early stage. Moreover, since the project is to be carried out in an area already being farmed and not on reclaimed land, it will be necessary to reduce as much as possible, the influences on which construction works will have on farming activity.

### 4.1.3 Concept for Water Source Development

The study area is located at the hilly plain developed by Santa Ana River. At the plain along the river, irrigation is carried out using the river water through the irrigation canal system constructed by the farmers. In the dry season, however, the river water dries up, and the farm management relying only on such an irrigation system is limited to the rainy season. Such a natural condition in the area causes a situation that would not allow even self-supply to each farm household, and farmers to keep the income balance of their economy by working in other places. Under the circumstances, improvement in farmers' income balance by themselves can hardly be expected. In case of formulating the agricultural and rural development plan in the study area, therefore, year round farm management through development of water resources and especially, improvement of the farm management conditions through the introduction of irrigated agriculture during the dry season are indispensable. An expansion of cultivated area in the rainy season alone would not bring forth a fundamental solution taking the land holding of individual farm households, family labor distribution, and poor marketability of agricultural products due to the concentration of harvest into account.

As already mentioned in the chapter 3 "PRESENT CONDITIONS OF THE STUDY AREA", the annual mean precipitation in the study area is 470 mm and the total annual outflow of Santa Ana River is 21 (MCM). However, there is almost no rainfall and run-off in the dry season from April to September, and it is impossible to take run-off of the river for irrigation throughout the year utilizing the facility such as diversion weir. In case of planning the irrigation for arable land in the area by means of the gravitational system from the reservoir, the irrigated area is estimated to be 1,100 ha out of the arable land of 2,200 ha, and the required water volume to be 5.8 (MCM) per year. Furthermore, considering the inflow sediment of 50 years at dam site, the total amount of sediment volume is 8.6 (MCM) and the reservoir, of which the total reservation volume is 15 (MCM), is necessary. As to groundwater and under-flow, on the other hand, a water supply capacity of 500 - 1,000 $m^3$ per day (less than 0.5 MCM per year) is estimated at a depth below the elevation of the river bed of Santa Ana River and as a water they are excluded as a supply resource.

With the annual outflow of the river it is possible to supply irrigation water to the total cultivated area if a reservoir is constructed. However, if some reservoirs would be constructed at suitable sites in the study area and it surrounding area, the total amount of

reservoir capacity is estimated to be only 11 (MCM). In case of planning, it is necessary that the inflow sediment into the reservoir are reduced by means of constructing the sedimentation dam above the upper stream and the water requirement is reduced by means of decreasing the irrigation area during the dry season. In all cases, the construction of reservoir will play the basic role as a mean of developing useful water resources in the area.

The surface run-off of Santa Ana River (it is called Yesera River above the point where a tributary called Gamoneda River flows in) and its tributaries is intended to be utilized as the water resource to be developed. A reservoir is selected as the major water source facility for the mentioned above. Considering possibility of constructing the facilities such as small-scale reservoir for supplementary water source facilities and diversion weir, the most suitable plan about the scale of water resources development will be proposed after comparing with the agricultural development plan.

### 4.1.4 Concept for Agricultural Development

With the view of the present conditions of the farm management and the farm economy in the study area, irrigation during the dry season and increase of irrigated area during the rainy season are indispensable requirement to establish living fundamental for farm household. Therefore, improvement of irrigation facilities (ensure of stable water resource and supply of irrigation water throughout the year) is the most important issue to establish the plan.

Land holding of small-scale farmer which account for more than 90% in the area are about 7 ha, out of which an tillable land is 4 ha on average. Under present conditions, the land is cultivated only once a year during the rainy season, and the average of cropping acreage is about 2 to 3 ha. The agricultural development plan will target these small-scale farmers, who form the majority in the objective area, and the objective area for each farm household is 4 ha , which is the average tillable land. In regard to the annual cropping ratio, a comprehensive plan is established from the viewpoint of project cost taking into account the developing scale of water resources and the farm economy.

As for cropping pattern of each farm household, intensive farming is managed by adopting annual crops such as breed crops, cereal crops, vegetable and etc. with concentration on perennial crops, mainly grapes. As the results, the project will try to establish the district of agricultural products consisting mainly of grapes, and enable farmers to continue farming. Moreover, the development projects in the two nearby areas of San Jacinto and Guadalquivir both of which are agriculturally more advanced, should also be taken into consideration. In order to raise the marketability of introduced products, adjustments should be

made regarding what is being produced in each of the districts. With these measures, the project will try to rectify the existing gap between the districts.

### 4.1.5 Concept for Rural Development

With the agricultural development as a turning point, it is necessary to elevate the farm income and modernization of agriculture through improvement of the infrastructure of agricultural production. This would help sustain the growth of the region. At the same time it is necessary to encourage settlement in the area and activate the rural community by improving standard of living for the farmers. The scheme for the rural development, which is part of the project, will be planned in conjunction with the scheme for the agricultural development. It will, therefore, have to be a plan that improves the conditions for settlement in the area by improving the infrastructure through the construction of new facilities and the rehabilitation of existing ones. Furthermore, it should improve the bond and solidarity between the habitants in the area.

The area is made up of three communities and, with the exception of parts of Santa Ana Nueva, the villages are scattered throughout the area. Most of the land within the area is owned by farmer. Although there would be no new settlers, farmers who have left the area may be induced to return to their land. Presently unused fields may be re-cultivated, or new arable land may be opened up. The existing farms along the river are fitted with canal systems and form independent farming blocks around each of these systems. Since the arable land that is to be newly opened will also form such independent blocks around small streams, there will be no need for re-plotting even if new irrigation facilities are built. Although, in regard to the plan for the improvement of living conditions, it would be better for the colonies to be located close to each other so that they could share the same facilities, consideration of the nature of the infrastructure needed and the above-mentioned factors suggest that the present structure of colonies will be maintained.

The contents of the infrastructure will be decided on the basis of the needs of the people in the area. The facilities essential for the improvement of living conditions will be considered, and their usefulness judged, in relation to the facilities already existing. In deciding the level of improvement, due consideration will be given to the standard of improvement by similar operations in other parts of the department of Tarija.

## 4. 2 Development Plan

A development plan for the objective area will be defined with mutual relationship on the extent of the water resources development and agricultural development plans. Therefore, in deciding on a blue print for development plan in connection with the basic concept for the project, mentioned above, two possible cases need to be considered. The first case would involve the year-round irrigation of arable land during both the rainy and dry seasons. In the second case, there would be a reduction of area to be irrigated, thus decreasing costs and raising the efficiency rate for expenditures (cultivation during the rainy season alone will also be considered, tentatively). The profitability of the undertaking itself as well as the financial effects on farm household, maintenance costs, and the repayment of construction costs for the facilities after the completion of the project will be analyzed in regard to both of the cases mentioned above. A development plan that is considered economically and technically most feasible will be decided upon. Although, there is no direct relation between the scale of the rural development plan and those for the development of water resources and farm management in the area, since the plan is a part of the synthetic project, this will be taken into account in calculations regarding the economical efficiency of the project as a whole.

The following 10 cases will be studied as alternatives on the water resource development plan. The objective area for irrigation of each case will be taken as 4 ha per farm household, which is the average arable land per farm household in the study area. In cases where perennial crops are not adopted for the farming plan, 3 ha will be taken as the cultivation area in consideration of the family labor force of each farm household.

| CASE | Irrigation area per farm household (ha) | |
|---|---|---|
| | Rainy Season | Dry Season |
| CASE 1 | 4.0 | 4.00 |
| CASE 2 | 4.0 | 3.00 |
| CASE 3 | 4.0 | 2.00 |
| CASE 4 | 4.0 | 1.75 |
| CASE 5 | 4.0 | 1.50 |
| CASE 6 | 4.0 | 1.25 |
| CASE 7 | 4.0 | 1.00 |
| CASE 8 | 4.0 | 0.50 |
| CASE 9-1 | 3.0 (for only present cultivated area) | |
| CASE 9-2 | 3.0 (for whole objective area) | |

The following conditions will be established for comparison of each case.

a. When cultivation is performed only in the rainy season, the diversion weir will be proposed for the intake facilities. In case of irrigating also in the dry season, a reservoir will be

proposed, and a concrete gravity type for dam structure will be adopted considering the conditions at the site.

b. The effective storage capacity of the reservoir will be decided on the basis of a 5-year probability (a water shortage occurs once in every 5 years) to reduce the construction cost of dam.

c. Since topographical condition, the pocket capacity of the reservoir is small, a sedimentation dam will be constructed in the upstream basin to reduce the sediment at the reservoir. For the sediment volume at the proposed reservoir, the volume from the downstream basin (remaining basin) at the sedimentation dam point will be considered.

d. Irrigation will be made by means of gravitational system. The irrigable area which is downstream from the site proposed for the water resource facilities, Santa Ana dam site and is possible to be conducted with the gravitational system, is 1,090 ha. The incremental irrigable area at the proposed upstream point is 13 ha between Santa Ana site and Yeara downstream site and is 7 ha between yesera downstream site and upstream site, respectively. Therefore, the irrigable area for the plan will be studied based on the area of 1,090 ha.

e. As for the construction of canals, the scope and level of improvement will be the same among the cases, with the exception of Case 9-1, and the scope of the improvement plan will include the main canal up to the secondary canal. For Case 9-1, plans will be drawn up to divide the canal system into two systems, the right bank and the left bank.

f. The water balance will be calculated for the period from 1977 to 1988 for which data on river discharge is available. The overall irrigation efficiency will be 54% as furrow irrigation method.

### 4.2.1 Proposed Cropping Pattern

To formulate the proposed cropping pattern, a crop calendar is formed taking a reduction of required irrigation water into account and the following is considered to select the crops and their cultivation area.

- Intercropping and mixed cropping systems should be avoided to increase agricultural productivity (yield) for each crop and to maintain soil fertility. Rotation cropping system is proposed.
- Profitability of corn, wheat and beans is low, though those

crops are basic foods and traditional crops. Therefore, cultivation area of those crops is planned mainly for self consumption in the plan.

- Priority is put to the cropping of vegetables taking profitability and marketability into consideration.
- Harvest of alfalfa for forage crops is planned seven times per annum with soilage. Ratooning cultivation is made during September to October.
- Due to defoliation and torpor of the grape from July to September which is the perennial crop, irrigation of the vineyards is minimized.

Taking the above-mentioned into consideration, proposed crops and its cultivated area for each case is laid out as follows. Each crop calendar is shown in Annex E.

(Unit: ha)

| CROP | CASE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9-1 | 9-2 |
| Rainy Season | | | | | | | | | | |
| Corn | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.00 |
| Wheat | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.50 | 0.50 | 0.50 |
| Potatoes | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Beans | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.50 | 0.50 | 0.50 |
| Tomatoes | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | - | - |
| Onions | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | - | - |
| Garlic | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | - | - | - |
| Alfalfa | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.50 | 0.50 | 0.50 |
| Grapes | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.50 | - | - |
| Sub-Total | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 | 3.50 | 3.00 | 3.00 |
| Dry Season | | | | | | | | | | |
| Wheat | 0.25 | - | - | - | - | - | - | - | - | - |
| Corn | 0.50 | 0.50 | - | - | - | - | - | - | - | - |
| Beans | 0.25 | 0.25 | 0.25 | - | - | - | - | - | - | - |
| Tomatoes | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | - | - | - | - | - |
| Onions | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | - | - | - | - | - |
| Carrot | 0.25 | 0.25 | 0.25 | 0.25 | - | 0.25 | - | - | - | - |
| Alfalfa | 0.50 | 0.50 | - | - | - | - | - | - | - | - |
| Grapes | 1.50 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.50 | - | - |
| Sub-Total | 4.00 | 3.00 | 2.00 | 1.75 | 1.50 | 1.25 | 1.00 | 0.50 | - | - |
| Total | 8.00 | 7.00 | 6.00 | 5.75 | 5.50 | 5.25 | 5.00 | 4.00 | 3.00 | 3.00 |
| Cropping intensity (%) | 200 | 175 | 150 | 145 | 140 | 130 | 125 | 100 | 100 | 100 |

From the cropping pattern mentioned above, the area ratio of perennial to annual crops for each case in the projected area of 1,090 ha is as follows. The following areas are of applying the cropping acreage per 4 ha to the area which subtracts the present orchard from the objective area. The objective areas of Case 1 to 7 are 1,090 ha and the area of Case 8, 9-1 and 9-2 are 953 ha, 388 ha and 817 ha, respectively.

(Unit: ha)

| Item | Case | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9-1 | 9-2 |
| Objective area per farm household | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 |
| Dry season | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 | 3.50 | 3.00 | 3.00 |
| Rainy season | 4.00 | 3.00 | 2.00 | 1.75 | 1.50 | 1.25 | 1.00 | 0.50 | - | - |
| Perennial crop | | | | | | | | | | |
| Without project | 112 | 112 | 112 | 112 | 112 | 112 | 112 | 112 | 112 | 112 |
| With project | 479 | 357 | 357 | 357 | 357 | 357 | 357 | 234 | - | - |
| Annual crop | | | | | | | | | | |
| Without project | 388 | 388 | 388 | 388 | 388 | 388 | 388 | 388 | 388 | 388 |
| With project | | | | | | | | | | |
| Whole season | 1,222 | 1,222 | 977 | 916 | 855 | 794 | 733 | 721 | 388 | 817 |
| Dry season | 611 | 488 | 244 | 183 | 112 | 61 | - | - | - | - |
| Rainy season | 611 | 733 | 733 | 733 | 733 | 733 | 733 | 721 | 388 | 817 |

### 4.2.2 Water Balance Study

Calculation results of crop water requirement and water balance study are shown in Annex Table F.3.2 to F.3.5 based on the review results of proposed crops and crop calendar. The water balance is carried out for the purpose of deciding the reservoir capacity. The reservoir capacity is decided on the basis of the design year that a water shortage statistically occurs once in 5 year. From the water balance study, the consumptive use and water requirement in each case is as follows:

| Case | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Consumptive use (mm) | 746.8 | 677.0 | 604.6 | 583.8 | 565.4 |
| Water requirement (MCM) | 5.34 | 4.05 | 2.46 | 2.25 | 2.06 |

| Case | 6 | 7 | 7 | 9-1 | 9-2 |
|---|---|---|---|---|---|
| Consumptive use (mm) | 549.9 | 531.6 | 487.9 | 487.5 | 487.5 |
| Water requirement (MCM) | 1.70 | 1.54 | 0.71 | - | - |

### 4.2.3 Dam and Irrigation Facilities

(1) Dam facilities

Dam, small-scale reservoir in the irrigation area and diversion weir excluding groundwater can be considered for the water source facilities of the project. The conditions for construction these facilities in the objective area are as follows.

