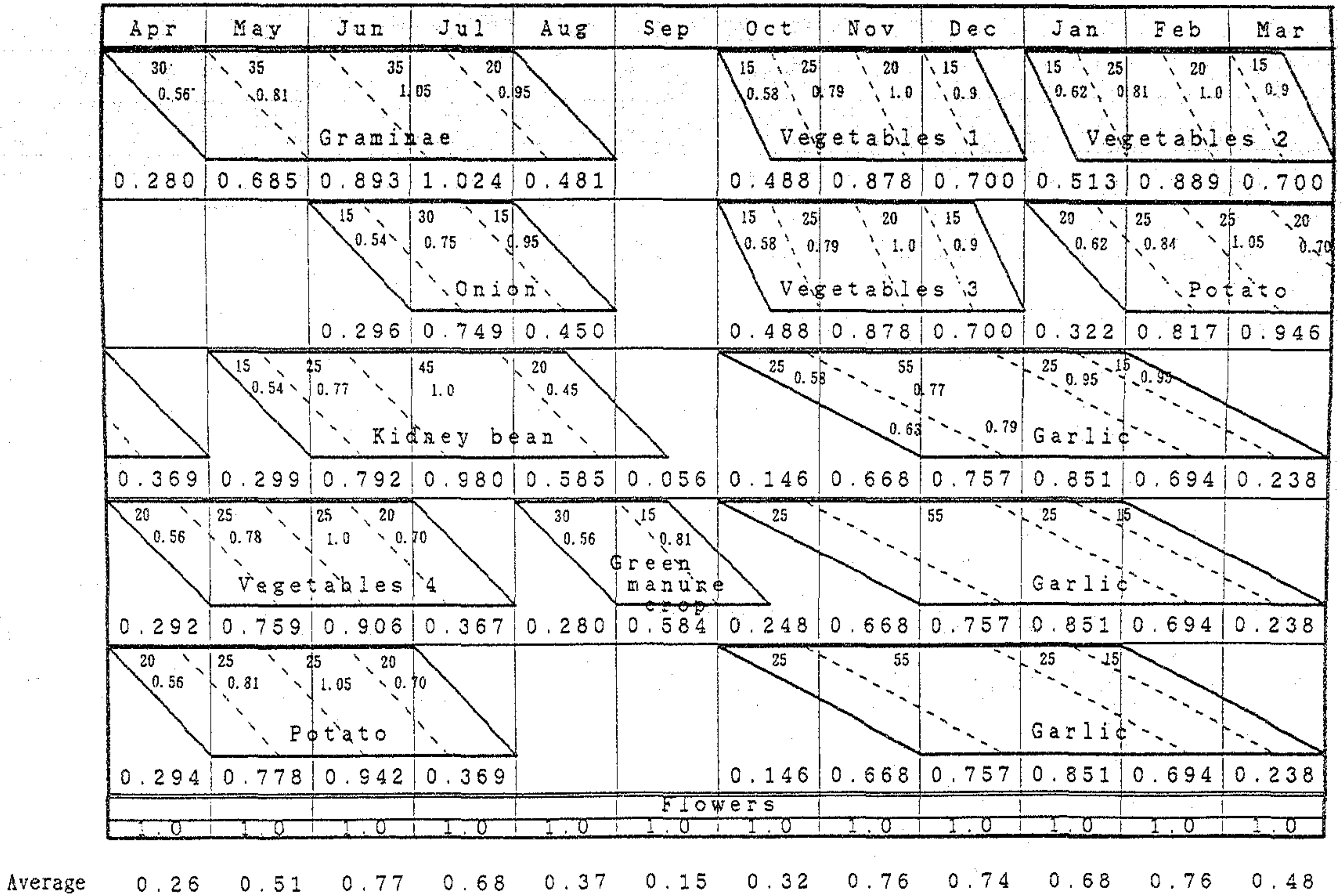


Fig. 2.2.1-1 Crop Coefficient(Kc)

Table 2.2.1-2 Evapotranspiration(ETcrop) for Crops (I)

(mm/month)

Month	ETo	Graminae Kc	Graminae ETcrop	Vegetable (1,3) Kc	Vegetable (1,3) ETcrop	Vegetable(2) Kc	Vegetable(2) ETcrop	Vegetable(4) Kc	Vegetable(4) ETcrop	Onion Kc	Onion ETcrop	Potato(1) Kc	Potato(1) ETcrop
Apr	99.0	0.28	27.72					0.29	28.91			0.37	36.53
May	108.5	0.69	74.87					0.76	82.64				
Jun	105.0	0.89	93.45					0.91	95.55	0.30	31.50		
Jul	117.8	1.02	120.16					0.37	43.59	0.75	88.35		
Aug	111.6	0.48	53.57							0.45	50.22		
Sep	99.0												
Oct	93.0			0.49	45.57								
Nov	72.0			0.88	63.36								
Dec	71.3			0.70	49.91								
Jan	77.5					0.51	39.53					0.32	24.80
Feb	75.6					0.89	67.28					0.82	61.99
Mar	105.4					0.70	73.78					0.95	100.13

Table 2.2.1-2 Evapotranspiration(ETcrop) for Crops (II)

(mm/month)

Month	ETo	Potato(2)		kidney bean		Green manure crop		Garlic(1,2,3)		Flower			
		Kc	ETcrop	Kc	ETcrop	Kc	ETcrop	Kc	ETcrop	Kc	ETcrop	Kc	ETcrop
Apr	99.0	0.29	29.11							1.00	99.00		
May	108.5	0.78	84.63	0.30	32.55					1.00	108.50		
Jun	105.0	0.94	98.70	0.79	82.95					1.00	105.00		
Jul	117.8	0.37	43.59	0.98	115.44					1.00	117.80		
Aug	111.6			0.59	65.48	0.28	31.25			1.00	111.60		
Sep	99.0			0.06	5.94	0.58	57.42			1.00	99.00		
Oct	93.0					0.10	9.30	0.15	13.95	1.00	93.00		
Nov	72.0							0.67	48.24	1.00	72.00		
Dec	71.3							0.76	54.19	1.00	71.30		
Jan	77.5							0.85	65.88	1.00	77.50		
Feb	75.6							0.69	52.16	1.00	75.60		
Mar	105.4							0.24	25.30	1.00	105.40		

2.3 Irrigation Water Requirement

Irrigation water requirement is calculated by the following formula:

$$I.W.R. = \frac{F.W.R. - \text{Effective Rainfall}}{\text{Irrigation efficiency}}$$

where, I.W.R. = Irrigation Water Requirement
F.W.R. = Field Water Requirement

(1) Effective Rainfall

Effective rainfall can be determined by various computation methods. In this report, Evapotranspiration and precipitation ratio method (adopted from USDA) was employed using past meteorological record and actual results of irrigation. Data of monthly ETcrop and precipitation for five years return period was used.

(Unit: mm/month)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation	15.8	24.9	26.6	54.0	152.1	83.9	59.0	125.6	108.1	89.0	52.4	39.9	831.3
Eff. rainfall	10.3	16.5	17.2	25.3	55.3	55.5	39.2	41.3	13.9	27.9	34.5	25.8	362.7

(2) Irrigation Efficiency

Irrigation efficiency is calculated as follows:

$E = Ec.Eb.Ea = 0.50$

where, E : Irrigation efficiency
Ec : Conveyance efficiency = 0.9
Eb : Field canal efficiency = 0.8
Ea : Field application efficiency = 0.7

(3) Irrigation Water Requirements

Irrigation water requirement for each month is calculated from field water requirement, effective rainfall and irrigation efficiency.

Table 2.3.1-1 Irrigation Water Requirement

Month	1	2	3	4	5	6	7	8	9	10	11	12
1 ETo (mm)	77.5	75.6	105.4	99.0	108.5	105.0	117.8	111.6	99.0	93.0	72.0	71.3
2 Kc	0.68	0.76	0.48	0.26	0.51	0.77	0.68	0.37	0.15	0.32	0.76	0.74
3 ETcrop (mm)	52.7	57.5	50.6	25.7	55.3	80.9	80.1	41.3	14.9	29.8	54.7	52.8
4 Pe (mm)	10.3	16.5	17.2	25.3	55.3	55.9	40.6	41.3	14.9	29.8	34.1	25.8
5 In=(3-4)(mm)	42.4	41.0	33.4	0.4	-	25.0	39.5	-	-	-	20.6	27.0
6 I.R.=5/EP	84.8	82.0	66.8	0.8	-	50.0	79.0	-	-	-	41.2	54.0
7 I.W.R.(m^3/s)	0.48	0.51	0.38	0.01	-	0.30	0.46	-	-	-	0.24	0.30

where:

ETo	Related crop evapotranspiration (mm)
Kc	Crop coefficient
ETcrop	Evapotranspiration for crops (mm)
Pe	Effective Rainfall (mm)
In	Net irrigation water requirement (mm)
IR	Irrigation water requirement (mm)
Ep	Irrigation efficiency
I.W.R	Irrigation water requirement (m^3/s)

3. Irrigation Water Supply Plan

3.1 Shortage of Irrigation

The intake water discharge by the head works at the Rio Grande is selected as the principal water resource for irrigation and the construction of the Pantuflas dam has been determined in order to supplement in dry season. The irrigation water requirement, the designed available discharge and the shortage volume are shown in Table 3.1.1-1.

Table 3.1.1-1 Irrigation Water Requirement and Shortage of Irrigation

	1	2	3	4	5	6	7	8	9	10	11	12
I.W.R.	0.48	0.51	0.38	0.01	-	0.30	0.46	-	-	-	0.24	0.50
D.A.D.	0.30	0.34	0.34	0.46	0.86	0.57	0.48	0.76	0.69	0.60	0.46	0.40
S.W.	0.17	0.17	0.04	-	-	-	-	-	-	-	-	-

I.W.R.: Irrigation water requirement
D.A.D.: Designed available discharge
S.W. : Shortage Volume

These shortage volume should be supplemented by the Pantuflas dam. The required storage volume of the Pantuflas dam is calculated as follows.

$$V=(0.17x31+0.17x28+0.04x31)x24x3600$$
$$=980,000m^3$$

Irrigation water is to be supplemented from the Pantuflas dam from January to March when water discharge from the Rio Grande alone is not sufficient.