- As the proposed dam site, the Santa Ana site which is selected by CODETAR, the Yesera lower site (2.7 km upper above the Santa Ana site), the Yesera upper site (1.7 km above the Yesera lower site) and the San Agustin site (the upstream of the san Agustin which is the tributary to the Santa Ana River)

are studied on the basis of field investigation and the study of topographic map in and around the projected area. In view of the topographical and geological conditions and the construction costs, the maximum reservoir capacity is estimated as follows.

| Propose dam site | Catchment area ($km^2$) | Sediment volume (MCM) | Dam height (m) | Maximum reservoir capacity (MCM) |
|---|---|---|---|---|
| Yesera upper | 227 | 8.0 | 30 | 3.2 |
| Yesera lower | 228 | 8.1 | 33 | 2.0 |
| Santa Ana | 243 | 8.6 | 44 | 6.0 |
| San Agustin | 164 | 5.8 | 30 | 2.5 |

- The construction of small-scale reservoir, which utilizes the streams in the area and its surrounding area, is excluded from water resource facility taking the followings into consideration. The catchment area of these streams is small (4 to 10 $km^2$ on average) and its run-off is limited and moreover, there is no appropriate dam site where the total amount of run-off discharge (estimated to be 300 to 800 thousand cubic meter) can be stored. Since the stream is developed on the fluviatile and/or lacustrine deposits, the great amount of cost will be necessary for the foundation treatment of dam.

- For the development of the projected area, the water supply to the area during the dry season is indispensable and the provision of diversion weir which aims at continuous intake of the surface run-off is taken place as supplementary water source because almost no river run-off during the dry season is occurred in the projected area. Three points of Santa Ana dam site, Gamoneda site and San Agustin are proposed as the sites of diversion weir

The topographical and geological conditions at the sites mentioned above are described in Annex C.

From the above, dam plan will be proposed as water source facilities. The Santa Ana site which is situated at the closest site to the irrigation area, and of which the reservoir capacity is maximum among the proposed sites, is given priority. The other proposed dam sites located at the upstream reach of Santa Ana are added in connection with the required water amount of the plan. Sedimentation volume in the reservoir is accounted over fifty years. Comparing the costs for storage per cubic meter between the sedimentation dam constructed above the upstream reach and the reservoir itself, the sedimentation dam is low construction cost because of the simplified structure. Therefore, the sedimentation dam will be constructed at the upstream of the Santa Ana dam site and the reservoir will store the inflow sediment from the remaining basin.

Since farming is managed only during the rainy season in the plan of Case 9, diversion weir is constructed. Taking the beneficial area and the proposed canal system into account, the diversion weir will planned at the Santa Ana and San Agustin points for the plan of Case 9-1 and only at the santa Ana point for the plan of Case 9-2. The general features of water resources facilities are as follows.

| Case | V (MCM) | Dam Site | Va (MCM) | Vde (MCM) | Vds (MCM) | Vdt (MCM) | H (m) | L (m) |
|---|---|---|---|---|---|---|---|---|
| 1 | 5.34 | Santa Ana | 6.0 | 5.40 | 0.60 | 6.00 | 44.00 | 315 |
| 2 | 4.05 | Santa Ana | 6.0 | 4.10 | 0.60 | 4.70 | 38.71 | 245 |
| 3 | 2.46 | Santa Ana | 6.0 | 2.50 | 0.60 | 3.10 | 34.85 | 187 |
| 4 | 2.25 | Santa Ana | 6.0 | 2.30 | 0.60 | 2.90 | 24.55 | 166 |
| 5 | 2.06 | Santa Ana | 6.0 | 2.10 | 0.60 | 2.70 | 33.60 | 154 |
| 6 | 1.70 | Santa Ana | 6.0 | 1.70 | 0.60 | 2.30 | 32.35 | 146 |
| 7 | 1.54 | Santa Ana | 6.0 | 1.60 | 0.60 | 2.20 | 32.10 | 142 |
| 8 | 0.71 | Santa Ana | 6.0 | 0.80 | 0.60 | 1.40 | 28.65 | 122 |
| 9-1 | - | Santa Ana | - | - | - | - | 8.00 | 36 |
| | | San Agustin | - | - | - | - | 8.00 | 24 |
| 9-2 | - | Santa Ana | - | - | - | - | 15.00 | 60 |

V : required water volume
Va : available storage volume
Vde: designed effective storage volume
Vds: designed sediment volume
Vdt: total reservoir storage volume
H : dam height
L : dam crest length

(2) Sedimentation dam facilities

The following five (5)sites are selected as the construction sites of sedimentation dam. The specific sediment volume from the basin is estimated to be 714 $m^3/km^2$/year (1,000 $ton/km^2$/year) referring to the value in the neighboring river basin. Total storage capacity of sedimentation dams is considered for 50 years.

| No. Site | River basin($km^2$) A | Acc.A | Vin (MCM) | Vd (MCM) | Dam type | H (m) | L (m) |
|---|---|---|---|---|---|---|---|
| Yesera Sur | 64.47 | 227.0 | 2.29 | 3.50 | concrete | 15 | 78 |
| Caldera Chica | 50.30 | 136.7 | 1.79 | 2.18 | concrete | 15 | 83 |
| Caldera Grande | 25.75 | - | 0.91 | 0.84 | masonry | 10 | 75 |
| Yesera Norte | 61.67 | - | 2.19 | 1.25 | concrete | 15 | 46 |
| Rio Mollecancha | 24.73 | - | 0.88 | 0.29 | masonry | 10 | 61 |
| Total | | | 8.06 | 8.06 | | | |

Vin: inflow sedimentation volume, Vd: designed dam capacity

(3) Canal facilities

Canal routes are planned along the existing road taking the location of the irrigation block and the operation and maintenance in the future into consideration. Projected irrigation area with the gravitational system is 1,090 ha as stated and those areas can be divided into 35 irrigation blocks due to topographical features and existing canal systems. The irrigation facilities will be planned on the basis of following points.

- The irrigation canal will consist of the main and secondary canals. The secondary canal will connect with the existing canal systems. In the area of newly reclaimed farmland, a secondary canal up to the top of the most elevated farmland is planned.
- The main canal will have concrete lining. A canal of wet masonry is planned for the secondary canal.
- The canal will be a trapezoidal section, and a road for O/M will be constructed on the valley side. The width of the service road will be 2.0 m for the main canal and 1.5 m for the secondary canal.
- Drainage canal will not be provided, considering the soil and topographic conditions in the area.

Fourteen small-scale reservoirs will be constructed along the canal at the intersections of the canal and the Quebrada and/or the hollow. Purpose of such reservoirs is the restoration of the eroded outline by spreading vegetation around the reservoir, discharge adjustment between main and secondary canals and utilization of supplementary water sources for the farmland around the reservoir. Water from the canal during the rainy season or run-off from the spillway will be stored in the reservoir. Following dimensions will be adopted the proposed reservoirs.

- The water storage capacity will be about 2,000 $m^3$. The reservoir will be constructed at the site where the basin of the stream (Quebrada) is small. When a simple weir will be constructed at a point, it would adequately serve without hindering the safety of the neighborhood and the cost of spillway facilities is low.

- For embankment, the center section of the dam body will be filled with cohesive soil available in the neighborhood, and stone masonry will be used at the upstream and downstream slopes. Embankment will be about the same as the road filling, the width of the dam crest will be 5 m, and the gradient of upstream and downstream will be about 1:2.7.

The general features of the irrigation facilities are as follows. Since the design discharge of the canal is calculated on the basis of crop consumption use of water in January, the canal capacity for Case 1 to 8 and Case 9-2 are same dimensions.

| Case | Principal | | Secondary | | Total | Number of reservoir |
|---|---|---|---|---|---|---|
| | Distance (km) | Discharge ($m^3/s$) | Distance (km) | Discharge ($m^3/s$) | (km) | |
| 1 to 8 & 9-2 | 5.36 | 0.74 - 0.41 | 24.85 | 0.40 - 0.04 | 30.2 | 14 |
| 9-1 | - | - | 12.7 | 0.27 | | |
| | | | 5.0 | 0.10 | 17.7 | 8 |

The general features of the dam and the irrigation facilities for each case are shown in Fig. 4.2.1 and 4.2.2.

### 4.2.4 Project Cost

A preliminary estimate of the project cost for each case is shown in Table 4.2.1. The unit cost of each works has been estimated using the prevalent unit cost of similar project in the neighborhood and the costs investigated in the site. The project cost for each case is as follows:

(Unit:US$ 1,000)

| Case | Irrigation facilities | Rural infra. | Equipment for O/M | Others expenses | Total |
|---|---|---|---|---|---|
| 1 | 14,298 | 785 | 443 | 3,039 | 19,195 |
| 2 | 12,722 | 785 | 443 | 2,798 | 16,748 |
| 3 | 11,904 | 785 | 443 | 2,712 | 15,844 |
| 4 | 11,307 | 785 | 443 | 2,650 | 15,185 |
| 5 | 11,141 | 785 | 443 | 2,630 | 14,999 |
| 6 | 10,810 | 785 | 443 | 2,594 | 14,632 |
| 7 | 10,677 | 785 | 443 | 2,577 | 14,482 |
| 8 | 9,822 | 785 | 443 | 2,485 | 13,535 |
| 9-1 | 3,967 | 785 | 443 | 1,336 | 6,531 |
| 9-2 | 4,811 | 785 | 443 | 1,708 | 7,817 |

### 4.2.5 Agricultural Production Cost and Value

The proposed yield per hectare, production cost and producer's price are indicated as follows, assuming the effect of the increasing yield accompanying the supply of the irrigation water, present farming techniques, the environment of growing the crops and by referring to the data prepared by CODETAR, MACA and Centro Vitivinicola.

| Crop | Yield (ton/ha) | Production Cost (US$/ha) | Producer's Price (US$/kg) | Production Value (US$/ha) | Benefit (US$/ha) |
|---|---|---|---|---|---|
| Corn | 2.5 | 110.0 | 0.17 | 425 | 315 |
| Wheat | 2.0 | 87.0 | 0.19 | 380 | 293 |
| Potatoes | 18.5 | 474.0 | 0.09 | 1,665 | 1,191 |
| Beans | 2.6 | 101.0 | 0.16 | 416 | 315 |
| Tomatoes | 22.0 | 427.0 | 0.09 | 1,980 | 1,553 |
| Onions | 12.0 | 329.0 | 0.11 | 1,320 | 991 |
| Carrot | 12.0 | 281.0 | 0.09 | 1,080 | 799 |
| Garlic | 9.5 | 1,740.0 | 0.43 | 4,085 | 2,345 |
| Alfalfa | 49.0 | 89.0 | 0.022 | 1,000 | 911 |
| Grapes | 16.0 | 994.0 | 0.30 | 4,800 | 3,806 |

Details of production cost and value for each case are shown in Annex E. The summary of production cost and value for each case is as follows:

| Case | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9-1 | 9-2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation Area (ha) | | | | | | | | | | |
| Rainy Season | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 953 | 388 | 817 |
| Perennial crop | 479 | 357 | 357 | 357 | 357 | 357 | 357 | 234 | - | - |
| Annual crop | 611 | 733 | 733 | 733 | 733 | 733 | 733 | 721 | 388 | 817 |
| Dry Season | 1,090 | 845 | 601 | 540 | 469 | 418 | 357 | 234 | - | - |
| Perennial crop | 479 | 357 | 357 | 357 | 357 | 357 | 357 | 234 | - | - |
| Annual crop | 611 | 488 | 244 | 183 | 112 | 61 | - | - | - | - |
| Production cost and Production value (US$1,000) | | | | | | | | | | |
| Without Project | | | | | | | | | | |
| P.C | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 33 | 10 | 10 |
| P.V | 375 | 375 | 375 | 375 | 375 | 375 | 375 | 224 | 72 | 72 |
| With Project | | | | | | | | | | |
| P.C | 822 | 701 | 677 | 671 | 653 | 623 | 606 | 382 | 63 | 132 |
| P.V | 3,681 | 3,095 | 2,995 | 2,969 | 2,903 | 2,759 | 2,693 | 1,794 | 279 | 587 |
| Increased Benefit | 2,541 | 2,076 | 2,000 | 1,980 | 1,932 | 1,818 | 1,769 | 1,221 | 154 | 393 |

## 4. 3 Selection of Development Plan

### 4.3.1 Economical Efficiency of the Project

In selecting the most suitable development plans mentioned above, the economic efficiency of the project is measured on the basis of the financial internal return rate of return and the balance of farm economy. The major benefit of the project will be the increase in profits from agricultural production that the realization of year-round irrigation will make possible. The reduction in the transportation cost of agricultural products and materials used in their production, as a result of improvements in the network of roads in the area, the land reclamation, and the prevention of erosion due to the construction of small-reservoir in the area are some of the qualitatively and quantitatively measurable benefits that can be expected.

(1) Financial internal rate of return

The financial internal rate of return is calculated on the basis of the project cost and increased benefit, the results regarding each plan are as shown below. The increased benefit is estimated on the basis of the agricultural benefit that is expected to show the greatest amount of benefit. The details of the calculations are shown in Annex. E.

| Case | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9-1 | 9-2 |
|---|---|---|---|---|---|---|---|---|---|---|
| FIRR (%) | 9.6 | 9.0 | 9.1 | 9.4 | 9.3 | 9.0 | 8.8 | 6.5 | 0 | 2.4 |

(2) Balance of farm economy

The results of analysis for the balance of farm economy help to show the economic impact which the implementation of project will have on beneficiaries. These results will be an important factor in the evaluation and selection of the different cases under consideration. Balance of farm economy considered in each case are those for small-scale farm

households who constitute the majority in the area. In deciding the economic factors concerning these small-scale farm households, in regard to the project, the amount of repayment for project cost incurred and the operation and maintenance costs were calculated so that they would not exceed the farmer's means. At the same time, projected incomes for the year 2001 were calculated with the idea that they would be at the same level as those of farmers of the agriculturally more advanced areas and urban laborers during the same period (surplus of US$ 700 per year).

When farming is carried out on a stable basis (target year 2001) in each case, and living expenses, O/M costs, and the amount for the repayment of project costs incurred are subtracted from the income of farm households, the balance will be as follows.

(Unit: US$)

| Case | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Production costs | 2,908 | 2,366 | 2,312 | 2,287 | 2,217 |
| Gross farm income | 12,851 | 10,471 | 10,049 | 9,945 | 9,575 |
| Net farm income | 9,943 | 8,105 | 7,737 | 7,658 | 7,458 |
| Living expenses | 2,300 | 2,300 | 2,300 | 2,300 | 2,300 |
| O/M fee | 290 | 290 | 290 | 290 | 290 |
| Repayment amount | 5,780 | 5,042 | 4,761 | 4,583 | 4,505 |
| Sub-total | 8,370 | 7,632 | 7,351 | 7,173 | 7,095 |
| Surplus | 1,573 | 473 | 386 | 485 | 363 |

| Case | 6 | 7 | 8 | 9-1 | 9-2 |
|---|---|---|---|---|---|
| Production costs | 2,093 | 2,023 | 1,121 | 485 | 485 |
| Gross Farm income | 9,087 | 8,817 | 5,383 | 2,155 | 2,155 |
| Net farm income | 6,994 | 6,794 | 4,262 | 1,670 | 1,670 |
| Living expenses | 2,300 | 2,300 | 2,300 | 2,300 | 2,300 |
| O/M fee | 290 | 290 | 291 | 318 | 291 |
| Repayment amount | 4,403 | 4,352 | 4,068 | 4,143 | 2,352 |
| Sub-total | 6,993 | 6,942 | 6,559 | 6,761 | 4.943 |
| Surplus | 1 | -148 | -2,397 | -5,091 | -3,273 |

The living expenses listed above (US$ 2300/year) are based on the estimated increase in the total rate of consumption (yearly rate: 5.2%) in the department of Tarija from the years 1987-2000 with the present level of living expenses (US$ 1200/year) as the standard. The O & M costs, 3% for canal construction costs, was calculated on the basis of the acreage involved. In deciding the amount for the repayment of costs regarding the project, after taking into account the rate of increase in prices in the country, the period of repayment was set at 20 years and the yearly interest rate at 6%.