The area which is to be irrigated by water from the Pantuflas dam is as follows.

January	$Ab1=1510x0.17/0.48=530ha$
February	$Ab2=1510x0.17/0.51=503ha$
March	$Ab3=1510x0.04/0.38=159ha$

3.2 Irrigation Water Distribution Plan

Considering efficient utilization of the water resources and the existing canal networks, new irrigation water networks is designed in order to distribute the water equally over the study area as shown in Fig. 3.2.1-1, 2 and Table 3.2.1-1.

The irrigation water distribution plan is shown in Fig. 3.2.1-3.

Table 3.2.1-1 Division of Irrigable Area

Canal Nueva Constanza (469ha)						
	N-1	59ha	N-5	88ha		
	N-2	59ha	N-6	62ha		
	N-3	63ha	N-7	51ha		
	N-4	87ha				
Canal Pantuflas (157ha)						
Canal Constanza (884ha)						
	C-1	15ha	C-6	32ha	C-11	80ha
	C-2	18ha	C-7	70ha	C-12	58ha
	C-3	102ha	C-8	63ha	C-13	144ha
	C-4	91ha	C-9	65ha		
	C-5	70ha	C-10	76ha		

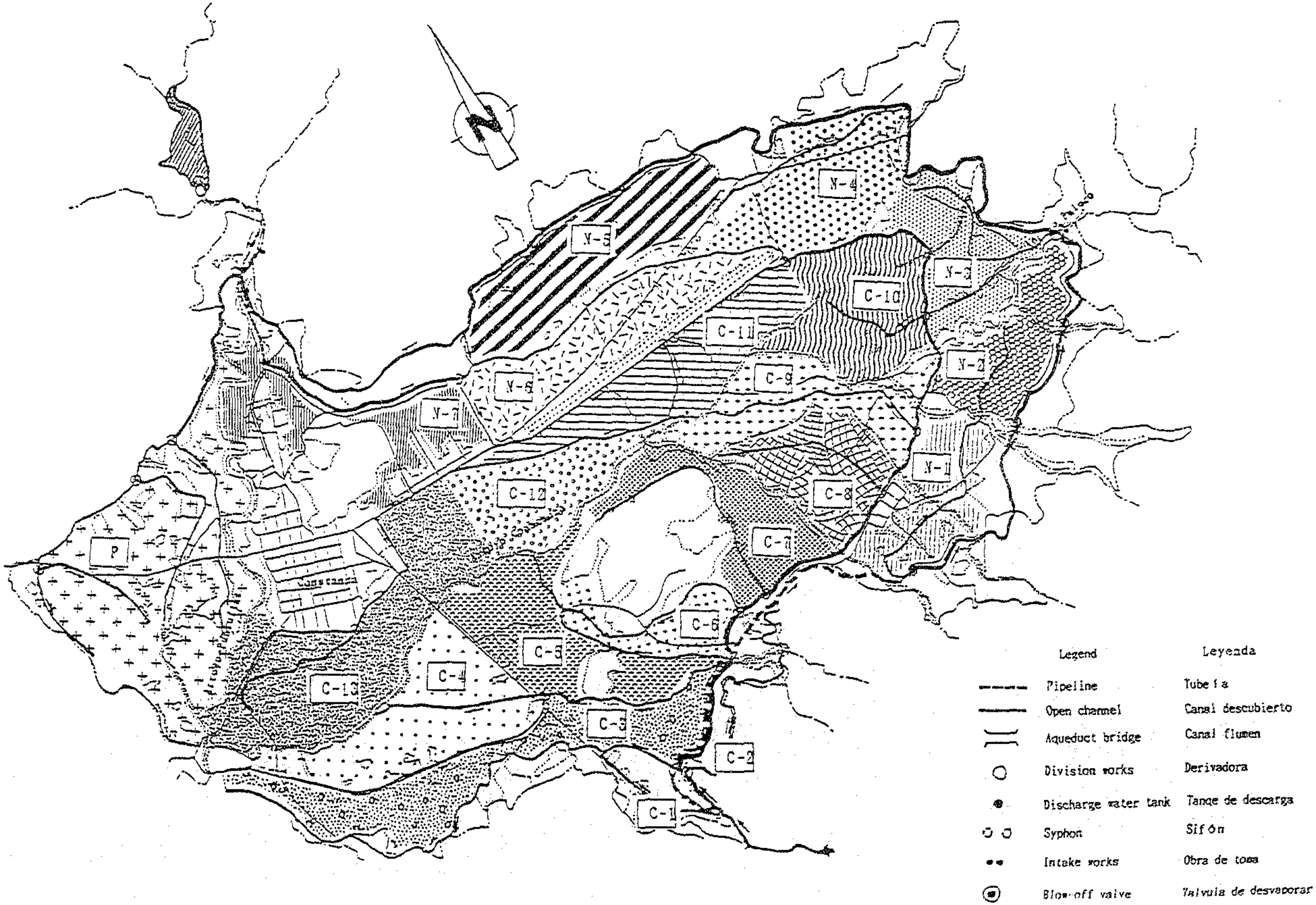


Fig. 3.2.1-1 Irrigation Block in Constanza Valley

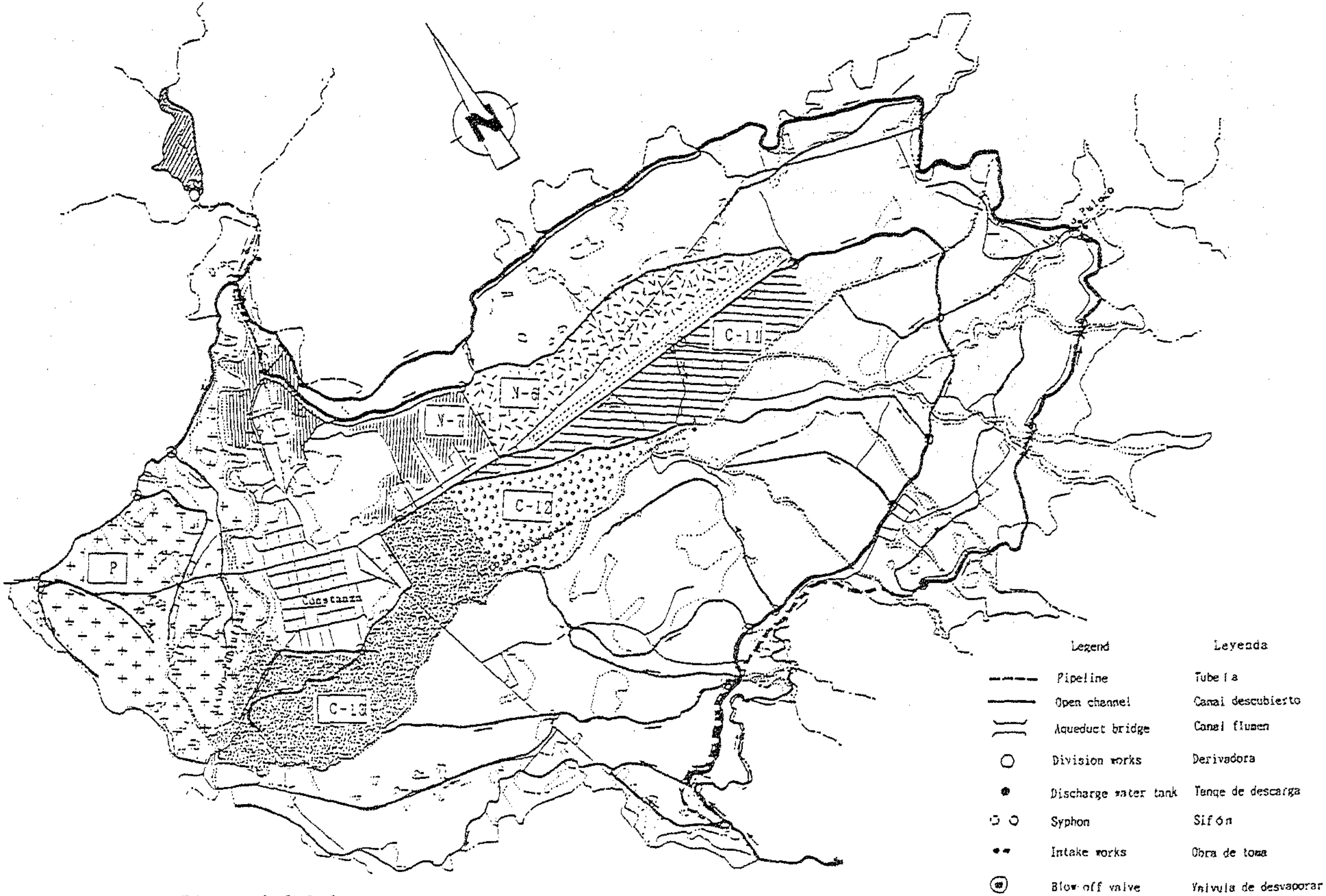


Fig. 3.2.1-2 Irrigation Block from the Pantuflas Dam in ON Dry Season

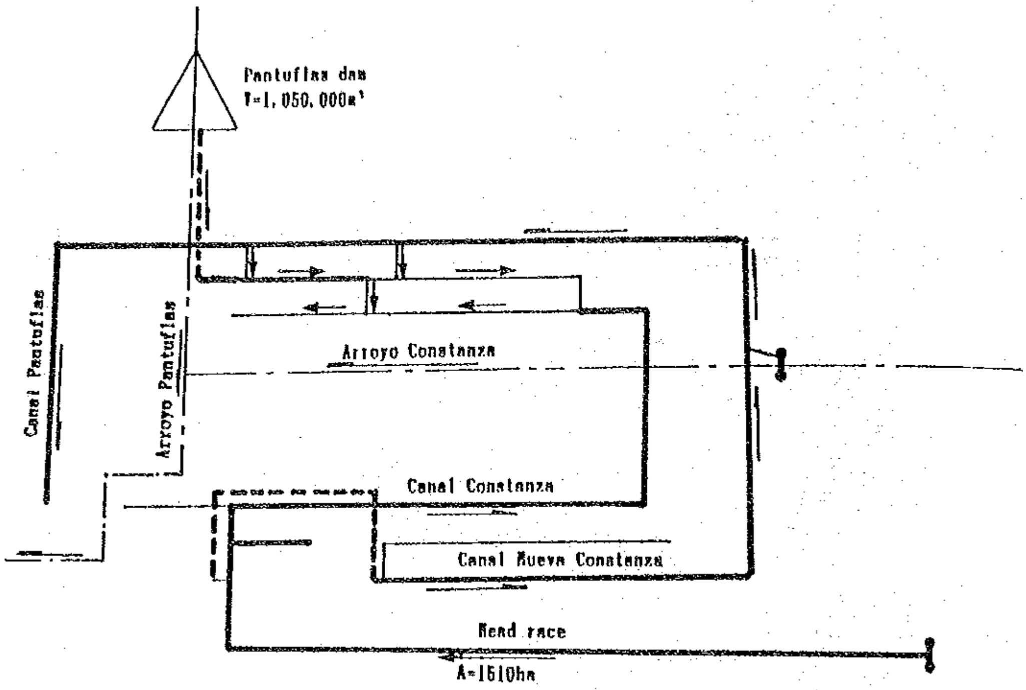


Fig. 3.2.1-3 Irrigation Water Distribution Plan

3.3 Irrigation Method

3.3.1 Intake Rate

The intake rate test was carried out at 9 points in the study area to review the irrigation plan. The result of the field intake rate test may be expressed with the basic intake rate, as shown below.

Table 3.3.1-1 Basic Intake Rate

	Location	Basic intake rate (mm/hr)
1	Las Auyamas (1)	6.56
2	Las Auyamas (2)	7.75
3	El Salto	20.11
4	El Cercado	34.20
5	Aserradero	12.82
7	Colonia Espanola	23.13
8	Colonia Hangara	33.19
9	Los Higos (1)	26.73
10	Los Higos (2)	4.33
	Average	18.76

Intake rate is described by the following formula;

$D = Ctn$

$I = KTm = 60\ CnTn\text{-}1$

Where:

D = Cylinder accumulated intake		(mm)
I = Cylinder intake rate		(mm/hr)
T = Time		(min)
C, n, K, m = Constants		
	K = 60 Cn,	
	m = n-1	

Basic intake rate is estimated by the following formula;

$Ib = 60\ Cn\ 600\ (1\text{-}n)\ n\text{-}i$

Where: Ib = Basic intake rate (mm/hr)

In accordance with the value for Ib, the following irrigation method can be proposed.

Ib Value (mm/hr.)	Irrigation Method
50 mm/hr	Furrow and Other Surface Irrigation
50-75 mm/hr	Furrow and Sprinkler
75 mm/hr	Sprinkler

The result of cylinder intake rate test is shown in Table 3.3.1-2. The location map of the intake rate test is shown in Fig. 3.1.1-1 and the results of the intake rate test are shown in Fig. 3.3.1-2(1) - Fig. 3.3.1-2(9)

Table 3.3.1-2 Summary of Intake Rate Test

D=C*T^n : Df=Cf*T^n
I=K*T^m : If=Kf*T^m

Name of Point	C	n	K	m	Ib	Cf	Kf
P1A	1.66	.62	61.37	-.38	7.60	.47	17.53
P1B	3.11	.50	93.73	-.50	5.52	.89	26.78
MEAN	2.38	.56	77.55	-.44	6.56	.68	22.16
P2A	.85	.63	31.96	-.37	4.20	.24	9.13
P2B	.50	.83	24.71	-.17	11.29	.14	7.06
MEAN	.67	.73	28.33	-.27	7.75	.19	8.10
P3A	.48	.71	20.40	-.29	4.47	.14	5.83
P3B	.90	.92	49.30	-.08	35.76	.26	14.09
MEAN	.69	.81	34.85	-.19	20.11	.20	9.95
P4A	2.61	.77	119.65	-.23	37.46	.74	34.19
P4B	2.99	.72	129.32	-.28	30.94	.85	36.95
MEAN	2.80	.74	124.49	-.26	34.20	.80	35.57
P5A	1.80	.72	77.37	-.28	18.06	.51	22.10
P5B	.87	.70	35.34	-.30	7.59	.25	10.38
MEAN	1.33	.71	56.35	-.29	12.82	.38	16.24
P7A	.92	.75	41.23	-.25	11.72	.26	11.78
P7B	2.62	.75	118.61	-.25	34.55	.75	33.89
MEAN	1.77	.75	79.92	-.25	23.13	.51	22.34
P8A	8.72	.53	276.45	-.47	19.32	2.49	78.99
P8B	1.28	.90	69.50	-.10	47.07	.37	19.86
MEAN	5.00	.72	172.98	-.28	33.19	1.43	49.42
P9A	7.31	.49	214.92	-.51	11.59	2.09	61.41
P9B	2.78	.77	128.61	-.23	41.87	.79	36.74
MEAN	5.05	.63	171.76	-.37	26.73	1.44	49.08
P10A	.36	.84	17.37	-.16	8.54	.10	5.13
P10B	.99	.22	13.15	-.78	.11	.28	3.76
MEAN	.68	.53	15.56	-.47	4.33	.19	4.45

NOTE

D	:	Cylinder Accumlated Intake	(mm)
Df	:	Furrow Accumlated Intake	(mm)
T	:	Time	(min)
I	:	Cylinder Intake Rate	(mm/hr)
If	:	Furrow Intake Rate	(mm/hr)
Ib	:	Basic Intake Rate	(mm/hr)
C,Cf,n	:	Constants of Accumlated Discharge	