(3) Comparison of project cost per hectare

The comparison, in each case of project costs per hectare and the financial internal rate of return (FIRR) including the projects planned in the neighboring area would be as follows:

| Project | Total project cost (US$ 1,000) | Acreage involved (ha) | Project cost per ha (US$) | FIRR (%) |
|---|---|---|---|---|
| Case 1 | 19,195 | 1,090 | 17,610 | 9.6 |
| 2 | 16,748 | 1,090 | 15,365 | 9.0 |
| 3 | 15,844 | 1.090 | 14,536 | 9.1 |
| 4 | 15,185 | 1,090 | 13,931 | 9.4 |
| 5 | 14,999 | 1,090 | 13,761 | 9.3 |
| 6 | 14,632 | 1,090 | 13,424 | 9.0 |
| 7 | 14,482 | 1.090 | 13,286 | 8.8 |
| 8 | 13,535 | 953 | 14,203 | 6.5 |
| 9-1 | 6,531 | 388 | 16,832 | 0 |
| 9-2 | 7,817 | 817 | 9,568 | 2.4 |
| San Jacinto project | 62,000 | 3,225 | 19,225 | 12.0 |
| Guadalquivir project | 35,321 | 3,215 | 10.986 | 5.9 |

### 4.3.2 Selection of Development Plans

On the basis of the water resources development in the projected area, formulation of a synthetic development plan has been made through the studies and analyses such fundamental dimensions as the extent of the area to be developed, cropping pattern, agricultural production costs, projected yields, proposed facilities and etc. As the results of these deliberations, Case 4 from among the cases discussed above is selected, for the following reasons.

- From the results of the financial analysis of farm household, it is clear that, for an improvement in their income, more than 1 ha of land would have to be cultivated during the dry season From this, it can be seen that, for the improvement of farming in the area, it will be necessary to introduce intensive farming, which would include the cultivation of dry season crops, particularly perennial crops, as the base. From the viewpoint of the economic standard of the small-scale farmer in the area. also, cases positioned higher than Case 5 would be desirable.

- For the introduction of dry season crops, the construction of reservoirs is essential. The scale of the reservoir (the amount of water necessary) greatly affects the cost of the project per hectare. From among cases that involve the construction of dams, it will be necessary to select one in which the cost per hectare is more than US$ 13,000. When the opportunity costs in Bolivia are considered, cases involving costs per hectare higher than US$ 15,000 would be inappropriate from the viewpoint of the realization of the project, even if the project itself were considered economical. For this

reason, cases positioned lower than Case 3 will need to be considered.

- The financial internal rate of return for the project is highest for Case 4 among cases listed. The case also offers the farmers the highest surplus of their income balance.

Table 4.2.1 Project Cost of Development Plans

UNIT: US$ 1,000

| ITEM | Case A-1 | Case A-2 | Case A-3 | Case A-4 | Case A-5 | Case A-6 | Case A-7 | Case A-8 | Case A9-1 | Case A9-2 | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Irrigation facilities | | | | | | | | | | | |
| Dam | 9,503 | 7,297 | 6,479 | 5,882 | 5,716 | 5,385 | 5,252 | 4,397 | - | - | |
| Head Works | - | - | - | - | - | - | - | - | 2,510 | 2,000 | |
| Sabo Dam | 2,544 | 2,544 | 2,544 | 2,544 | 2,544 | 2,544 | 2,544 | 2,544 | - | - | |
| Canal | 1,758 | 1,758 | 1,758 | 1,758 | 1,758 | 1,758 | 1,758 | 1,758 | 996 | 1,758 | |
| Reservoir | 880 | 880 | 880 | 880 | 880 | 880 | 880 | 880 | 376 | 880 | |
| On-Farm Facilities | 243 | 243 | 243 | 243 | 243 | 243 | 243 | 243 | 85 | 243 | |
| Sub-Total | 14,928 | 12,722 | 11,904 | 11,307 | 11,141 | 10,810 | 10,677 | 9,822 | 3,967 | 4,881 | |
| 2. Rural Infrastructure Improvement | | | | | | | | | | | |
| Agricultural Extension Office | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 | |
| Road | 501 | 501 | 501 | 501 | 501 | 501 | 501 | 501 | 501 | 501 | |
| Electricity | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | |
| Water Supply | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | |
| Health Center | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | |
| Radio System | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | |
| School Facilities | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | |
| Sub-total | 785 | 785 | 785 | 785 | 785 | 785 | 785 | 785 | 785 | 785 | |
| 3. O & M Equipment | | | | | | | | | | | |
| Equipments | 443 | 443 | 443 | 443 | 443 | 443 | 443 | 443 | 443 | 443 | |
| Sub-Total | 443 | 443 | 443 | 443 | 443 | 443 | 443 | 443 | 443 | 443 | |
| 4. Engeering & Administration | | | | | | | | | | | |
| Land Acqui. & Compen. | 42 | 37 | 33 | 31 | 28 | 25 | 22 | 15 | 7 | 10 | |
| Consulting Services | 870 | 855 | 855 | 855 | 855 | 855 | 855 | 855 | 513 | 684 | |
| Administration | 465 | 465 | 465 | 465 | 465 | 465 | 465 | 465 | 279 | 372 | |
| Physical Contingency | 1,662 | 1,441 | 1,359 | 1,299 | 1,282 | 1,249 | 1,235 | 1,150 | 537 | 642 | |
| Sub-Total | 3,039 | 2,798 | 2,712 | 2,650 | 2,630 | 2,594 | 2,577 | 2,485 | 1,336 | 1,708 | |
| Total | 19,195 | 16,748 | 15,844 | 15,185 | 14,999 | 14,632 | 14,482 | 13,535 | 6,531 | 7,817 | |

General Features

| Case | Dam(Headworks) Santa Ana Site | Sabo Dam | Canal | Reservoir | Irrigation Area Rainy | Irrigation Area Dry |
|---|---|---|---|---|---|---|
| 1 | V = 6.00 MCM | places | km | places | ha | ha |
| | H = 44.00 m | 5 | 30 | 14 | 1,090 | 1,089 |
| 2 | V = 4.70 MCM | places | km | places | ha | ha |
| | H = 38.71 m | 5 | 30 | 14 | 1,090 | 845 |
| 3 | V = 3.10 MCM | places | km | places | ha | ha |
| | H = 34.85 m | 5 | 30 | 14 | 1,090 | 601 |
| 4 | V = 2.90 MCM | places | km | places | ha | ha |
| | H = 34.55 m | 5 | 30 | 14 | 1,090 | 540 |
| 5 | V = 2.70 MCM | places | km | places | ha | ha |
| | H = 33.60 m | 5 | 30 | 14 | 1,090 | 469 |
| 6 | V = 2.30 MCM | places | km | places | ha | ha |
| | H = 32.35 m | 5 | 30 | 14 | 1,090 | 418 |
| 7 | V = 2.20 MCM | places | km | places | ha | ha |
| | H = 32.10 m | 5 | 30 | 14 | 1,090 | 357 |
| 8 | V = 1.40 MCM | places | km | places | ha | ha |
| | H = 28.65 m | 5 | 30 | 14 | 953 | 234 |
| 9-2 | Headworks | places | km | places | ha | ha |
| | H = 15 m | - | 30 | 14 | 817 | - |

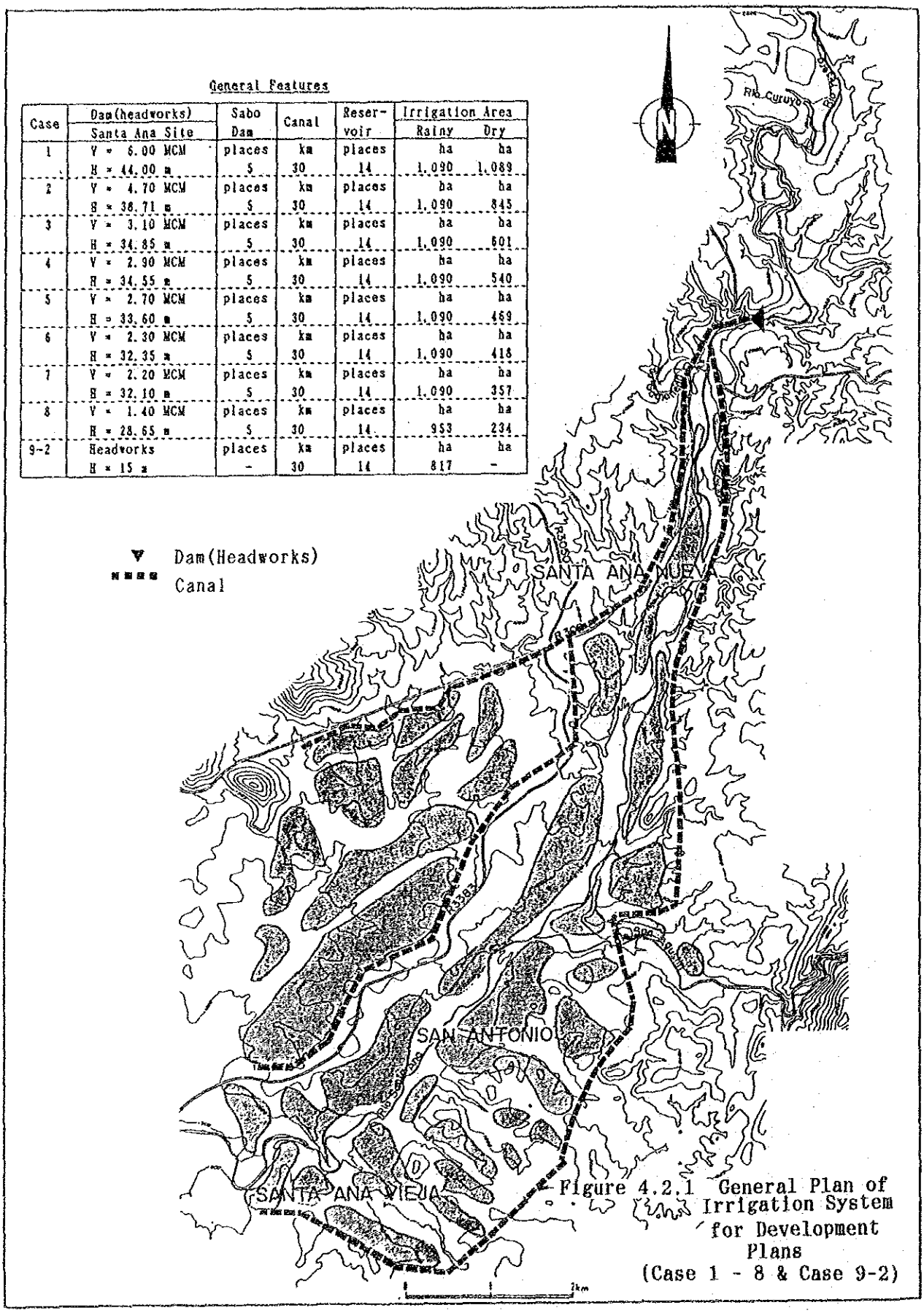



Figure 4.2.1 General Plan of Irrigation System for Development Plans (Case 1 - 8 & Case 9-2)

General Features

| Case | Headworks | | Canal | Pond | Irrigation Area | |
|---|---|---|---|---|---|---|
| | Santa Ana(S) | San Agustin(A) | | | Rainy | Dry |
| 9-1 | | | km | places | ha | ha |
| | H = 8 m | H = 8 m | 17.7 | 8 | 388 | - |

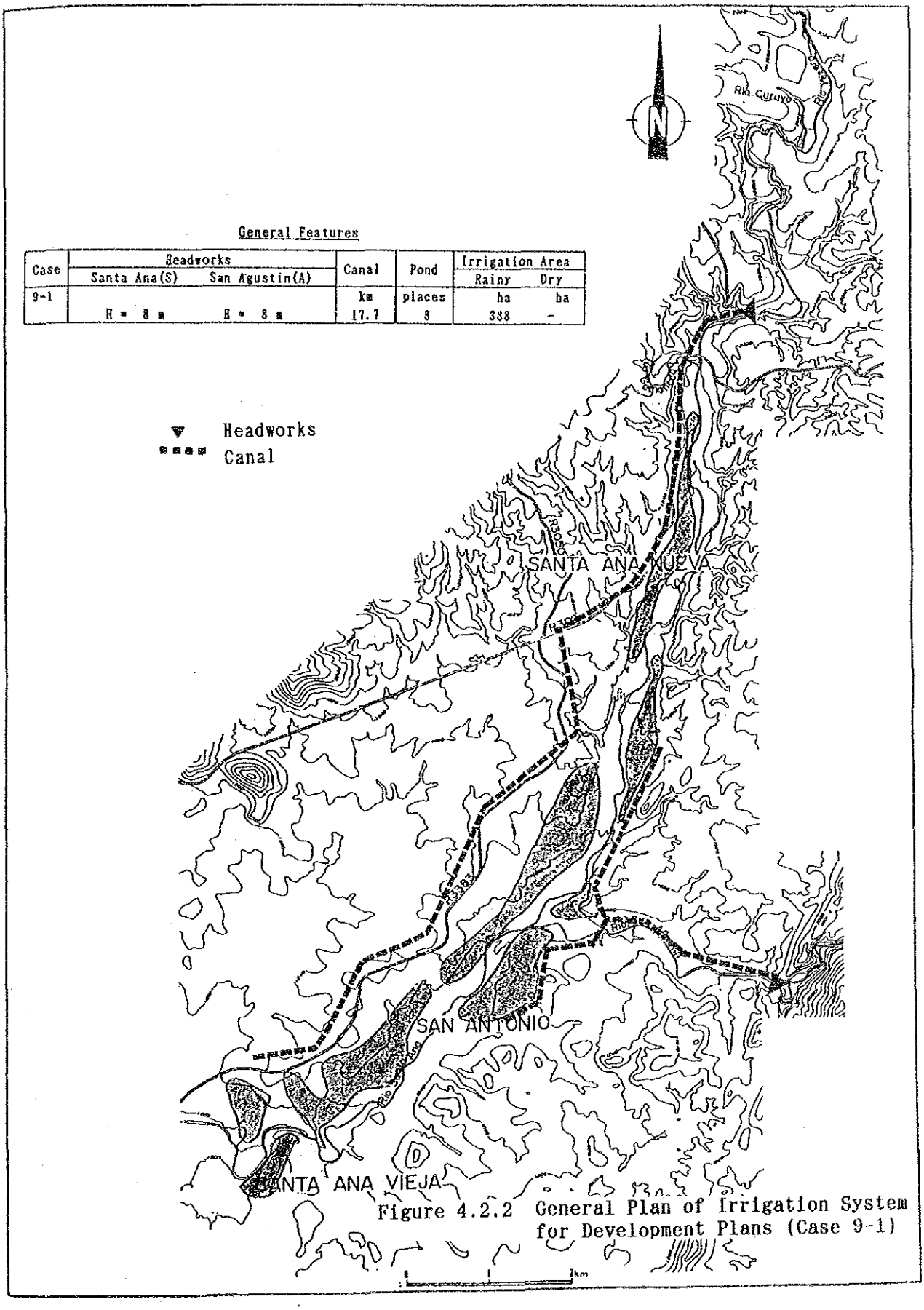



Figure 4.2.2 General Plan of Irrigation System for Development Plans (Case 9-1)

# CHAPTER 5 AGRICULTURAL AND RURAL DEVELOPMENT PLAN

# CHAPTER 5 AGRICULTURAL AND RURAL DEVELOPMENT PLAN

## 5. 1 Objective Area for the Development

### 5.1.1 Land Use Plan

Taking the natural conditions such as topography and soil, and the environmental conditions surrounding the rural area into account, forest and pasture are let alone to preserve the natural environment in the area. The land which is reclaimed as agricultural land by the project, is the land which classified as an arable land out of the waste land based on the results of land classification.