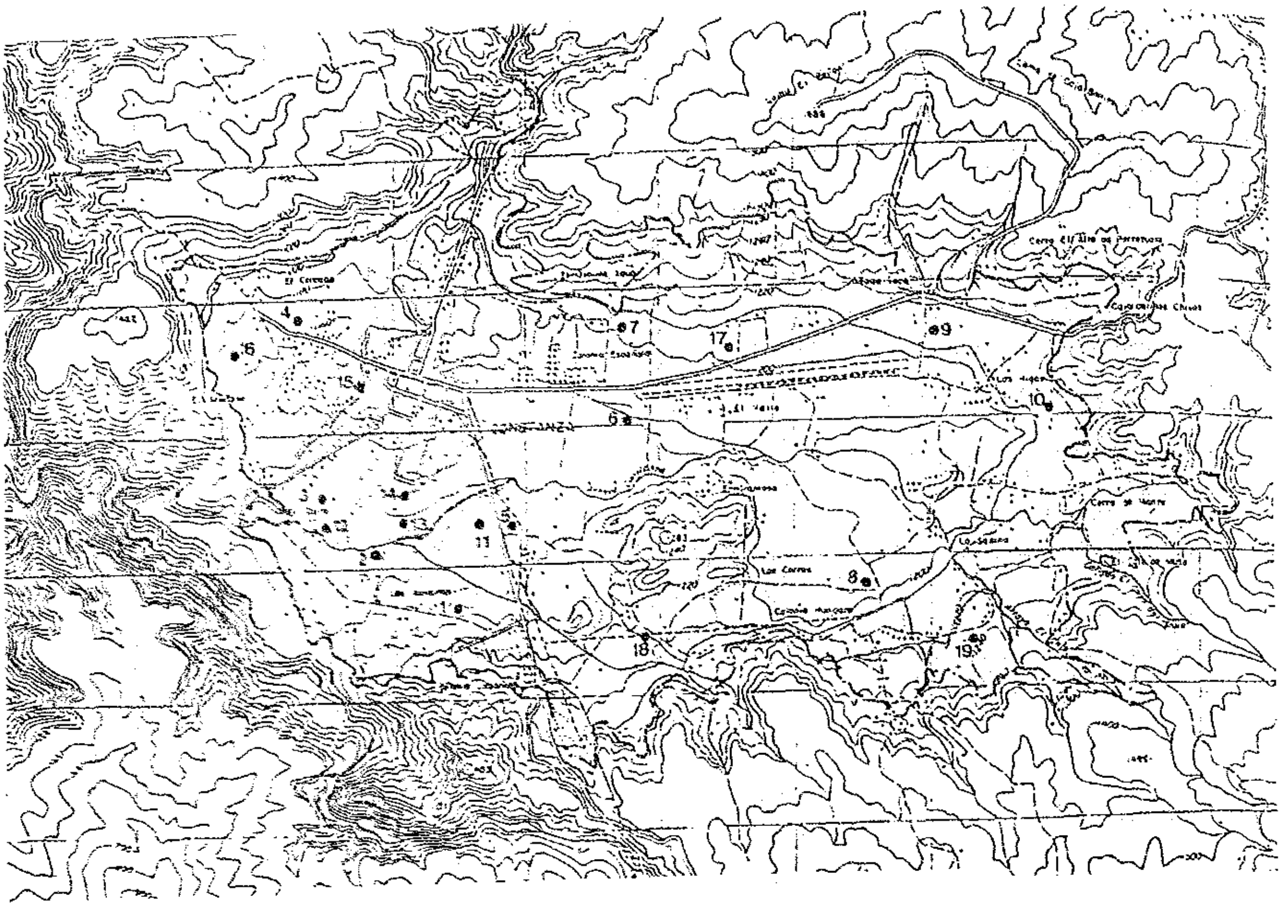


Fig. 3.3.1-1 Location Map of Intake Rate Test

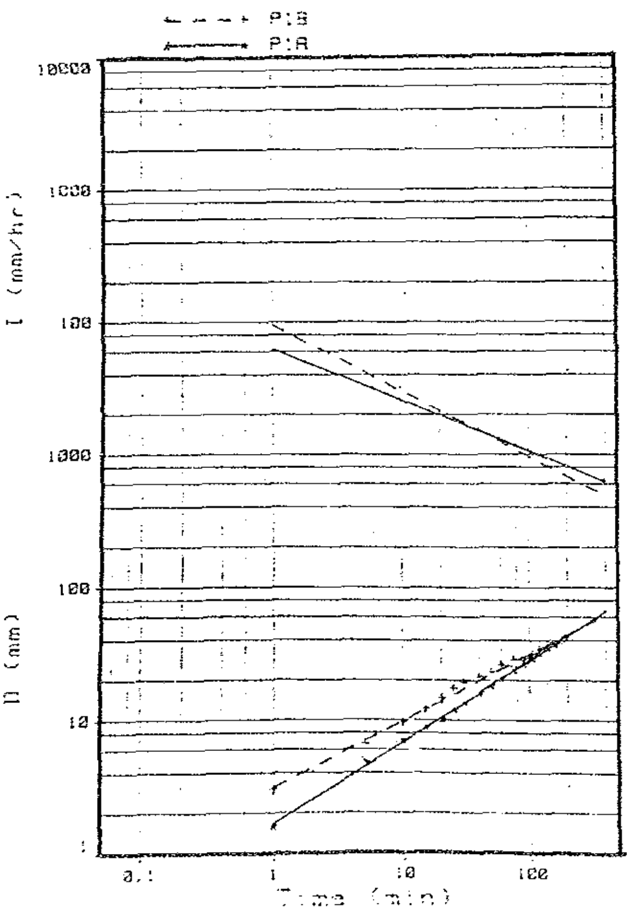


Fig. 3.3.1-2(1) Intake Rate

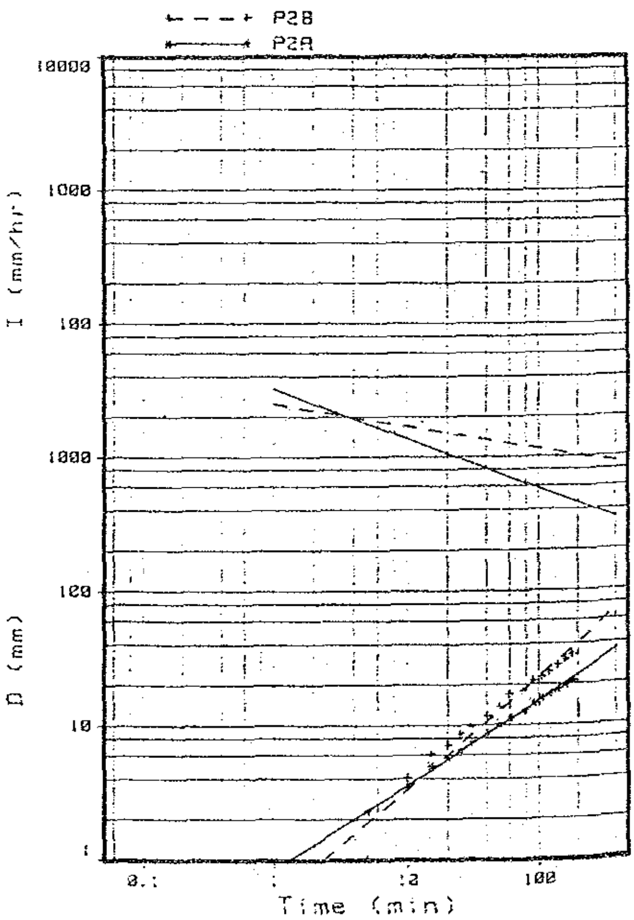


Fig. 3.3.1-2(2) Intake Rate

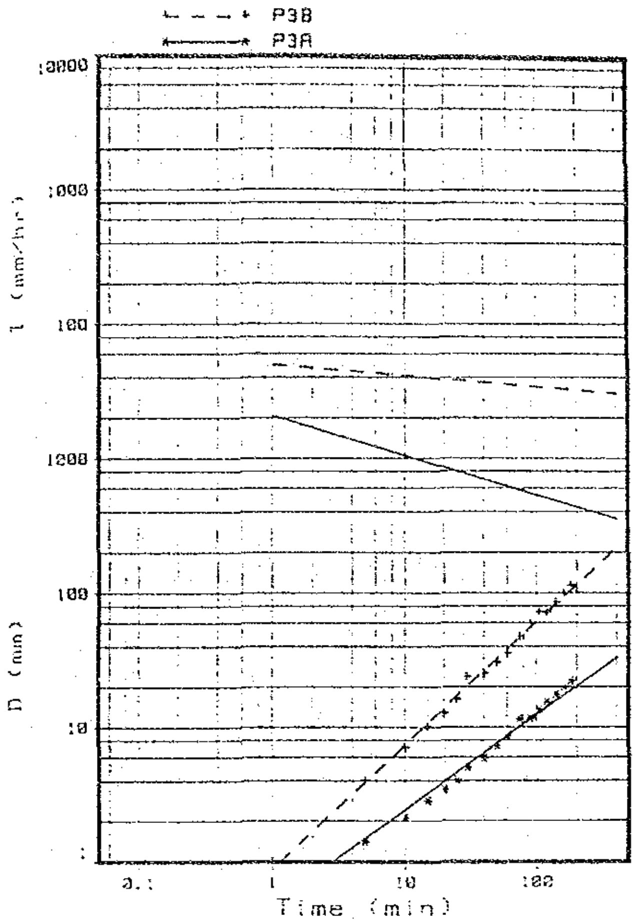


Fig. 3.3.1-2(3) Intake Rate

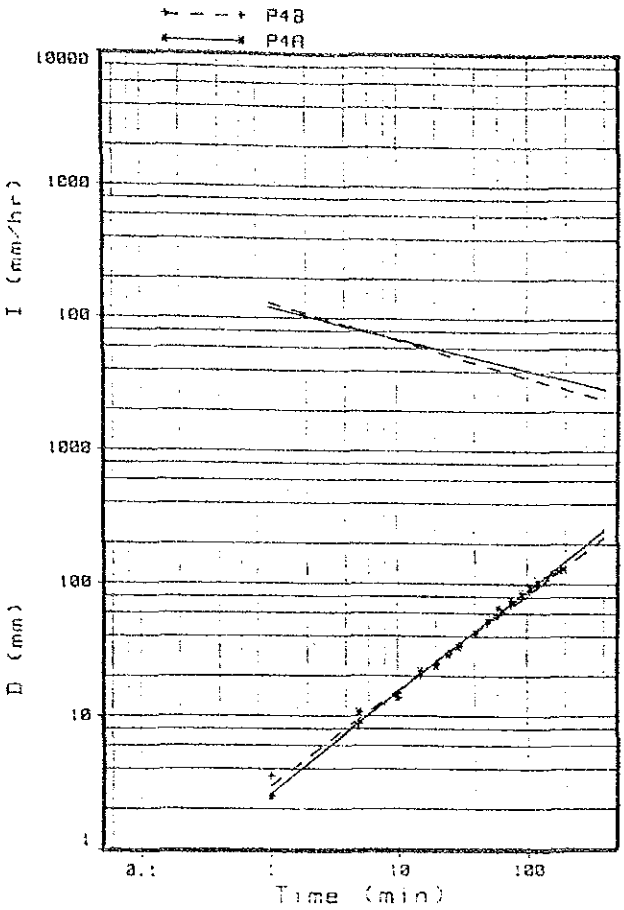


Fig. 3.3.1-2(4) Intake Rate

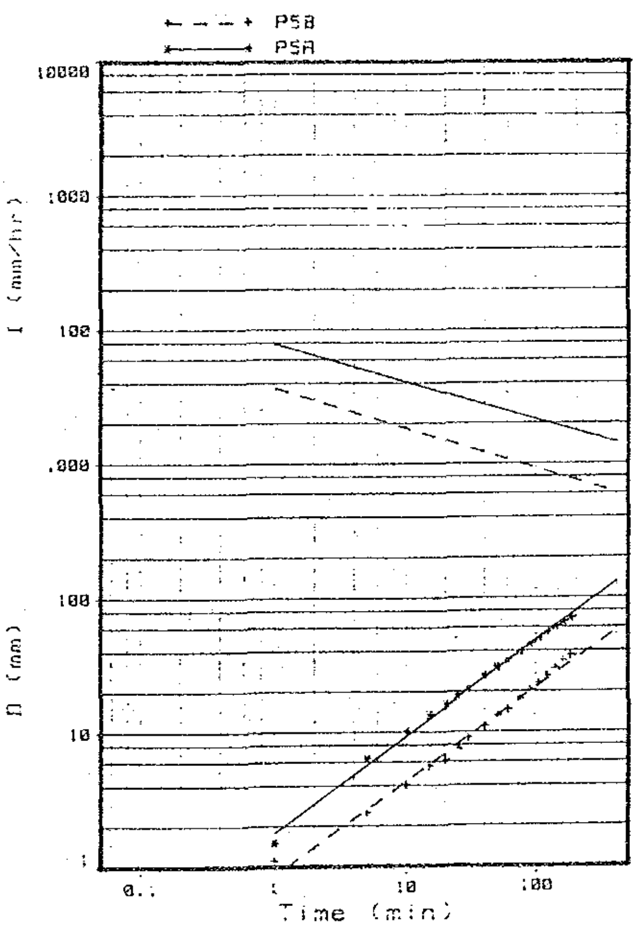


Fig. 3.3.1-2(5) Intake Rate

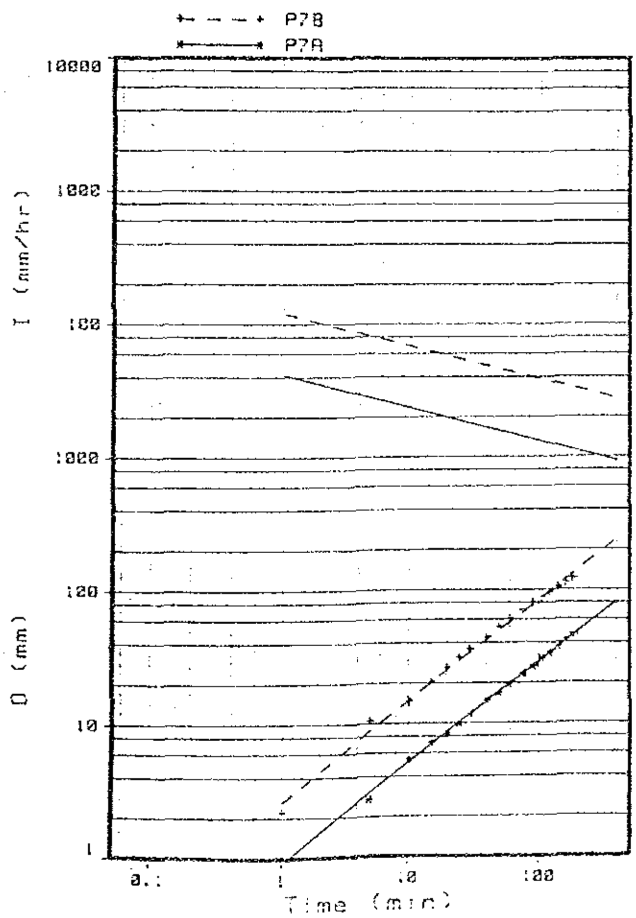


Fig. 3.3.1-2(7) Intake Rate

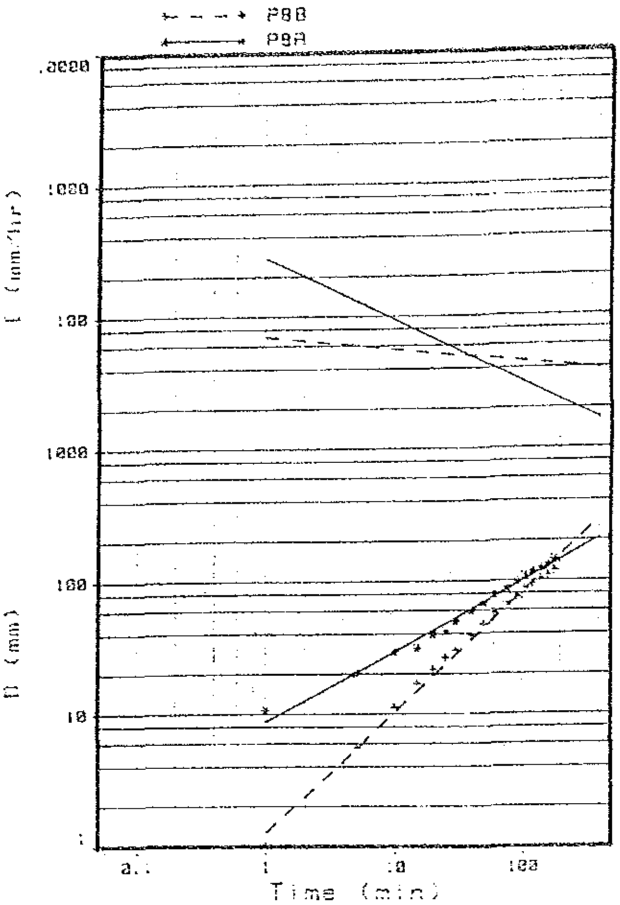


Fig. 3.3.1-2(8) Intake Rate

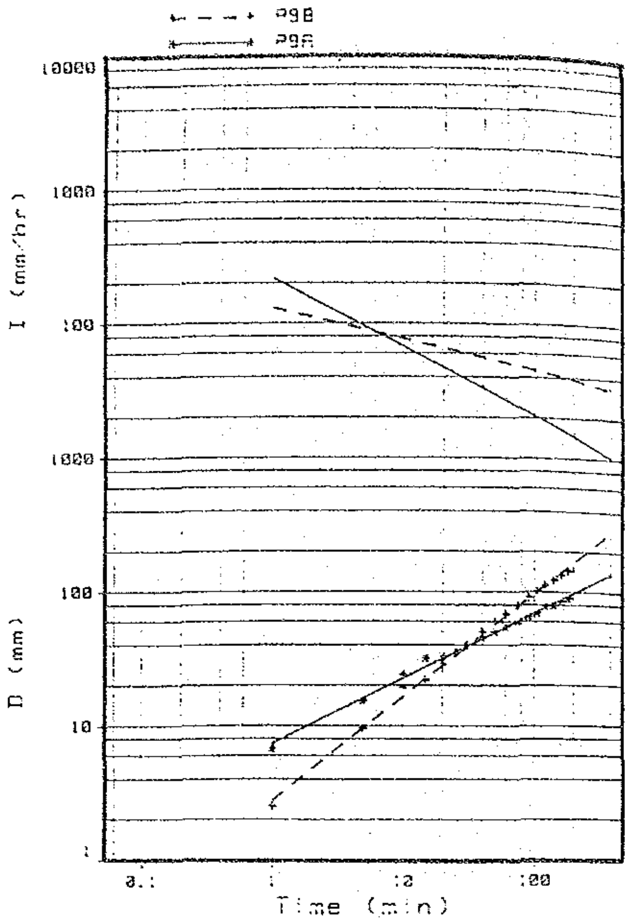


Fig. 3.3.1-2(9) Intake Rate

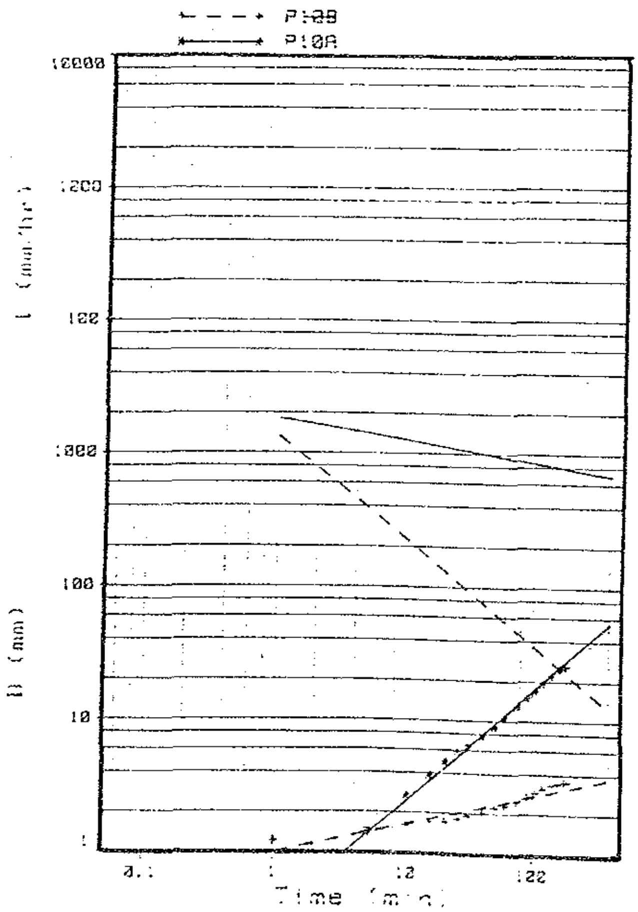


Fig. 3.3.1-2(10) Intake Rate

3.4 Selection of Irrigation Method

The irrigation method in the area is to be determined considering the natural conditions, agricultural management, and economic conditions, etc.

Sprinkler irrigation will be adopted in the benefited area because of the following main reasons.

- Sprinkler irrigation is not restricted by topographic conditions and crop conditions in the study area.

- Sprinkler irrigation is not influenced by wind with a velocity of less than 2m. At present sprinkler irrigation is employed in most of this area.

- In the conditions of habitual water shortage and limited water resources potentiality in the study area, sprinkler irrigation with higher irrigation efficiency is more suitable for the project.

3.5 Irrigation Water Requirement and Irrigation Interval

Soils were sampled at the intake rate measuring point to analyze physical properties of soil such as specific gravity, field capacity, and wilting point.

This analysis accompanies the calculation of effective moisture content of each soil layer and total readily available moisture (TRAM).

Table 3.5.1-1 Total Readily Available Moisture

	Location	TRAM (mm)
1	Las Auyamas (1)	32
2	Las Auyamas (2)	31
3	El Salto	33
4	El Cercado	21
5	Aserradero	36
6	El Valle	40
7	Colonia Espanola	30
8	Colonia Hungara	29
9	Los Higos (1)	28
10	Los Higos (2)	33
	Average	33

As shown in Table 3.5.1-1, representative soil has the TRAM value of 33mm. Irrigation interval for each crop is obtained from the TRAM value and daily water requirement.

Table 3.5.1-2 Irrigation Interval for Crops

Crops	TRAM (mm)	Max. daily water requirement (mm/day)		Interval (day)
Graminae	33	3.88	(Average)	8
Vegetable 1.3	33	2.11		
2	33	2.38	2.56	12
4	33	3.19		
Onion	33	2.85		11
Potato 1	33	3.23		
2	33	3.29	3.26	10
Kidney beans	33	3.72		8
Green manure	33	1.91		16
Garlic	33	2.13		14
Flower	33	3.80		8
Average	33	3.0		12

Irrigation interval depends on crops and cropping time as shown above, and the mean value of daily water requirement in the growing period is about 90% of the maximum value. Irrigation interval may be regarded as 12 days in average.