Accordingly, the proposed land use plan is shown as follows based on the present land use, the land classification and the proposed farm management plan.

| Kind of land | Area (ha) |
|---|---|
| Cultivated land | 1,442 |
| Annual crop | (1,065) |
| Perennial crop | (357) |
| Forest | 425 |
| Pasture | 190 |
| Waste land | 5,314 |
| Suitable land for cultivation | (2,040) |
| Unsuitable land for cultivation | (1,926) |
| Erosion area | (1,348) |
| Others | 242 |
| Total | 7,593 |

### 5.1.2 Objective Area for the Development

Administrative boundary of the objective area to be studied is extended over the Santa Ana, Yesera Sur, San Agustin and Portillo districts. These districts are further divided into several communities. Major villages in the area are composed with these communities as a unit.

Out of the study area of 7,593 ha, arable land (present cultivated area and arable land) is estimated 3,460 ha based on the results of present land use and soil surveys. Based on the water source development and canal system plans, projected irrigation area is proposed at 1,090 ha spreading downstream from the proposed Santa Ana dam site. The area consists of 388 ha of annual crop fields, 112 ha of perennial crop fields and 590 ha of arable land. Therefore, the objective area of agricultural development plan includes these 1,090 ha of irrigable area. The number of beneficial farmers distributed in the project area is 152 and they are small-scale farmers with the average cultivable area of less than 4 ha except two large-scale farmers specializing in grape

production.

Besides, other than the projected areas of the existing cultivated areas and cultivable areas, present agricultural productivity and yield of that areas will be improved taking the problems and measures (details are shown in Annex E) on the agricultural management and cultivation derived from the field study into account.

The communities will be taken as a basic unit for the establishment of the rural development plan in the area. With the adjustment of the agricultural development plan and the distribution of villages in the area, three communities, Santa Ana Nueva, San Antonio and Santa Ana Vieja, will be selected as the objective areas for the rural development plan.

## 5. 2 Agricultural Development Plan

The agricultural development plan for the objective areas is studied through the consideration of the proposed development plans in the project formulation. According to the results, farm management scale of 4 ha in the rainy season and 1.75 ha for the dry season from the average cultivable area of 4 ha for each farmer in the project area is proposed as the agricultural development plan in view of the project's economy. General features of the proposed agricultural development plan will be explained in connection with the proposed agricultural management plan.

### 5.2.1 Agricultural Production Plan

(1) Objective farm households and crops to be introduced

In the area, over 90% of the farm households are small-scale farmer with an average of less than 4 ha of land that can be cultivated. Since the present farming pattern of these farmers are almost alike, a similar farm management plan can be established in the study. Therefore, supposing the improvement of the water shortage which is the most impediment factor on the farm management during the dry season, the agricultural production plan will be drawn up for these small-scale farmers. Also, with regard to crops to be introduced, a plan will be drawn up as follows:

Annual crops : corn, wheat, potatoes, beans (arveja, garbanzo, etc.), vegetables (tomatoes, onion, garlic, etc.)
Perennial crop: grapes
Forage crops and livestock
: alfalfa and dairy cattle

These crops have been decided taking account into social and economic conditions, such as cultivation conditions, marketability, the agricultural development plan by CODETAR, crops to be introduced by the agricultural council, and crops increased on the national development plan. The reasons for selection of the crops are as follows:

a. Annual crops
Out of the introduced crops, corn, wheat, potatoes and beans are traditional crops and basic food crops not only in the area but also in Tarija Department. Especially, since the corn is consumed as food and forage crops, corn is the indispensable crop in the area. Vegetable such as tomato, onion, garlic and etc. have marketability next to grapes and, moreover, are of high cash crops. Therefore, those will contribute to farm economy and it is expected that the demand accompanied with the future increase of population in the urban areas will be the greatest. Also, vegetable is able to be cultivated throughout the year in the area and rivalry with other area is avoided by shipping at the pre-harvest month.

b. Grapes
The yield of grape in the area exceeds not only the average yield of Tarija Department but that of the entire country. Grapes are positioned as suitable crops for the area, and the producing district has a settled make-up as a wine brewery area. Furthermore, the demand of grapes not only for processing materials but also edible grapes is increasing mainly in the metropolitan area and major cities. And, the benefit rate per hectare is 70% and the amount of benefit is about US$3,800. Therefore, grape cultivation become a core on farm management

c. Alfalfa
Alfalfa will be introduced for the purpose of producing and selling forage crop for beef cattle and dairy cattle. Comparing with the meat weight of cattle bred on the natural pasture and on the artificial pasture or with forage crops in Tarija department, difference of 100 - 200 kg for beef cattle, 1,000 lit. for dairy cattle come out. Therefore, the cattle breeding with forage crops is encouraged and it is expected that the demand of alfalfa will increase in future.

(2) Cropping pattern

The cropping pattern, which is the basis of the farm management plan, will be formulated taking into account the basic policy of proposed cropping pattern described in Clause 4.2.1 on the premise that the introduction of the dry season farming with the water source development and characteristic of present agricultural management in the projected area.

a. The yearly cropping rate through the supply of irrigation water is improved. The extent of cropping acreage will be that to which farming practice is possible with the present family labor force.
b. It is important that the crops to be introduced are effectively planted in the increased irrigable area. Agricultural extension service and supporting by IBTA and CODETAR are made full use so that the present farming technique can sufficiently meet the proposed cropping plan.
c. The rotation system by combination of crops is to be planned giving consideration to maintaining a high yield. Avoiding injury by continuous cropping, and preventing seasonal peaks of labor demand.

The proposed cropping acreage per farm household is shown as below and the cropping pattern is shown in Fig.5.2.1.

| Crop | Rainy season | Dry season |
|---|---|---|
| | ha | ha |
| Vine | 1.00 | 1.00 |
| Alfalfa | 1.00 | - |
| Wheat | 0.25 | - |
| Corn | 0.25 | - |
| Potatoes | 0.50 | - |
| Beans | 0.25 | - |
| Onions | 0.20 | 0.20 |
| Tomatoes | 0.30 | 0.30 |
| Carrot | - | 0.25 |
| Garlic | 0.25 | - |
| Total | 4.00 ha | 1.75 ha |

One hectare, which is equivalent to 20% of cultivated land, is cropped with gape for the average arable land of 4 ha on the proposed cropping plan. The rotation by combination of grain crops, beans and vegetable is carried out at the rest land. As the results, according to the permanent cropping during the rainy season and partial cropping during the dry season, the annual total of cropping intensity become 145% and it is possible to increase the cropping intensity by 95% in comparison with the present one. Also, the introduction of grapes and the rotation system by combination of vegetable, grain crops and beans are necessary in order to continuously maintain the high benefit for each farm household

Further, regarding utilization of farm land in the plan, the present farm land for planting perennial crops (grapes) will be left in the present condition as farm land for perennial crops. The proposed farming pattern for remaining farm lands will be applied. By the identification of farming pattern in the project area, fixed quantity and quality standardization of the agricultural production will be easily be realized and formation of a production district will also be accelerated.

From the cropping plan mentioned above, cropped area in the projected area is increased as follows.

| | | |
|---|---|---|
| Perennial crop | Present | 112 ha |
| | With project | 357 ha |
| Annual crop | Present | 388 ha |
| (dry season) | With project | 916 ha (183 ha) |

(3) Projected production volume

Total agricultural production volume and its production value after completion of the project is shown below. These values increase about 9 times of the present agricultural production volume for major food, including grapes, and 7 times of the present production value. Absorption of this projected production volume in the market will be possible as described in Annex E according to the prospect of supply and demand for agricultural produce in Tarija Department as stated in the Chapter 3.

| Crops | Present | | | | Project | | | | Increase (Decrease) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | P.Vol | P.Val | (%) | Area | P.Vol | P.Val | (%) | Area | P.Vol | P.Val |
| Corn | 155 | 93 | 15.8 | 4.2 | 61 | 153 | 25.9 | 0.9 | -94 | 60 | 10.2 |
| Wheat | 85 | 51 | 9.6 | 2.6 | 61 | 122 | 23.1 | 0.8 | -24 | 71 | 13.4 |
| Potatoes | 62 | 248 | 22.3 | 6.0 | 121 | 2,238 | 201.4 | 6.8 | 59 | 1,990 | 179.1 |
| Beans | 44 | 22 | 3.5 | 0.9 | 61 | 159 | 25.3 | 0.9 | 17 | 137 | 21.8 |
| Tomato | 9 | 54 | 4.8 | 1.3 | 147 | 3,238 | 291.0 | 9.8 | 138 | 3,180 | 286.2 |
| Onion | 12 | 72 | 7.9 | 2.1 | 98 | 1,176 | 129.3 | 4.4 | 86 | 1,104 | 121.4 |
| Carrot | 1 | 5 | 0.4 | 0.1 | 61 | 732 | 65.8 | 2.1 | 60 | 727 | 65.4 |
| Garlic | 2 | 6 | 2.5 | 0.7 | 61 | 580 | 249.1 | 8.4 | 59 | 574 | 246.6 |
| Alfalfa | 18 | 270 | 5.5 | 1.5 | 245 | 12,005 | 244.9 | 8.2 | 227 | 11,735 | 239.3 |
| Grapes | 112 | 1,008 | 302.4 | 80.6 | 357 | 5,712 | 1,713.6 | 57.7 | 245 | 4,704 | 1,411.2 |
| Total | 500 | 1,892 | 374.7 | 100.0 | 1,273 | 26,111 | 2,969.4 | 100.0 | 773 | 24,282 | 2,594.5 |
| Cropping intensity | 50% | | | | 100% | | | | 70% | | |

Note) Area: (ha), Production volume: ton, Production value: US$1,000

## 5.2.2 Farm Income Improvement Plan

Farm income, which is estimated on the basis of cropping acreage, yield, production cost and production value, is become increase of 7 - 8 times of the present one as shown below and farm economy is greatly improved. Agricultural gross income and net income (farm income - production cost) progress and moreover, it can be expected that a surplus for farm economy ( deducting the living expenses, O&M cost and repayment of the project cost, from the net farm income) will come out.

(Unit: US$)

| Description | Present | With Project |
|---|---|---|
| Gross farm income | 1,200 - 1,500 | 9,945 |
| Production cost | 250 - 400 | 2,288 |
| Net farm income | 950 - 1,100 | 7,657 |
| Living expense | 1,000 - 1,200 | 2,300 |
| Amortization, etc. | - | 4,854 |
| Surplus of farm economy | 0 | 503 |

Comparison between the expected farm income level after completion of the project, the farm income level in the Guadarquivir and the San Jacinto areas and urban laborers' income level in Tarija Department are as follows. As the results, since the surplus of the farm households in the area dose not amount to the surplus of urban laborers, achievement of farm income and surplus as well as the Guadarquivir and San Jacinto areas, which are advanced area in the agricultural sector of the Department, is possible and differential of a social stratum among districts is rectified.

Unit: US$/year

| Area | A | B | C =B-A | D | E | F | G =D+E+F | H =C-G |
|---|---|---|---|---|---|---|---|---|
| Santa Ana | 9,945 | 2,288 | 7,657 | 2,300 | 271 | 4,583 | 7,154 | 503 |
| Guadarquivir | 13,230 | 5,583 | 7,737 | 2,560 | 1,200 | 3,280 | 7,040 | 697 |
| San Jacinto | 12,120 | 4,110 | 8,010 | 2,600 | 1,300 | 3,500 | 7,400 | 610 |

A: Gross farm income, B: Production cost, C: Net farm income
D: Expenses, E: O/M fee, F: Repayment, G: Sub-total H: Surplus

Unit: US$/year

| | Item | Present | 1993 | 1995 | 1997 | 1999 | 2001 | rate of increase |
|---|---|---|---|---|---|---|---|---|
| Urban | Income | 2,800 | 3,040 | 3,076 | 4,000 | 4,310 | 4,612 | 5.4 %/year |
| | Expenses | 2,400 | 2,900 | 3,150 | 3,400 | 3,650 | 3,900 | 5.2 %/year |
| laborer | Surplus | 400 | 504 | 556 | 600 | 660 | 712 | |

### 5.2.3 Improvement Plan for Agricultural Supporting Organization

(1) Agricultural experiments and extension.

For promoting highly productive agriculture in the project area, improvement of the cultivation and farming techniques is essential. For that purpose, it is necessary to carry out the following agricultural experiments and extension of the agricultural techniques, corresponding to the agricultural circumstances in the project area. Furthermore, reinforcement of staff and improvement of necessary equipment of agricultural extension organization is required to develop new cultivation techniques in the projected area derived from the experimental station. An extension service worker and a farm management director will be the principal staff of the organization and a life worker will also join the organization

Subjects for agricultural experiments

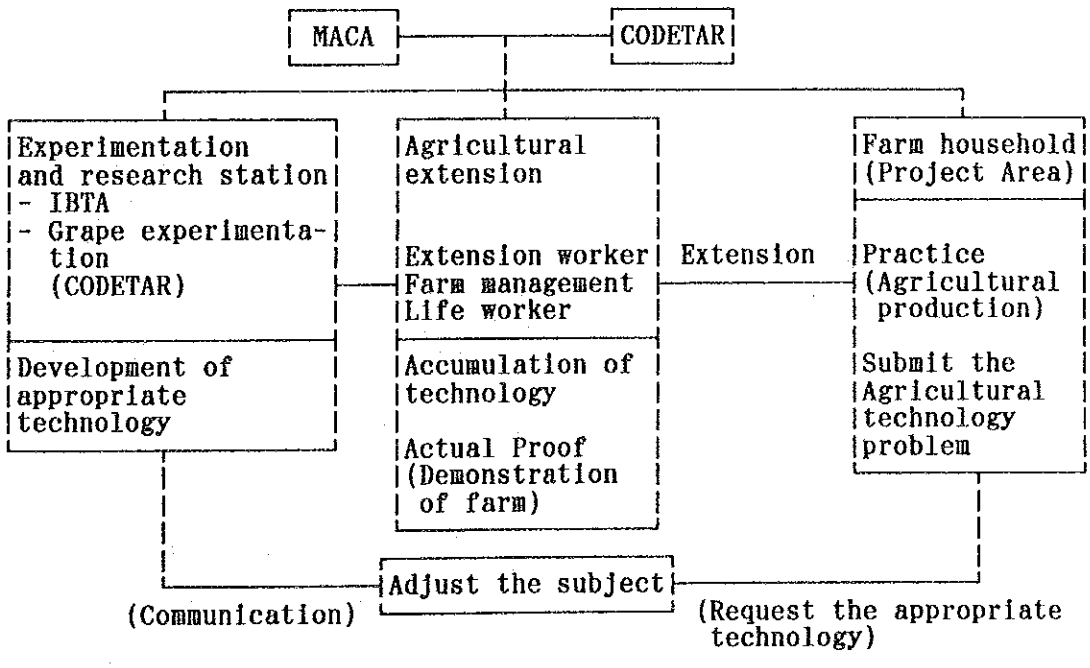
- Selection of good variety and high quality seed.
- Establishment of the planting system method under irrigation.
- Determination of the required water for each crop.
- Proposed manuring practice for each crop.
- Finding the control method for the damages by disease and insects.
- Establishment of the utilization method for the agricultural

machinery.

| Required personnel & equipment | Subjects for extension |
|---|---|
| a. Extension worker : 3 | Extension of cultivation techniques as mentioned above |
| b. Farm management director: 1 | Farm management improvement of marketing aspects |
| c. Life worker : 1 | Improvement of nutrition in the rural area |
| d. Jeep and Tractor each of 2 : | Transportation for the extension worker, and demonstration for the farmers. |
| c. Audio-visual materials : | Education and demonstration for lump sum the execution. |

In and around the project area, agricultural experiment, research and extension activities are performed mainly by the IBTA and the Grape Cultivation and Experimental Station. The IBTA has jurisdiction over the agricultural extension in the area and has the experimental field for the agricultural experiments of the introduced crops (annual crops) proposed on the cropping pattern and the accumulation of the technique and the know-how of cultivation experiment and technical extension is also abundance.

With establishing the co-operation system of the experimental stations proposed below, development of effective cultivation techniques and their distribution are expected due to administrative mutual cooperation of MACA and CODETAR.



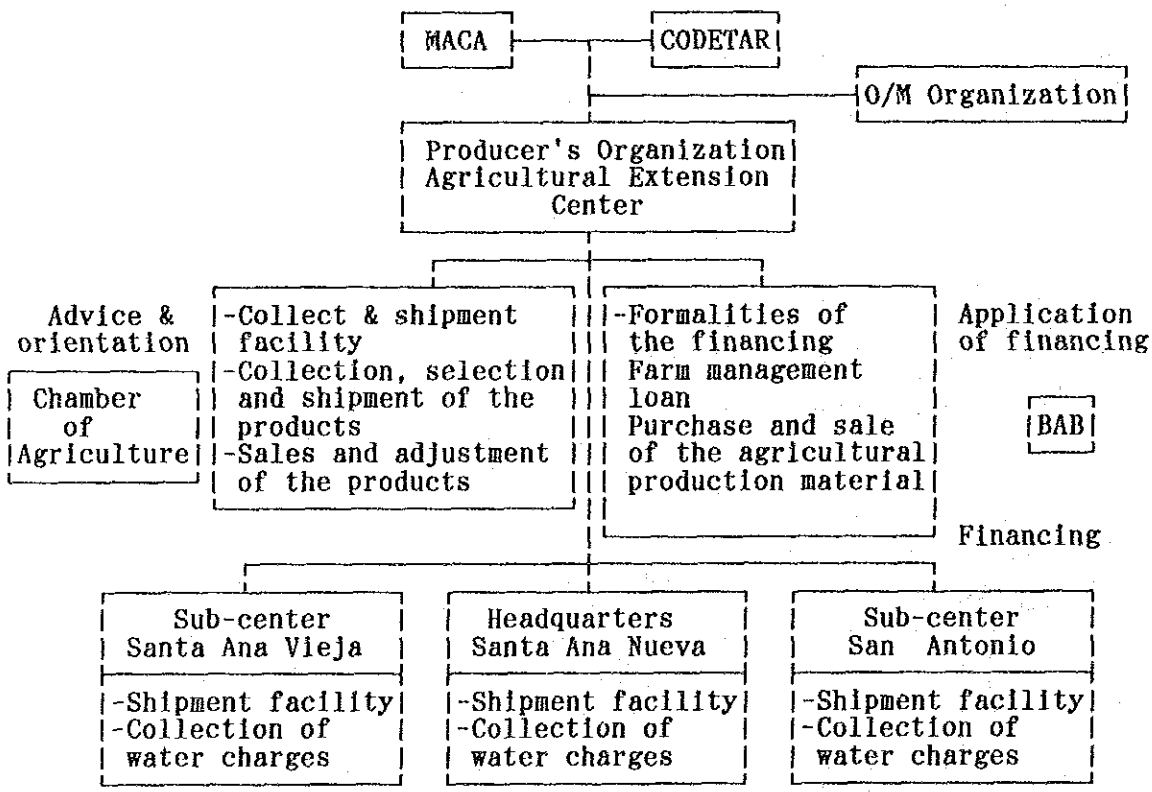
(2) Farmer's organization

In accordance with the project implementation, agricultural production mainly composed of cash crops such as grapes and vegetables will remarkably be increased in each farm. On that account, establishment and promotion of the producer's organization are required to sell the cash crops with favorable conditions and to increase farm income.

The following merits for farm management and agricultural produce can be received through the establishment of the producer's organization.

- reduction of the marketing expenditure (margin) by collective shipment.
- improvement of the quality and standard by selective shipment.
- reduction of the production cost by collective purchase of the agricultural production materials.
- acceleration in the formation of special production localities of the principal agricultural products by preservation and maintenance of a fixed quantity of the products.

From the above-mentioned considerations, the Agricultural Extension Center with the following structures can be proposed on the basis of the existing farmers' organization (Corregidor) which is formed at each community such as Santa Ana Vieja and San Antonio.




Principal function and role of the Agricultural Extension Center

are described below.

a. Agricultural Extension Center should be established at the community together with the shipment facility. The headquarters will be installed at Santa Ana Nueva in order to control each Sub-center.
b. Sub-center will have multi-purpose functions not only agricultural activities but also communal activities in the area. For that point of view, a consultation room for medical patrol, and lecture room for O & M facilities and agricultural extension will be established along with the shipment facilities.
c. Collected agricultural products from each shipment yard will be shipped together after selection and packing at the headquarters of the producers' organization.
d. Water charges will be collected by the producer's organization and paid to the project O & M office via the headquarters.
e. Headquarters will engage in the liquidation of sales of products instead of producers
f. Loan application to the financing organization is carried out by the producers' organization as a unit.

It is necessary for close co-operation with the following authorities for effective operation of the Agricultural Extension Center.

a. Bolivian Agricultural Bank (BAB) in the aspect of the agricultural financing.
b. Agricultural Chamber of Tarija Department in the aspect of the marketing and distribution of the agricultural products.
c. Operation and maintenance (O/M) office for the efficient utilization of irrigation water.
d. Administrative institutions such as MACA and CODETAR.

### 5.2.4 Proposed Measures for the Non-irrigated Area

Because of the topographic conditions in the study area, execution of the irrigation water supply by gravity system over the study area is difficult. Existing cultivated and/or cultivable areas excluded from the objective area of the irrigation water supply plan will be come out though such areas locate within the study area. The objective area is distributed between the proposed canal systems and Santa Ana River, and the area located within the range stated above will partly be excluded because of its elevation and farm plot formation. Excluding areas of existing cultivated and/or cultivable farm land from the irrigation water supply plan are estimated 332 ha and 2,040 ha, respectively. These areas are composed at the top of the river terrace and elevated land though proposed canal routes run near such area.

The following three beneficiary forms will appear in the study area due to the distribution of the farmer's land since the irrigation water supply area will be settled by the physical boundary such as topography, and etc.

a. whole farmer's land belongs to the beneficial area
b. a part of farmer's land belongs to the beneficial area
c. whole farmer's land belongs to the non-beneficial area

In case that whole farmer's land belongs to the beneficial area, stable agricultural management can be performed with the measures mentioned in the proposed agricultural development plan. When the farmer's land belongs to the beneficial area partly and/or none, farming conditions and income level will be improved with the following measures though target improvement level to perform the stable agricultural management proposed in the development plan could not be achieved.

1) When a part of farming plot can get irrigation water, perennial crop (vine) cultivation will take precedence for such areas.

2) Cultivable area which is non-objective area of irrigation water supply should be managed the annual crop cultivation with allowable extent of family labor force. Furthermore, indiscriminate pasturing of domestic animals being carried out in these cultivable areas should be avoided with the rationalistic land use plan of one's own land. Such land use plan will be established taking into account the whole projected area with the advice of agricultural assistance and extension organizations, and aims at soil conservation of the cultivable land in the projected area.

3) Productivity of single cropping is high in the farm land which planned the irrigation water supply. For the area which no irrigation water supply is planned, introduction of intercropping and mixed cropping is proposed to increase the total crop production volume and to dissolve the production risk. Crops shown below are advisable for the inter and/or mixed cropping.

Mixed cropping : maize + pea
(maize also uses as a support of pea)
Inter and mixed cropping: potato + chick pea

For the upland field which is fallow land during the dry season in the prevailing cropping system, application of the cropping pattern for the dry season is possible with the consideration of the cropping periods. Following attentions should be paid:

- Prevailing cropping system during the rainy season should be terminated during the period between August and January.
- As the winter cropping, cropping pattern which utilized the latter half of the rainy season and the first half of the dry season is introduced during February to July. Crops to be introduced are carrot, potatoes, beans and etc. of which growing periods are considerably short.
- For the crops which are stout of its drought resistance such as maize and chick pea, sod seeding and culture are carried out to conserve the soil moisture.

4) To execute the suitable seeding and planting, utilization of animal power mainly draft cattle is proposed for preparation works such as tilling, leveling including removal of gravels and ridging. Efficient preparation works will be useful for the formation of root zone by deep plowing, prevention of surface erosion of field by ridging, and effective use of rainfall adding to increase the production volume due to suitable seeding and planting.

With the proposed plans and measures for agricultural management, following effects can be expected not only for the farmers who live in the projected area and get the project benefits directly but also the farmers who live in the outside of the projected area and could not get the direct benefit of the project.

- Spreading the improvement measures for prevailing cultivation technique with the strengthen of the agricultural experiment and extension organizations.

- Co-operative shipping of the agricultural product using the improved collecting and shipping facilities.

- Betterment of the rural living conditions in connection with the improvement of sanitary, medical and educational facilities.

## 5. 3 Rural Infrastructure Improvement Plan

### 5.3.1 Basic Concept

(1) Potential for Improvement

To formulate the improvement plan of rural infrastructure in the projected area, potential of the area is summarized below to set up the standard of improvement;

a. Accumulation of the primary infrastructures,

b. High intention to improve the rural infrastructure,
c. High levels of human resources on both quantity and quality aspects, respectively. and
d. An ample scope for development.

(2) Constraints for Improvement

The area has high potential for improvement, however, constraints for more advanced improvement in the area, are as follows:

a. Complex land shapes with undulation,
b. Scattered houses in the rural area, and
c. Marked difference between dry and rainy season, and then maldistribution of useful water.

(3) Strategy for Improvement

With the conditions given above, the following strategies for improvement can be set up. Targets based on the long-term views which will be carried out in stages, should be established for improvement of the projected area.

a. Improvement will be proceeded with the sector-wise which is based on the administrative division as a unit,
b. Selection of the core sector and make the target for improvement,
c. Improvement of roads should be made as a main item of the project, then, basic social infrastructure such as drinking water supply, electrification and etc. will be established,
d. Moreover, the upgrading will attempt to make full use of existing facilities, then the improvement of quality aspects where basic infrastructure has been set up.

### 5.3.2 Target of Improvement

Based on the situation of the existing facilities and improvement level of rural area in Cercado province, targets for improvement of the projected area will be set up. The improvement level will be risen gradually with the stage-wise development. The process to complete rural infrastructure improvement are divided into three stages, then, urgent one will designate as the first stage and long-term ones as second and future stage.

With the view mentioned above, improvement of the first stage which is made up of urgent problems will be the target to be realized with the rural development of the project. The target year is scheduled for 10 years (2001 year). As the improvement level of second and future stage, it will be implemented by the habitants in the projected area when

agricultural produce and farmer's organization are well under way.

Thus, the target of improvement for each sector which is based on the administrative division is as follows:

| | Santa Ana Nueva | | | | San Antonio | | Santa Ana |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | I | II | Vieja |
| Main Roads | △ | ■ | ■ | △ | ■ | △ | ■ |
| Farm Roads | ● | ● | ● | ● | ● | ● | ● |
| Water Supply | ◎ | ◎ | ● | ◎ | ◎ | ● | ● |
| Electrification | - | - | ● | - | - | ● | ● |
| Medical Care | - | - | ■ | - | - | ● | ● |
| Education | - | - | ● | - | - | ● | ● |
| Collecting Shipping | - | - | ● | - | - | ● | ● |
| Meeting Hall | - | - | ● | - | - | ● | ● |
| Telecommunication | - | - | ● | - | - | ◎ | ◎ |
| Rural Park | △ | △ | ■ | △ | △ | △ | △ |

●:First Stage ◎:Second Stage △:Future Stage
-:Have no urgent use for ■:Enough

### 5.3.3 Rural Infrastructure Improvement Plan

Based on strategy and target of improvement, rural infrastructure improvement plan in the area is proposed as follows:

(1) Roads

The road is the fundamental facility for both the standard of living of the inhabitants and the productive activities, and thus plays an important role for the area. Especially, improvement of farm roads are directly connected with productive activities and daily life, for this reason, the priority should be given to farm road improvement over the other infrastructures.