Water requirement for each irrigation operation is 31mm as indicated by the TRAM value.

Table 3.5.1-3(1) Calculation of TRAM

Depth (cm)	F.C	W.P	AM %	AM mm	Rm %	Lr (h)mm	TRAM (mm)
No. 1 Las Auyamas (1)							
0 - 10	29.40	16.84	12.56	12.56	40	32	32
10 - 20	29.40	16.84	12.56	12.56	30	42	
20 - 30	29.40	16.84	12.56	12.56	20	63	
30 - 40	29.40	16.84	12.56	12.56	10	126	
40 cm					100		
No. 2 Los Auyamas (2)							
0 - 10	28.40	16.21	12.19	12.19	40	31	31
10 - 20	28.40	16.21	12.19	12.19	30	41	
20 - 30	29.56	16.94	12.62	12.62	20	63	
30 - 40	29.56	16.94	12.62	12.62	10	126	
40 cm					100		
No. 3 El Salto							
0 - 10	30.80	17.72	13.08	13.08	40	33	33
10 - 20	30.80	17.72	13.08	13.08	30	44	
20 - 30	28.00	15.96	12.04	12.04	20	60	
30 - 40	28.00	15.96	12.04	12.04	10	120	
40 cm					100		
No. 4 El Cercado							
0 - 10	18.40	9.92	8.48	8.48	40	21	21
10 - 20	18.15	9.77	8.38	8.38	30	28	
20 - 30	18.15	9.77	8.38	8.38	20	42	
30 - 40	19.24	10.45	8.79	8.79	10	88	
40 cm					100		
No. 5 Aserradero							
0 - 10	34.01	19.74	14.57	14.57	40	36	36
10 - 20	34.01	19.74	14.57	14.57	30	50	
20 - 30	35.61	20.75	14.86	14.86	20	74	
30 - 40	35.61	20.75	14.86	14.86	10	149	
40 cm					100		

Note: Depth: Root Zone (cm)
FC : Field Capacity
WP : Wilting Point
AM : Available Moisture
Rm : Ratio of Moisture Extraction
Lr : Restricting Layer of Moisture Extraction
TRAM: Total Readily Available Moisture

Table 3.5.1-3(2) Calculation of TRAM

Depth (cm)	F.C	W.P	AM %	AM mm	Rm %	Lr (h)mm	TRAM (mm)
No. 6 El Valle							
0 - 10	38.16	22.35	15.81	15.81	40	40	40
10 - 20	38.16	22.35	15.81	15.81	30	53	
20 - 30	34.20	19.87	14.33	14.33	20	72	
30 - 40	34.20	19.87	14.33	14.33	10	143	
40 cm					100		
No. 7 Colonia Española							
0 - 10	27.49	15.64	11.85	11.85	40	30	30
10 - 20	27.49	15.64	11.85	11.85	30	40	
20 - 30	27.49	15.64	11.85	11.85	20	59	
30 - 40	27.16	15.43	11.73	11.85	10	117	
40 cm					100		
No. 8 Colonia Hungaro							
0 - 10	26.63	15.10	11.53	11.53	40	29	29
10 - 20	26.63	15.10	11.53	11.53	30	38	
20 - 30	26.63	15.10	11.53	11.53	20	58	
30 - 40	31.49	18.16	13.33	13.33	10	133	
40 cm					100		
No. 9 Los Higos (1)							
0 - 10	25.41	14.33	11.08	11.08	40	28	28
10 - 20	25.41	14.33	11.08	11.08	30	37	
20 - 30	26.19	14.82	11.37	11.37	20	57	
30 - 40	29.19	14.82	11.37	11.37	10	114	
40 cm					100		
No. 10 Los Higos (2)							
0 - 10	31.47	18.14	13.33	13.33	40	33	33
10 - 20	31.47	18.14	13.33	13.33	30	44	
20 - 30	31.47	18.14	13.33	13.33	20	67	
30 - 40	30.19	17.34	12.85	12.85	10	129	
40 cm					100		

Note: Depth: Root Zone (cm)
FC : Field Capacity
WP : Wilting Point
AM : Available Moisture
Rm : Ratio of Moisture Extraction
Lr : Restricting Layer of Moisture Extraction
TRAM: Total Readily Available Moisture

3.6 Field Irrigation System

Sprinkler irrigation method is selected as the most suitable irrigation method in the study area. The irrigation capacity was calculated on the basis of the maximum ETcrop=80.9mm/mon with 12 days of irrigation interval.

- Net irrigation water requirement=80.9/30x12=32.4mm/one time
- Field irrigation water requirement=32.4mm/0.7=46.2mm/one time

The sprinkler irrigation has been determined in order to irrigate 1ha of standard area. The field irrigation system has been planned as shown in Fig. 3.6.1-1.

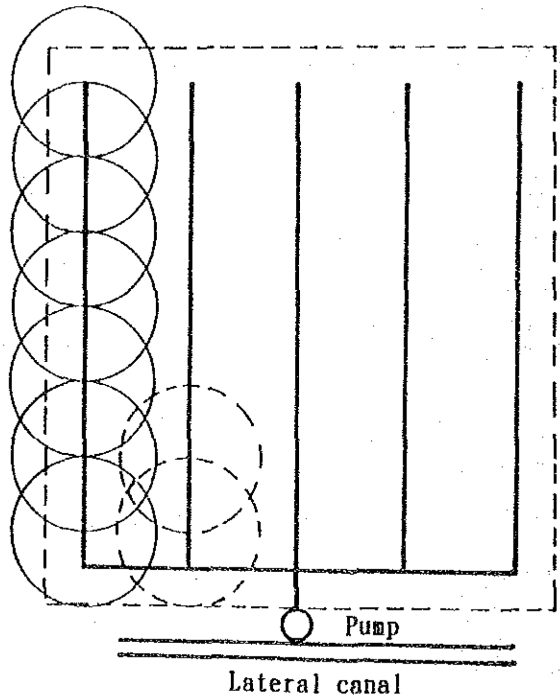


Fig. 3.6.1-1 Field Irrigation System

The capacity of the pump is calculated as follows:

$$Qp = \frac{10,000 \times h \times A \times D}{3,600 \times 1,000 \times T \times E} = \frac{h \times A \times D}{360 \times T \times E}$$

where Qp: Designed capacity (m^3/s)

h :	Net water requirement	h = 2.7mm/day
A :	Area (h)	A = 1.0ha
D :	Irrigation interval (day)	D = 12days
T :	Operation hour (hour)	T = 17hr
E :	Irrigation efficiency	E = 0.7

$$Qp = \frac{2.7 \times 1.0 \times 12}{360 \times 17 \times 0.7} = 0.008m^3/s = 0.45m^3/min.$$

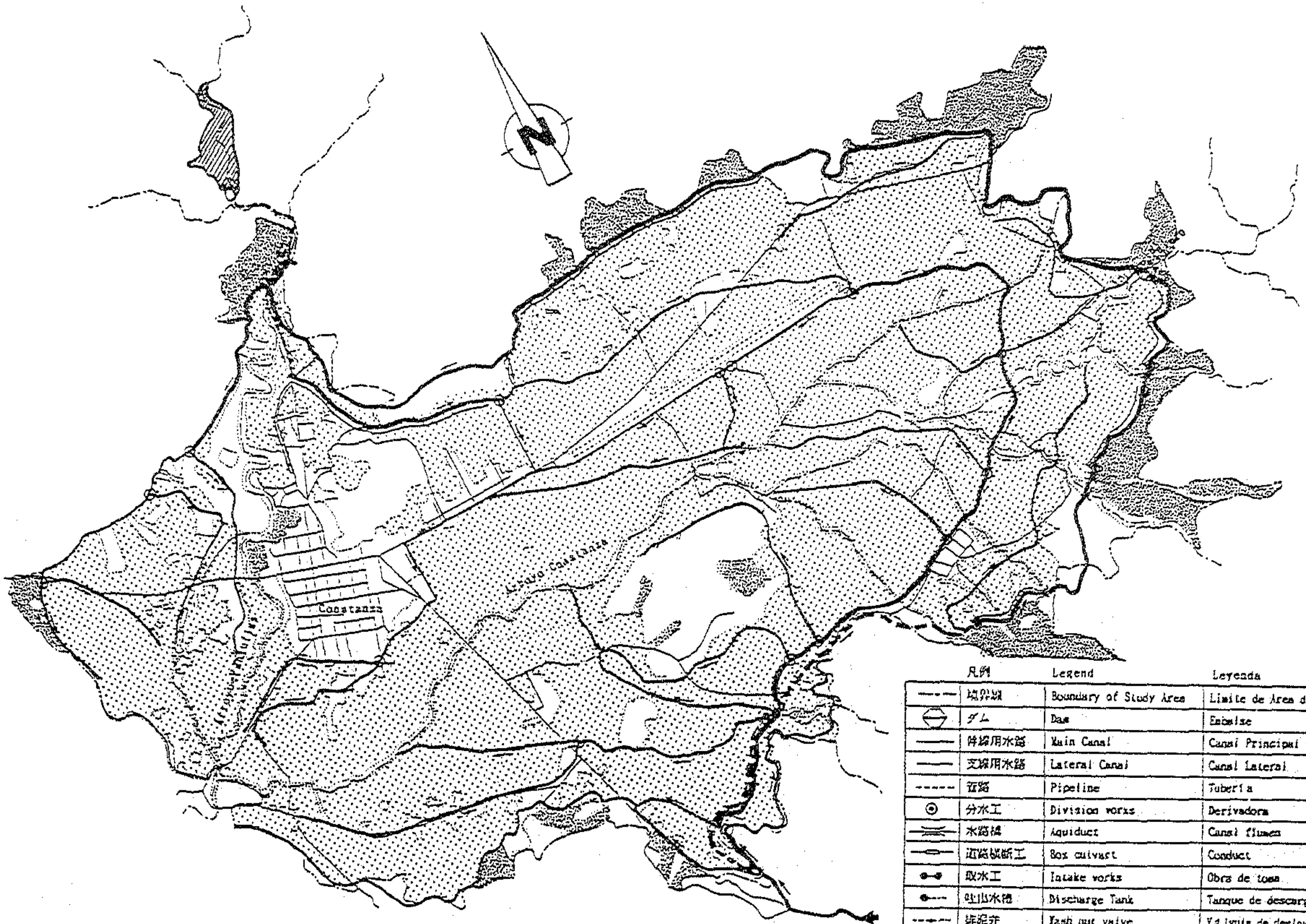
The pump capacity is determined as follows:

Type :	Volute pump
Pump up capacity:	$0.45m^3/min$
Head :	25m
Power :	5.5kw

3.7 Main Irrigation Canal and Irrigation Network

Based on the division of irrigation area, the main irrigation canal is delineated as shown in Fig. 3.7.1-1.