The selection of the farm roads to be improved will be decided taking the three major points into account. Factors for assessment are laid out as follows:

1. Relation to the agricultural activities

   a. Accessibility for farm land
   b. Convenience for collection and shipping of agricultural products
   c. Easiness of agricultural activities
   d. Relation to the irrigation water supply

2. Effectiveness of the road network

   a. Number of related farmers (as direct)

b. Number of related farmers (as indirect)
c. Ability to connect to other roads
d. Accessibility to public facilities

3. Feasibility for carrying out

a. Topographical features
b. Extent of improvement in sub-base
c. Necessity of related structures such as bridges
d. Extent of enlargement of road width

As a result of assessment, the urgent improvement items will be set up to establish the farm road networks on the left bank area of Santa Ana river. And these roads will be linked with the trunk road on the right bank area of Santa Ana river.

Road type-III (Categoria de la carretera-III) as to the standard provided by SENAC is used as the criteria for road structure. The effective width of proposed roads is 3.5 m, its design speed is 40 - 80 km/h and its surface has a gravel pavement. Moreover, the cross section, where the road crosses the river, is not a tow level crossing by bridge but a level crossing by ground sill. And the crossing point with the stream uses a culvert. The extent of improvement is as follows:

| Route | Length | Repair | Create | Related Facility | | Relational Zone |
|---|---|---|---|---|---|---|
| | | | | Culvert | Ground still | |
| | (km) | (km) | (km) | (please) | (m) | |
| R-1 | 1.1 | - | 1.1 | 3 | - | Nueva-IV |
| R-2 | 1.5 | 1.5 | - | 4 | 100 | Nueva-III |
| R-3 | 4.5 | - | 4.5 | 6 | 295 | Nueva-IV |
| R-4 | 4.8 | - | 4.8 | 6 | 50 | Nueva-IV Antonio-II |
| R-5 | 1.0 | 1.0 | - | 4 | 350 | Antonio-I |
| R-6 | 3.5 | 3.5 | - | 4 | - | Nueva-II |
| R-7 | 1.5 | 1.5 | - | - | 35 | Antonio-I |
| R-8 | 0.8 | 0.8 | - | 3 | - | Vieja |
| R-9 | 1.5 | 1.5 | - | 3 | 55 | Antonio-II Vieja |
| Total | 20.2 | 9.8 | 10.4 | 33 | 885 | |

(2) Drinking Water Supply

A stable drinking water supply is one of the most important factors for promoting people to settle down in the rural area and to establish agricultural activity. Especially, drinking water supply in the dry season is a important matter of life for households in the area, and it is a waste of labor beyond measure that each household digs a well for drinking water in rivers or streams site. Therefore, it will be of great contribution to not only the improvement of living conditions but also the improvement of agricultural activity that these households will be liberated of this job in the area.

In accordance with the above mentioned aspects, a method of stable drinking water supply must be planned. However, unified water supply system can not be installed because the houses are scattered in the rural area, there are no stable water sources, and there are complex land shapes with undulation. Then, to solve the drinking water problem, some public wells will be proposed to be dug in the bank area of Santa Ana river. One public well has to benefit an area of about 2 km distance, and it will be made for about 20 households. A public well will be equipped with a manual pump system. To summarize, the following improvements would be made.

| Zone | Well number | Remark |
|---|---|---|
| Santa Ana Nueva I | 1 | manual pump |
| Santa Ana Nueva II | 2 | ditto |
| Santa Ana Nueva III | 3 | ditto |
| Santa Ana Nueva IV | 4 | ditto |
| San Antonio I | 1 | manual pump |
| San Antonio II | 2 | ditto |
| Santa Ana Nueva | 2 | ditto |
| Total | 15 sets | |

(3) Electricity

The improvement of rural electric power supply will contribute greatly to the progress of living conditions and modernization of agricultural activity and to promote settling down in rural area. But power supply plan in the area, in scheduled by ENDE, is made at Phase III (after year 2000), and it is far from realization.

On the other hand, electric power for the construction works of the water source development will be required. On the plan, transmission line is provided from the Pan American Highway to the dam site. Therefore, rural power supply would be promoted together with the electric power supply plan of construction works.

The installation of a power transmission line to the center of each administrative district is planned and the cost for installing the service lines to each household will be borne by the individuals.

The extension of power transmission lines will be as follows:

| Line | Length | Voltage | Route | Remark |
|---|---|---|---|---|
| E-1 | 10.0 km | 25 kv | Route 1 Road-Santa Ana Nueva | High voltage for construction |
| E-2 | 9.5 | 220 v | Santa Ana Vieja-San Antonio | General use |
| E-3 | 0.5 | 220 v | Santa Ana Vieja | General use |
| Total | 20.0 km | | | |

(4) Medical Care

Substantial facilities for medical care have great significance not only for daily health control but also for promotion for people to settle down in the area. But, as to the present condition of medical care in the area, a public health center has been established in Santa Ana Nueva, where only a nurse is stationed, and medical supplies for primary stage treatment are insufficient. Moreover, the center has no telecommunication or radio communication facilities, and the center can not get in touch with the hospital in Tarija City for medical and emergency activities.

Full scale medical facilities are not necessary in the area as it is near the suburbs but a public health center such as to take care of daily health control, concentrating on primary stage treatment and check-up, is a major facility, however, it has to be provided with the facility for emergency medical care.

Accordingly, the medical care system in the area is set up as follows and improvement of necessary facilities will be proposed.

The present health center in Santa Ana Nueva will be positioned as the core medical care facility in the area with an improvement of equipment for medical treatment. Sub-health-center is provided at the branch office of the core health center at each administrative district for improvement of medical service in the rural area. In the future stage, a doctor will be requested to stay permanently at the center. But, for the time being, the medical patrol system will be proposed in the area.

To summarize, the following improvements should be made:

| Facility | Village | Improved Facilities |
|---|---|---|
| Main | Santa Ana Nueva | Enrichment of medical facilities<br>The permanency of a doctor<br>Communication system<br>Emergency medical system |
| Sub | Santa Ana Vieja | Establishment of health center ($20m^2$)<br>The permanency of a nurse<br>Communication system |
| Sub | San Antonio | Establishment of health center ($20m^2$)<br>The permanency of a nurse<br>Communication system |

(5) Education

To train the young people who will be the next generation is a important item to promote the regional development. Particularly, the education of the young generation who want to settle down in the area must be given the priority to push forward with the exploitation of the

area. Nevertheless, the junior school is the only one in Santa Ana Nueva, as the present educational situation in the area, and the other two schools have no advanced stage except primary education curriculum. Moreover, these primary schools have a very old building and have few exercise facilities. And the total education environment in these schools is in a poor condition.

Therefore, the following facilities are proposed for re-improvement of education environment in the area:

| Place | Improved Facilities |
|---|---|
| Santa Ana Vieja | Repair of schoolhouse |
| | Enhancement of exercise facilities |
| | Availability of mid-level education |
| San Antonio | Repair of schoolhouse |
| | Enhancement of exercise facilities |
| | Availability of mid-level education |

(6) Agricultural extension center

Agricultural extension center will be installed as the core facility for the regional, agriculture and rural developments and to function and maintain the proposed facilities of the project.

The main body (headquarters) of the agricultural extension center will be installed in Santa Ana Nueva, and the center will also function for the O & M of the proposed facilities, agricultural extension, collection and shipping facility, etc. The sub-center will be set up as the branch office of the main center in San Antonio and Santa Ana Vieja. The sub-center has the functions of collecting and shipping of the agricultural products and as a meeting-hall. Administrative body of the center will be left to the farmers' organization (producer's organization). And the head office of the organization will be set up in the main center.

To summarize, proposed improvement facilities are as follows:

| Facility | Site | Lot | Improved Facilities |
|---|---|---|---|
| Main Center | Santa Ana Nueva | 680 $m^2$ | Agricultural extension office |
| | | | Machine room for maintenance |
| | | | Collection & shipping place |
| | | | Wireless telephone |
| Sub-Center | Santa Ana Vieja | 175 $m^2$ | Collection & shipping place |
| | | | Meeting Room |
| | | | Wireless telephone |
| Sub-Center | San Antonio | 175 $m^2$ | Collection & shipping |
| | | | Meeting Room |
| | | | Wireless telephone |

## 5. 4 Facilities Plan

### 5.4.1 General

The facilities which will be constructed by the project, consist of water source facilities, irrigation facilities, rural infrastructure and agricultural facilities. Those proposed facilities are set up in compliance with the formulated agricultural and rural development plan. In the planning, prevailing technical and improvement levels in Bolivia will be considered to carry out the easy operation and maintenance of proposed facilities of the project. Furthermore, low-cost construction method will be planned to minimize the project costs.

### 5.4.2 Water Source Facility Plan

(1) Dam site and type of dam

1) Location

As the proposed dam site, the Santa Ana site which is selected by CODETAR, the Yesera lower site (2.7 km upper above the Santa Ana site), the Yesera upper site (1.7 km above the Yesera lower site) and the San Agustin site (the upstream of San Agustin river which is the tributary to Santa Ana River) are studied. After comprehensively considering the topographical and geological conditions, the maximum stored capacity and the relationship of location between the dam site and the irrigated area, the santa Ana site is selected as the site of dam construction.

2) Geology

The geology of the dam site consist of alternating strata of Paleozoic sandstone and mudstone, with a little more mudstone, having $5^{o}N$ - $10^{o}E$, $85^{o}$ - $90^{o}S$ strike and dip, respectively. The sandstone is firm and dense, including brownish gray, fine to middle-sized grains of mica, but there are many cracks and joints as well. A fresh bed rock is bluish gray, and will make a good basement rock without joints and cracks. It is 5 - 20 cm thick in general. It is 2 - 3 m thick at places, forming alternating strata with mudstone.

There is 2 - 3 m weathered layer on the mudstone, and it makes small pieces and is weak. On the mudstone forming a river bed, however, there are few joints and cracks. It is bluish white-gray in color and firm. The mudstone is 20 - 30 cm thick or thicker, and 1 - 2 cm thick phyllite is also observable at places.

The strike and dip are almost same on both banks. There is a fault and crash zone from the left side of the dam axis in the upstream to the right side in the downstream, slanting across the river. This

fault has a sector formed 3 - 5 m broad crash zone at the upper part of the right wall, but the fault surface itself is tightly pressed and no fault clay is observable. Masses of rocks located at both banks of the river, having the fault surface as the boundary, show a trace of displacement of approximately 8 - 10 m. There is a small concave on the right bank of the downstream. The main component of this place is mudstone, which is cut off with a fault running south and north. It is heavily disturbed and weathered, especially in the downstream.

Over the bed rock at the left side of the river, diluvial gravel and clay is distributed broadly in a thickness of 30 m in maximum to 5 m in minimum. It is considered to have buried the old river course nearly horizontally, it is inclined approximately $3^{o}$ - $5^{o}$ against the horizontal level from south to east. The gravel layer is extremely compact, and it can serve as the foundation of a small dam without problem in bearing capacity and permeability.

The bed rock, which is composed of alternation of strata with sandstone and mudstone in the Paleozoic period, is exposed at the river bed of the dam site. There are not many cracks and joints, and the fine bed rock ia formed. Over the bed rock at the left side of the river, diluvial gravel and clay is distributed broadly in a thickness of 30 m in maximum to 5 m in minimum but the gravel layer is extremely compact.

The geological profile of the Santa Ana dam axis is shown in Fig. 5.4.1.

2) Type of dam

As the type of the Santa Ana dam, both fill-type dam and concrete gravity-type dam can be considered. The concrete gravity-type dam is proposed with the following reasons:

- Since the dam site is located at a valley, both sides are relatively sharp in inclination, the valley is narrow, and the basement rock for foundation is strong enough. These conditions are suitable for constructing a concrete dam.

- In case of fill type dam, the physical properties of the core material used for the fill-type dam is not sufficient. When volcanic ash soil and clayey soil available near the site are used, the dam section will become large.

- A cofferdam is necessary for constructing any type of dam. The fill-type dam, according to its structural features, will need a larger cofferdam as compared with the concrete dam.

- Seeing that the river basin for the spillway is large at the dam site and that a large flooding discharge is expected, the

fill-type dam will need a larger cost for constructing a spillway as compared with the concrete dam.

- There is an arched concrete dam constructed in San Jacinto project adjoining the study area, and the capability needed for construction of a concrete dam has sufficiently been proven.

- As the results of making a comparison between the construction costs of fill-type dam and of concrete gravity-type dam, the construction cost of concrete gravity-type dam is lower than one of fill-type dam. (refer to Annex G)

(2) Main features of dam and the reservoir

1) Reservoir capacity

As shown in the alternative study of the development plan, storage capacity of the reservoir is small due to its topographic conditions. The total storage capacity at the dam site is decided on the basis of the effective storage volume which is calculated on the irrigation plan, and the dead storage (sedimented volume) which is inflow sediment from the downstream reach of sedimentation dam constructed at the upstream of the Santa Ana dam.

Inundation area and reservoir capacity for each reservoir water level are measured by utilizing the topographical map (with a scale of 1:2,000) which has been prepared by CODETAR. The water level and its storage curve is shown in Fig. 5.4.2. Effective reservoir storage is estimated to be 2.30 (MCM) for irrigation water supply in the irrigation plan.

Considering the specific sediment volume for dam in the Guadarquivir River basin (1,400t/km$^2$/year for the San Jacinto area and 1,000 t/km$^2$/yea for the Guadarquivir area) and the conditions of topography, geology and erosion in the Santa Ana River basin, a value of 1,000 t/km$^2$/year (714 m$^3$/km2/year) is applied as the specific volume in the area. As the results, the inflow sediment from the sub-basin is estimated to be 0.60 (MCM) taking into account of the project life of 50 years.

Therefore, the reservoir capacity of the Santa Ana reservoir is as follows.

| | |
|---|---|
| Effective reservoir capacity | 2.30 (MCM) |
| Dead storage | 0.60 (MCM) |
| Gross reservoir capacity | 2.90 (MCM) |
| Effective water depth | 10.85 (m) |
| Limited water level | EL. 1,962.60 (m) |
| Normal full water level | EL. 1,973.45 (m) |

2) Designed flood discharge and designed flood water level

The designed flood discharge of the Santa Ana dam is employed a 200-year flood, which statistically occurs once in 200 years. Flood discharge is estimated by utilizing the rainfall data at the stations in the Santa Ana River basin and its surrounding areas. Since the catchment area at the dam site is larger than the inundation area of the reservoir (C.A/I.A = 800), storage effects at the reservoir will not expected. Therefore, the designed flood discharge is applied to the design of the spillway. The design flood discharge is estimated on the basis of the annual maximum daily rainfall which has been recorded at the rain gauge stations located in the Santa Ana River basin and it surrounding area.

| | |
|---|---|
| Probable year | T = 200 (years) |
| Designed flood discharge | Q = 676 ($m^3/s$) |

The relationship between the effective crest length of the spillway and the total head above the crest are as follows.

| Effective length (m) | 40 | 60 | 80 | 100 |
|---|---|---|---|---|
| Total head (m) | 4.05 | 3.10 | 2.55 | 2.20 |

Considering the longitudinal section of the dam and the transversal section of the river, the effective length of the spillway crest will be 60 m. The total head above crest and the designed flood water level are as follows.

| | |
|---|---|
| Design Flood Discharge | 676 ($m^3/s$) |
| Total head above crest | 3.10 (m) |
| Designed flood water level | EL. 1,976.55 (m) |

3) Elevation of non-overflow section and dam crest

Elevation of the non-overflow section is the highest level among the normal full water level and designed flood water level, to which has been added freeboard, namely

Hf + hw + he (when hw + he < 2, Hf + 2)
Hh + hw (when hw < 1, Hh + 1)

where,

Hf : Normal full water level (m)
Hh : Designed flood water level (m)
hw : Wind induced wave height from reservoir surface (m)
he : Earthquake induced wave height from reservoir surface by earthquake (m)

The highest level out of them is adopted. From calculated result above, the elevation of the non-overflow section is;

hw + he
= 0.6+0.3 = 0.9 < 2

then,

Hf + 2
= 1973.45 + 2
= 1975.45 (m)

Meanwhile, the height for the designed flood water level

hw = 0.6 < 1

then,

Hh + 1
= 1976.55 + 1
= 1977.55 (m)

Then, the elevation of the non-overflow section is designed with the higher value of the above-mentioned, EL.1977.5 (m) is applied. (refer to Annex G)

(3) Preliminary design of the dam body and foundation

1) Seismic force

According to the earthquake records which have been occurred in Bolivia, the north of Chile and the Argentine during the last 50 years, the frequency and scales of earthquakes in Tarija department and its surrounding area to which the Project area belongs, are exceedingly small. Considering this phenomenon, the San Jacinto and the Guadarquivir projects, which are located near the Santa Ana area employed Kh = 0.1 as the designed seismic coefficient in the design of the dam. Therefore, the same seismic coefficient is applied for the Santa Ana Project.

2) Design conditions of the dam body and foundation

- Stability for overturning

Study of structural analysis for the fundamental triangle section of dam body and foundation shall be carried out for the water levels at the dam site and for load conditions as indicated below.

| Case | Water level in reservoir | Load to be considered |
|---|---|---|
| Case 1 | Design flood water level | W, P, Pe, U |
| Case 2 | Normal full water level | W, P, Pe, U, I, Pd |
| Case 3 | Empty | W, I |

(Note) Each symbol stands for the following loads.
where, W : Dead load of dam body
P : Hydrostatic pressure of storage water
Pe : Sedimentary pressure of sediment

Pd : Dynamic water pressure of storage water by earthquake
I : Inertia force of dam body by earthquake
U : Uplift of storage water

- Stability for shearing

Stability for sliding of the dam body at the joint part among dam body and basement rock and its neighboring part is studied by the Henny's formula.

- Fundamental triangle form

Under the load conditions mentioned above, the stability for the fundamental triangle section of the dam body should be examined. As the results, the upstream and downstream slopes required for the stability of dam body will be 1:0.05 and 1:0.72, respectively. The fundamental triangle section and the details of calculation are described in Annex G.

3) Foundation treatment

The basement rock of the Santa Ana dam is composed of the alternation strata of sandstone and mudstone in the Paleozoic period. By excavating the weathering layer of the basement rock, it can serve as the foundation of the dam without any problem in bearing capacity and permeability. However, in order to increase the bearing capacity and the watertightness of the foundation, consolidation grouting (hole spacing: 3m, injection depth: 7m) is proposed. And in order to reduce foundation seepage to within a tolerable limit, curtain grouting (hole spacing:2 m, row spacing:1.5m, injection depth: 26m) is proposed and also, because of drainage seepage from the foundation reducing the uplift acting on the dam body, a drainage hole (hole spacing:5 m, depth:10 m) is proposed.

Over the bed rock at the left side of the river, diluvial gravel and clay is distributed broadly but the thickness of the gravel layer is thin near the dam axis and extremely compact. Therefore, excavation will be made up to the bed rock in the foundation of dam. With regard to the leakage through the natural ground on the left bank, water depth at the gravel layer is shallow and the layer is extremely compact, therefore, the dam body will be plunged into the natural ground and creep length for leakage will take longer than originally planned.

4) Spillway

Considering the lag time of the gate operation, the installation of a crest gate is not recommended. A straight crest type as an inlet portion of the spillway, an overflow type as a guide portion and an endsill dissipator type as energy dissipator is proposed.

5) Intake facilities

The maximum intake volume calculated in the irrigation plan is 0.74 $m^3/s$. Irrigation water is taken from the intake installed above low water level and is released to the energy dissipator through the outlet pipe installed in the dam body. The water which is released to the energy dissipator is taken into the Main irrigation canal.

6) Inspection gallery

An inspection galley is installed in the dam body for inspection after completion of the dam facilities, and also for access to the valve operation room, to inspect the drainage of seepage water through the joints, dam body and foundation.

From the above, the feature of the Santa Ana reservoir and dam is shown in Table 5.4.1.

## 5.4.3 Sedimentation Dam Facility Plan

The maximum storage capacity of the Santa Ana reservoir is small. Then, the sedimentation dams, which store the most of inflow sediment from the upstream basin, will be constructed at the upstream reach of the Santa Ana dam. The dead storage of the Santa Ana reservoir will decrease with these measures. From the results of field survey in the river basin, five sedimentation dam sites is selected taking the sediment capacity to be stored, conditions of foundation and abutment at the proposed dam site and the construction cost into account.

Topographic conditions of the proposed sedimentation dam sites are steep slope on both banks and flat at the river bed. Geologically, the sandstone and the mudstone which are basement rock in the area are exposed. These basement rocks are firm and dense structure. The foundation treatment of the dam body is not necessary.

The specific volume of inflow sediment is 714 $m^3/km^2/year$ as stated and the measures for the inflow sedimented volume will be considered for 50 years in relation to the project life. The total amount of inflow sediment from the Santa Ana River basin (243 $km^2$) is estimated to be 8.6 (MCM) during 50 years. Total amount of inflow sediment is stored at the sedimentation dams and the Santa Ana dam. The sediment volume at each sedimentation dam is set up as follows on the basis of topographical survey of the reservoir basin. In order to reduce the construction cost of the sedimentation dam, the dam of which the height is lower than 10 m will be constructed with the wet masonry and the dam of which the height is higher than 10 m will be constructed with the concrete. The dimensions of the dam calculated through the stability analysis are as follows and the details are shown in Annex G.

| No. | Location | Catchment area ($km^2$) | Sediment volume (MCM) | Type | Height (m) | Slope up. | Slope dwn. | Crest length (m) |
|---|---|---|---|---|---|---|---|---|
| 1 | Yesera Sur | 64.47 | 3.50 | concrete | 15 | 0.40 | 0.20 | 78 |
| 2 | Cardera Chica | 50.30 | 12.18 | concrete | 15 | 0.40 | 0.20 | 83 |
| 3 | Cardera Grande | 25.75 | 0.84 | masonry | 10 | 0.35 | 0.20 | 75 |
| 4 | Yesera Norte | 61.67 | 1.25 | concrete | 15 | 0.40 | 0.20 | 46 |
| 5 | Rio Molle Cancha | 24.73 | 0.29 | masonry | 10 | 0.35 | 0.20 | 61 |

### 5.4.4 Irrigation Facilities Plan

(1) Irrigation Plan

1) Irrigation Method

Furrow irrigation is prevailing practice among the small-scale farmers who utilize the existing canal system though some farmers specializing in grape production are using drip irrigation. When all the year-round irrigation is available with the carrying-out of the project, it seems that introduction of drip irrigation which has high initial cost would be difficult for the small-scale farmers based on the result of financial analysis of farm household, until expiration of repayment of the project cost. For these reasons, irrigation methods with the project conditions are to be the same methods as present. When surplus of farm economy occurs from the investment of the farming activities (when repayment of the project cost is completed), irrigation methods utilizing certain facilities will be planned.

2) Irrigation efficiency

For estimation of water requirement, various water losses such as transportation from the dam to field, and at field level must be accounted. The following efficiencies are employed to estimate the various water losses in the plan.

| | |
|---|---|
| Application efficiency at field (furrow irrigation) | 70 % |
| Conveyance efficiency ( main & secondary canal) | 90 % |
| Conveyance efficiency ( other small canals ) | 85 % |
| Overall irrigation efficiency | 54 % |

3) Irrigation block

1,090 ha of the objective area for irrigation is divided into 35 irrigation blocks on the basis of the topography and existing canal systems. The irrigation block varies 2 ha in minimum, 73.8 ha in maximum and 30 ha in average.

4) Water requirement

Crop water requirement is estimated with evapo-transpiration (Eto) which is generated by the Penman method multiplied by crop coefficient (Kc) according to the growing stage of each crop. Calculation results of evapo-transpiration for each crop are shown in Table 5.4.2. Crop water requirement and crop coefficient in connection with the proposed cropping pattern of the project are summarized in Table 5.4.3.

Because of the decision of canal capacity, water requirement in January (95.7 =96 mm) which shows maximum water requirement throughout the year is used.

A rotational irrigation method will be carried out in each irrigation block. To decrease the construction cost and to carry out operation and maintenance easily, main and secondary canals and canals in the irrigation blocks will conduct continuously the irrigation water from the dam 24 hours per day.

5) Water balance

In order to decide the effective reservoir volume, the water balance from 1959 to 1988 was studied using the crop water requirement and the run-off discharge data of Santa Ana River. The results are shown in Table 5.4.4 and Fig.5.4.3. And also, the effective reservoir volume is equivalent to the scale that water shortage statistically occurs once in 5 years (5-year probability) for the purpose of reduction of construction cost.

(2) Proposed canal system

1) Canal route

Based on the distribution of the irrigation blocks, three canal routes are proposed. Across Santa Ana river, one is on the left bank and the other is on the right bank. The remaining canal route runs along the provincial road located on the north side of the project area. At the dam site, the main canal will start from the right bank and will run up to the junction point of the secondary canal on the left bank. Irrigation blocks governed by canal systems on the right and left banks are mainly distributed along the river, the canal route is set on the river terrace to keep the water head of canals. For the connection between proposed canals and irrigation blocks, which consist of new developed areas, a division structure will be constructed at the highest position in the block, on the other hand, a connection canal will be constructed from the proposed canal to the upstream reach of the existing canal system of the irrigation blocks, which consist of existing canal systems and divisional operations will be made at the downstream reach of

the connection canal.

Basically, the canal route is arranged along the contour line, however, the crossing method of the Quebrada which is developed in several places in the area, will be concluded with the comparison between the contour line arrangement of the canal and installation of the crossing structures.

2) Irrigation diagram

The irrigation diagram is shown in Fig. 5.4.4 together with the area of each irrigation block.

3) Canal facilities

As far as the canal structure is concerned, concrete linings are proposed for the main canal and masonry linings for the secondary canals. Canal sections will be trapezoidal and a passage for operation and maintains is provided on the valley side. The width of passage is 2.0 m for the main canal and 1.5 m for the secondary canals.

Siphon or aqueduct is planned for the crossing of the Quebrada and/or the roads. Concrete pipe wrapped with cast-in-place reinforced concrete will be used for the siphon structure and a blow-off device will also be installed near the lowest portion of the siphon. The aqueduct will be constructed by in-situ reinforced concrete. Check gates and spillways are installed at the place where the secondary canal is branched off. Division structures consist of the gate installed at the diverted canal and the stop-logs of the main canal.

Summary of the canal length, dimensions and related structures is as follows.

| Canal | Section | Length km | Q $m^3/s$ | B m | M | H m |
|---|---|---|---|---|---|---|
| Main Canal | Dam to junction of LBSC | 0.7 | 0.74 | 0.5 | 1:1 | 0.90 |
| | | 4.7 | 0.46 | 0.5 | 1:1 | 0.75 |
| Left Bank Secondary Canal (LBSC) | Santa Ana Nueva to Santa Ana Vieja | 3.9 | 0.27 | 0.4 | 1:1 | 0.70 |
| | | 3.9 | 0.24 | 0.4 | 1:1 | 0.65 |
| | | 1.5 | 0.18 | 0.4 | 1:1 | 0.60 |
| | | 3.0 | 0.12 | 0.3 | 1:1 | 0.55 |
| | | 1.4 | 0.07 | 0.3 | 1:1 | 0.45 |
| | Sub-total | 13.7 | | | | |
| Right Bank 1 Secondary Canal (RB1SC) | Junction of LBSC to along the provincial road | 2.2 | 0.11 | 0.3 | 1:1 | 0.55 |
| | | 1.6 | 0.07 | 0.3 | 1:1 | 0.45 |
| | Sub-total | 5.3 | | | | |

to be continued

| Canal | Section | Length km | Q $m^3/s$ | B m | M | H m |
|---|---|---|---|---|---|---|
| Right Bank 2 Secondary Canal (RB2SC) | Junction of provincial and county roads to along the county road | 1.5 | 0.30 | 0.5 | 1:1 | 0.70 |
| | | 2.8 | 0.25 | 0.4 | 1:1 | 0.65 |
| | | 3.0 | 0.14 | 0.3 | 1:1 | 0.60 |
| | Sub-total | 7.3 | | | | |
| Connection 1 | No.2 Irrigation block | 0.1 | 0.002 | 0.10 | | |
| 2 | No.4 Irrigation block | 0.5 | 0.024 | 0.20 | | |
| 3 | No.6 Irrigation block | 0.6 | 0.025 | 0.20 | | |
| 4 | No.8 Irrigation block | 0.7 | 0.004 | 0.10 | | |
| 5 | No.7 Irrigation block | 0.6 | 0.040 | 0.20 | | |
| 6 | No.15 Irrigation block | 0.4 | 0.045 | 0.20 | | |
| 7 | No.18 Irrigation block | 0.4 | 0.024 | 0.15 | | |
| | Sub-total | 3.3 | | | | |

Related structures of the irrigation canal are summarized as follows.

| Structures | Main canal | LBSC | RB1SC | RB2SC | Total |
|---|---|---|---|---|---|
| | nos. | nos. | nos. | nos. | nos. |
| Check gate | 4 | 6 | 3 | 5 | 18 |
| Division structure | 4 | 14 | 6 | 11 | 35 |
| Spillway | 4 | 7 | 4 | 5 | 20 |
| Siphon | 5 | 9 | 2 | - | 16 |
| Chute works | 6 | 36 | 8 | 30 | 80 |
| Cross drain | 2 | 8 | 4 | 6 | 20 |

4) Reservoir facilities

The site where the canals cross the creek (Quebrada) and/or around the diversion point of secondary canals, a small-scale reservoir will be planned. Surplus water during the rainy season will be stored through the canals. The purpose of the reservoirs is to prevent erosion, by planting trees around the reservoirs and to providing supplementary water sources to surrounding farm lands. The role of a regulating reservoir will be designed for each reservoir which will be constructed around the diversion point of a secondary canal. The following basic dimensions will facilitate the planning of proposed reservoir facilities.

- The site of the reservoir is the place where the basin of the Quebrada is small and no problem is expected for safety if a simple dam is constructed.