The plan of irrigation system is illustrated in Fig. 3.7.1-2.



	凡例	Legend	Leyenda
	境界線	Boundary of Study Area	Limite de Area del Estudio
	ダム	Dam	Embalse
	幹線用水路	Main Canal	Canal Principal
	支線用水路	Lateral Canal	Canal Lateral
	管路	Pipeline	Tuberia
	分水工	Division works	Derivadora
	水路橋	Aquiduct	Canal flumen
	道路横断工	Box culvert	Conduct
	取水工	Intake works	Obra de toma
	吐出水槽	Discharge Tank	Tanque de descarga
	排泥弁	Wash out valve	Valvula de deslave
	河川	River	Rio
	排水路	Drainage	Canal de drenaje

Fig. 3.7.1-1 Main Irrigation Canal

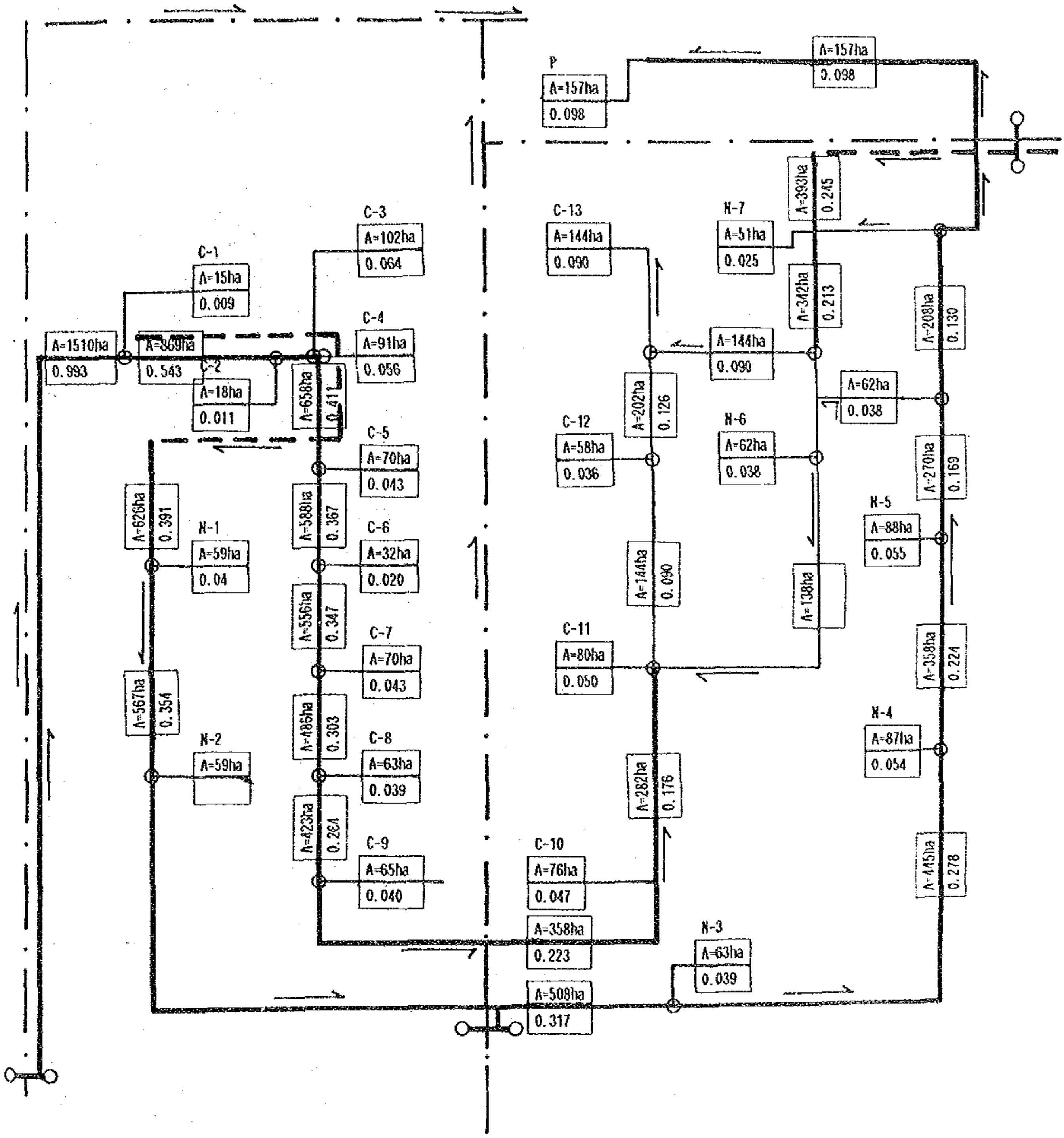
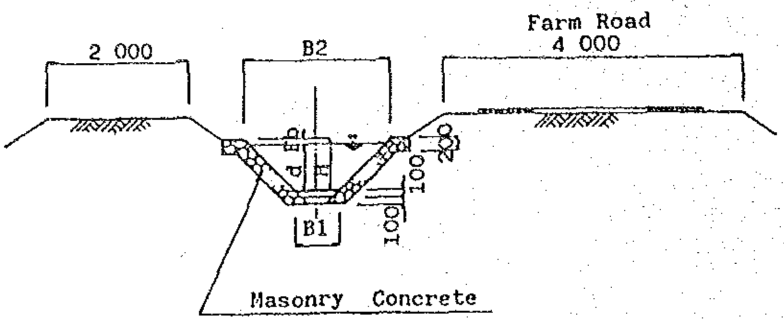


Fig. 3.7.1-2 Plan of Irrigation System

3.7.1 Irrigation Canal

(1) Canal Section

In relation to the section of main irrigation canals, wet masonary lining structure is proposed for canals.



(2) Hydraulic Calculation

Manning formula is employed to calculate the canal velocity as follows:

$$V = \frac{1}{n} \cdot R^{2/3} \cdot I^{1/2} \qquad (m/sec)$$

$$Q = A \cdot V \qquad (m^3/sec)$$

where, V = mean velocity (m/sec)

n = coefficient of roughness

(Assumed to be 0.03 for earth canal)

R = hydraulic mean depth (m) = A/P

A = cross-sectional area of flow (m)

P = wetted perimeter (m)

I = hydraulic gradient (= bed slope)

Q = discharge (m^3/sec)

B = width of canal invert (m)

d = water depth (m)

hv = velocity head (m)

F.b = free board

H = Height of sidewall (m)

ANNEX N : DRAINAGE PLAN

ANNEX N : DRAINAGE PLAN

Page

LIST OF FIGURES

ANNEX N: DRAINAGE PLAN

1. Basic Consideration

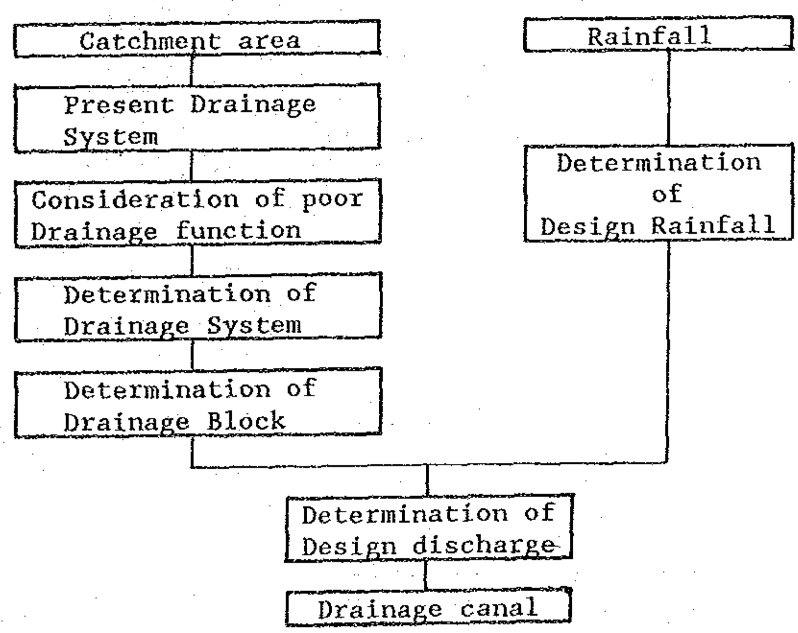
Basic consideration for the drainage plan is the timely removal of surplus water from the land so as to minimize the crop damage.

The improvement of present ill drainage condition is constituted from the principal objective of the plan to remove excess rainfall produced by 5 year return period.

The drainage plan covers only the present ill drained area.

2. Planning Methodology

The establishment of the drainage plan has been made in line with the following chart.



3. Design Criteria

3.1 Project Level

(1) Design Drainage Discharge

The design drainage discharge was established for 5 years return period which is currently employed by the INDRHI.

(2) Design Daily Rainfall

Design daily rainfall to determine the drain section was established based on the maximum daily rainfall for 5 years return period; daily rainfall is expected to be removed within the same day.

(3) Allowable Flooding Depth and Duration

Allowable flooding depth and duration are as follows:

Allowable flooding depth : 30cm
Allowable flooding duration: 24hours

3.2 Design Daily Rainfall

(1) Design Daily Rainfall

Maximum daily rainfall for each return period at Constanza Station is as follows:

Return period	Daily Rainfall (mm)
100 year	268.1
50 year	202.8
30 year	161.7
20 year	132.9
10 year	90.7
5 year	56.3

Consequently, design daily rainfall for drainage plan was established as follows:

Daily rainfall: 56.3mm

(2) Rainfall Pattern

Rear mountain type rainfall pattern was employed for the sake of safety.

(3) Hourly Distribution of Rainfall

Hourly distribution of rainfall is computed using following formula:

$$R_t = R_{24} \left(\frac{t}{24}\right)^K$$

where, R_t : Total Rainfall on T hours

R_{24} : Daily Rainfall

K : Coefficient (employed 0.5 which was estimated by Sharman)

$$R_t = 56.3\left(\frac{1}{24}\right)^{0.5}$$

$$= 11.5\text{mm/hour}$$

(4) Design Discharge

Design discharge for the drainage canal is calculated by the following formula.

$$Q = \frac{1}{36} A.R.K$$

where, A: Area in Km^2

R: Rainfall intensity = 11.5mm/h

K: Run off coeficiency 0.5

4. Drainage Plan

4.1 General Description of the Plan

For the purpose of improving actual drainage system, a drainage plan has been formulated in order to improve the drainage capacity of the poorly drained area, specially in the lower reach of the Arroyo Constanza.

4.2 Drainage Canal

4.2.1 Canal Network

Drainage canal network, as illustrated in Fig. 4.2.1-1, has been delineated according to the following main consideration.

- Actual rivers and drains will be used as far as possible and these systems will constitute for the trunk of the network.

The following drainage improvement works should be carried out.

a. Drainage canal 1, 2, 3 and 4 are to be constructed. The structure should be of unlined canal.

b. Maintenance of drainage canal 5 should be done.

c. The lateral 2 utilized for both irrigation and drainage canals is to be diverted to a drainage canal by reexcavation.

The cross section of the drainage canal should be trapezoidal and the dimension should be dicided from the existing cano and discharge.

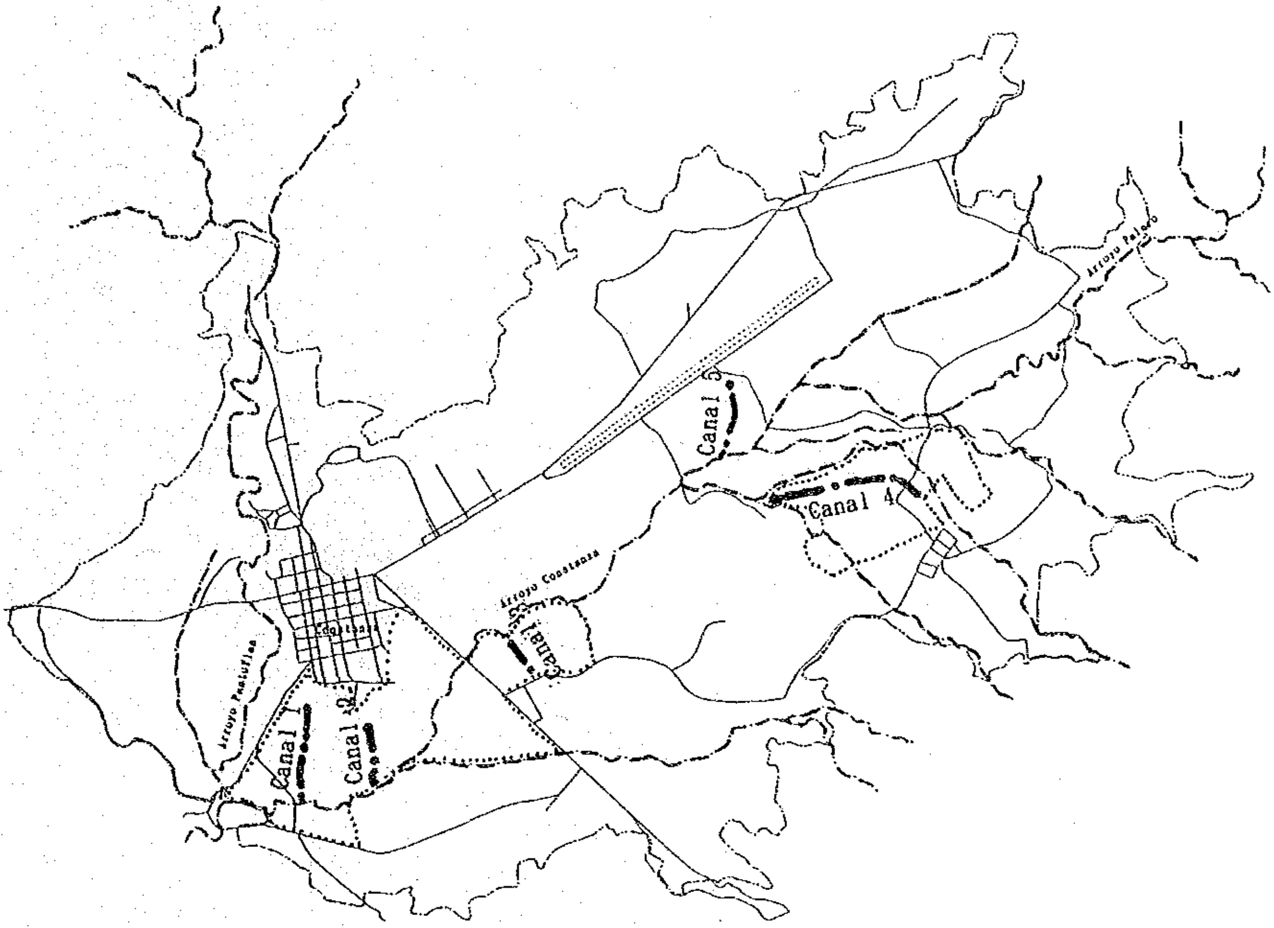


Fig. 4. 2. 1-1 Drainage Plan

ANNEX O : FACILITIES PLAN

ANNEX O: FACILITIES PLAN

LIST OF TABLES

LIST OF FIGURES

1. General

The facility plan of the project is divided into the following three categolies.

1. Water resource plan

   - Pantuflas dam
   - Mountain stream diversion works
   - Rehabilitation of existing head works
   - New head race
   - Rehabilitation of existing head race

2. Water distribution plan

3. Drainage plan

Design criteria for the facility plan is as follows:

a. Irrigation & drainage plan is carried out for rainfall of 5 year return period.

b. Flood discharge : 200 years return period

c. Temporary flood discharge: 10 years return period

d. Deposit period : 100 years return period

2. Pantuflas Dam

2.1 Location and Design Criteria

(1) Location

The location of the Pantuflas dam has been decided at the place of 650 m upstream of the existing intake works for the followings reasons:

- This site is most suitable to store water volume of 1,000,000m^3, in view of the dam storage capacity.

- To be able to minimize the compensation cost since the site is located at the upstream of the Arroyo Arriba.

- Geological condition is suitable for the construction of dam comparing to the other sites.

(2) Design Criteria

For the determination of the dam dimensions, the following design criterias are employed.

Flood discharge	:	200 years return period Q = 100 m^3/s
Temporary flood discharge	:	10 years return period Q = 10 m^3/s
Horizontal seismic coefficient of earthquake	:	0.1
Available storage volume	:	V = 980,000 m^3
Sediment volume	:	V = 70,000 m^3
Total storage volume	:	V = 1,050,000 m^3

2.2 Calculation of the Capacity of the Pantuflas Dam

2.2.1 Effective Storage Capacity

By the rehabilitation of the intake facilities, it is expected that the conveyance efficiency will be improved. The dam should have the capacity to supplement the water shortage in dry season against the Rio Grande water resource.

The irrigation water demand, available water discharge from the Rio Grande and water shortage are shown in Table 2.2.1-1.

Table 2.2.1-1 Water Demand, Available Water Discharge and Water Shortage

	1	2	3	4	5	6	7	8	9	10	11	12
Water demand (m^3/s)	0.47	0.51	0.38	0.05	-	0.30	0.29	-	-	-	0.29	0.30
Available water discharge (m^3/s)	0.30	0.34	0.34	0.46	0.86	0.57	0.48	0.76	0.69	0.60	0.46	0.40
Water Shortage	0.17	0.17	0.04	-	-	-	-	-	-	-	-	-

Required capacity = 0.17 x 3600 x 24 x 31 + 0.17 x 3600 x 24 x 28 + 0.04 x 3600 x 24 x 31 = 973,728m^3

Hence in this alternative, the dam should have the capacity to reserve a volume of 980,000m^3.

2.2.2 Calculation of Deposit of the Arroyo Pantuflas

Catchment area : 6.76 km^2

Deposit quantity per sq.km area : 100 m^3/km^2

Deposit period : 100 years

Quantity of deposit

Q = 6.76 km^2 x $100^3/km^2$/Year x 100 Years

= 67,600 m^3 = 70,000 m^3

Design deposit quantity : 70,000 m^3

2.2.3 Capacity of the Pantuflas Dam

The total capacity of the dam is the sum of available storage capacity and dead water capacity including sediment.

Available storage capacity V = 980,000 m^3

Sediment volume V = 70,000 m^3

Total storage capacity V = 1,050,000 m^3

2.2.4 Design Flood Discharge

The design flood discharge is estimated as 100m^3/sec by Cremer's formula and Izzard's formula. The temporary flood discharge under construction is 10m^3/sec which is 1/10 of the above value.