- The dam body is planned to be built with earth filling. For the embankment, the center section of the dam body will be filled with cohesive soil available in the neighborhood, stone materials will be used for the upstream and downstream slopes.

- Specification for the embankment will be about the same as the road filling, the width of the crest will be 5 m and the gradient of up and down stream will be about 1 : 2.7.

- For intake, a concrete covered concrete pipe is prepared at the bottom outlet. A channel type of spillway is employed for the reservoir.

Dimensions and locations of reservoirs are as follows.

| No. | Location | H (m) | L (m) | V ($m^3$) | Remarks |
|---|---|---|---|---|---|
| 1 | Junction point of LBSC | 10 | 40 | 2,300 | |
| 2 | 5.6 km point of LBSC | 8 | 35 | 1,800 | |
| 3 | 7.5 km point of LBSC | 6 | 30 | 2,000 | |
| 4 | 8.8 km point of LBSC | 8 | 40 | 1,500 | |
| 5 | 9.7 km point of LBSC | 6 | 40 | 2,100 | |
| 6 | 12.1 km point of LBSC | 8 | 50 | 1,700 | |
| 7 | 12.7 km point of LBSC | 6 | 45 | 2,100 | |
| 8 | Junction point of RB2SC | 7 | 40 | 1,600 | |
| 9 | 2.5 km point of RB1SC | 7 | 30 | 1,800 | |
| 10 | 5.1 km point of RB1SC | 6 | 35 | 1,500 | |
| 11 | 0.6 km point of RB2SC | 8 | 60 | 2,000 | |
| 12 | 1.3 km point of RB2SC | 6 | 30 | 1,300 | |
| 13 | 3.4 km point of RB2SC | 8 | 60 | 1,700 | |
| 14 | 5.5 km point of RB2SC | 7 | 35 | 1,500 | |

### 5.4.5 Rural Infrastructure

(1) General

The improvement of rural infrastructure will be planned with the stage-wise improvement. The components of the rural development of the project will be taken as high priority items such as roads, rural water supply, rural electricity, medical care, education and agricultural extension facilities. Proposed improvement facilities are as follows.

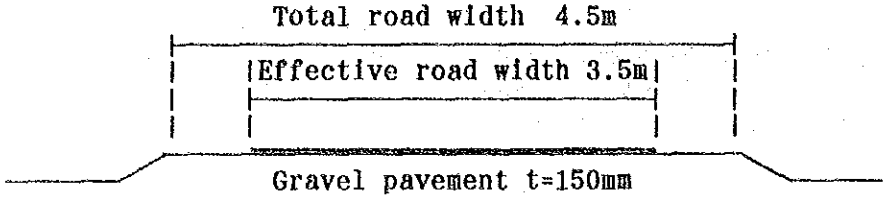
(2) Road

1) Road Structure

The fundamental concepts of road improvement aims to support agricultural activity, therefore, standards provided by SENAC is used as the criteria for road structure. The criteria is as follows:

a. Standard : Road Type III (SENAC)
b. Design Speed : 40 - 80 km/hr.
c. Total Road Width : 4.5 m
d. Effective Road Width : 3.5 m
e. Pavement : Sediment

f. Cross Section : Typical road cross section is as shown below:

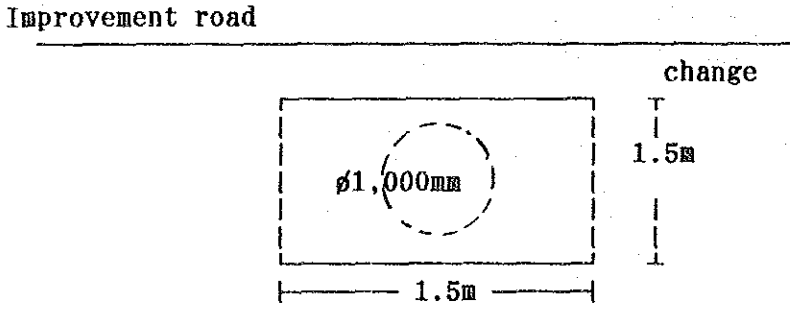



2) Related structures of roads

Related structures of the roads are crossing conduits and ground sills. No bridges are planned at the crossing point of rivers. The details of related structures are as follows:

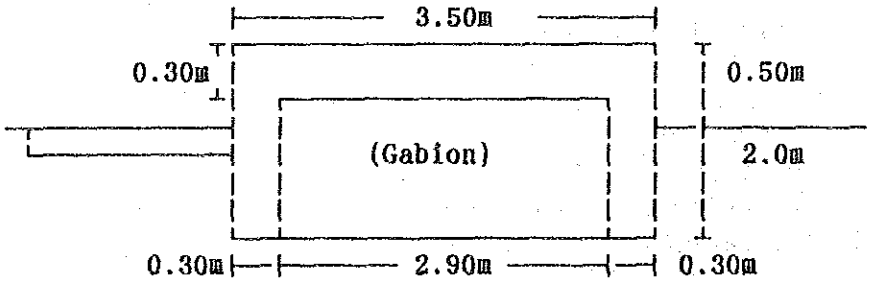
a. Conduit

Conduit will be installed where road meets the small stream. The conduit has a concrete pipe (ø1,000 mm) with rapped in-situ concrete. The typical cross section is as follows:




b. Ground sill

Ground sill will be adapted where the road crosses the river. During the normal water level of the river, ground sill is used for river crossing. Moreover, ground sill will serve for stabilization of river bed and reinforcement of ground water. Basic structure of ground sill is made of gabion and concrete lining, and its downstream will be covered with the gabion mattress.



3) Summary of Road Improvement

The extent of improvement is as follows:

| Route | Total Length (km) | Repair (km) | Treat (km) | Total Width (m) | Effective Width (m) | Pave-ment | Related structures Culvert (place) | Ground sill (m) |
|---|---|---|---|---|---|---|---|---|
| R-1 | 1.1 | - | 1.1 | 4.5 | 3.5 | Gravel | 3 | - |
| R-2 | 1.5 | 1.5 | - | 4.5 | 3.5 | Gravel | 4 | 100 |
| R-3 | 4.5 | - | 4.5 | 4.5 | 3.5 | Gravel | 6 | 295 |
| R-4 | 4.8 | - | 4.8 | 4.5 | 3.5 | Gravel | 6 | 50 |
| R-5 | 1.0 | 1.0 | - | 4.5 | 3.5 | Gravel | 4 | 350 |
| R-6 | 3.5 | 3.5 | - | 4.5 | 3.5 | Gravel | 4 | - |
| R-7 | 1.5 | 1.5 | - | 4.5 | 3.5 | Gravel | - | 35 |
| R-8 | 0.8 | 0.8 | - | 4.5 | 3.5 | Gravel | 3 | - |
| R-9 | 1.5 | 1.5 | - | 4.5 | 3.5 | Gravel | 3 | 55 |
| TOTAL | 20.2 | 9.8 | 10.4 | | | | 33 | 885 |

(3) Rural Water Supply

Rural water supply will be carried out with the public wells. No individual facilities for farm household is planned.

The standard of public well is as follows:

a. Diameter of well : ø1,000 mm, brick masonry and mortar lining
b. Depth of well : H = 10 m
c. Suction pump : Manual pump ø50 mm
d. Suction pipe : ø50 mm L= 8 m
e. Infiltration gallery: ø500mm L= 20m

The location of wells is as follows:

| Place | Public Well | Remark |
|---|---|---|
| Santa Ana Nueva I | 1 set | Manual pump |
| Santa Ana Nueva II | 2 sets | Manual pump |
| Santa Ana Nueva III | 3 sets | Manual pump |
| Santa Ana Nueva IV | 4 sets | Manual pump |
| San Antonio I | 1 set | Manual pump |
| San Antonio II | 2 sets | Manual pump |
| Santa Ana Vieja | 2 sets | Manual pump |
| Total | 15 sets | |

(4) Electricity

The improvement of rural electric power supply is pushed on forward with utilization of temporary power transmission line for the dam construction works. The electricity in rural area lays stress on the establishment of fundamental power line, therefore, the service lines to

each household are borne by the individuals. The improvement of fundamental power lines are as follows:

| Route | Length | Voltage | Transformer | Utility Pole |
|---|---|---|---|---|
| E-1 | 10.0 km | 25 kv | 5 sets | 51 poles |
| E-2 | 9.5 km | 220 v | 2 sets | 8 poles |
| E-3 | 0.5 km | 220 v | 2 sets | 3 poles |
| Total | 20.0 km | | 9 sets | 62 poles |

(5) Medical Care

Present health center in Santa Ana Nueva is utilized as the core of medical care in the area. Besides, sub-health-center is provided at San Antonio and Santa Ana Vieja. These sub-centers are installed in the agricultural extension office.

| Name | Place | Office | Medical Facility | Tele-com. System | Ambulance |
|---|---|---|---|---|---|
| Core | Santa Ana Nueva | exist | 1 set | 1 set | 1 car |
| Sub | San Antonio | 20 $m^2$ | 1 set | 1 set | - |
| Sub | Santa Ana Vieja | 20 $m^2$ | 1 set | 1 set | - |

(6) Education

Old school buildings at Santa Ana Vieja and San Antonio will be repaired and improvement of educational courses for elementary and junior high school will be planned. Improvement item is as follows.

| Place | Elementary Class | Mid-level Class | Practical Room | Staff Room | Pupil per class | Floor Space | Structure |
|---|---|---|---|---|---|---|---|
| Santa Ana Vieja | 2 | 2 | 1 | 1 | 20 | 250 $m^2$ | Brick masonry |
| San Antonio | 2 | 2 | 1 | 1 | 20 | 250 $m^2$ | Brick masonry |

(7) Agricultural extension center

The details of proposed facilities will be explained next section (5.4.6 Improvement of Agricultural Facility). Garage for O & M machine and sub-health-center facilities will be added to the agricultural extension center.

The extents of facilities except items of agricultural extension are as follows:

| Facility | Site | Improved Facilities | Space |
|---|---|---|---|
| Main | Santa Ana Nueva | Machine room for maintenance | 200 $m^2$ |
| Sub | Santa Ana Vieja | Sub-health-center | 20 $m^2$ |
| Sub | San Antonio | Sub-health-center | 20 $m^2$ |

### 5.4.6 Improvement of the Agricultural Facilities

(1) General

An agricultural extension center will be established in the area for dissemination of modern agricultural techniques, agricultural supporting services and systematized collection and shipment of agricultural produce. Headquarters will be constructed at Santa Ana Nueva and branch offices will be set up at Santa Ana Vieja and San Antonio.

(2) Proposed Facility

Proposed facilities are as follows:

| Section | Site | Lot | Facility | Floor space | Structure |
|---|---|---|---|---|---|
| Maine | Santa Ana Nueva | 1,000 m$^2$ | Agricultural Extension Office | 480 m$^2$ | Brick work |
| | | | .Collection & Shipping | 200 m$^2$ | |
| | | | .Storage yard | 50 m$^2$ | |
| | | | .Carrying-in yard | 80 m$^2$ | |
| | | | .Administration room | 30 m$^2$ | |
| | | | .Training room | 100 m$^2$ | |
| | | | .Toilet & Kitchen | 20 m$^2$ | |
| | | | Garage for O & M machine | 200 m$^2$ | Gauge steel |
| Sub | Santa Ana Vieja & San Antonio | 500 m$^2$ | Agricultural Extension Office | 175 m$^2$ | Brick work |
| | | | .Collection & shipping | 80 m$^2$ | |
| | | | .Storage yard | 10 m$^2$ | |
| | | | .Carrying-in yard | 40 m$^2$ | |
| | | | .Administration room | 15 m$^2$ | |
| | | | .Training room | 20 m$^2$ | |
| | | | .Toilet & Kitchen | 10 m$^2$ | |

## 5. 5 Summary of Agricultural and Rural Development Plan

The agricultural and rural development project for the objective area are summarized as follows:

| | | |
|---|---|---|
| Area to be developed: | | 1,090 ha |
| Area to be irrigated: | Rainy season(fruit and vegetable) | 1,090 ha |
| | Dry season (the same as above) | 540 ha |
| Crops to be introduced: | Perennial crop ; Grapes | |
| | Annual crops ; Corn, wheat, potatoes, beans, tomatoes, onions, garlic and carrots | |
| | Forage crop ; Alfalfa | |
| Farming area per household : | Rainy season | 4.00 ha |
| | Dry season | 1.75 ha |

to be continued

| | | | |
|---|---|---|---|
| Improvement of water source facilities: | | | |
| | Concrete gravitation-type dam | | |
| | Height of dam | 34.55 | m |
| | Dam crest length | 166.00 | m |
| | Total storage capacity | 2.3 | MCM |
| | Dead storage capacity | 0.6 | MCM |
| | Sedimentation dam | 5 | Nos. |
| Improvement of canal facilities: | | | |
| | Main canal | 5.4 | km |
| | Secondary canals | 24.8 | km |
| | Reservoirs | 14 | Nos. |
| Road improvement: | 9 route | 20.2 | km |
| Water supply facilities: | Shallow wells | 15 | Nos. |
| Rural electrification: | Transmission line | 20 | km |
| Public health center: | | 3 | Places |
| Education facilities: | Repair of schoolhouse | 2 | Places |
| O & M facilities: | Collection & shipping facilities, | | |
| | Administration office | 3 | Places |
| | Bulldozer 11t | 1 | Unit |
| | Shovel tractor $0.6m^3$ | 1 | Unit |
| | Back hoe $0.3m^3$ | 1 | Unit |
| | Dump truck 4t | 1 | Unit |

Table 5.4.1 Outline of Santa Ana Dam and Reservoir

| Description | Dimension |
|---|---|
| 1. General | |
| Name of the Basin | Santa Ana river basin |
| Name of the River | Yesera river |
| Base Rock | Sand & Mud Stone |
| Watershed Area | 243 ($Km^2$) |
| Annual Mean Rain Fall | 627 (mm) |
| Annual Mean Discharge | 21 (MCM) |
| 2. Reservoir | |
| Area of Water Surface | 46 (ha) |
| Total Capacity | 2.90 (MCM) |
| Effective Capacity | 2.30 (MCM) |
| Dead Water Capacity | 0.60 (MCM) |
| Design Flood Water Level | EL.1,976.55 (m) |
| High Water Level | EL.1,973.45 (m) |
| Low Water Level | EL.1,962.60 (m) |
| Effective Water Depth | 10.85 (m) |
| 3. Dam | |
| Dam Type | Concrete Gravity |
| Height of Dam Crest | 34.55 (m) |
| Length of Dam Crest | 166.00 (m) |
| Width of Dam Crest | 4.00 (m) |
| Elevation of Dam Crest | EL.1,977.55 |
| (Non-over Flow Section) | |
| Dam Volume | 28,700 cu.m |
| 4. Spill Way | |
| Type | Over-flow Type |
| Design Flood Discharge | 676 ($m^3/s$) |
| Over-flow Depth | 3.10 (m) |
| Length of Over-flow Section | 60 (m) |
| Type of the Guide Wall | Ladder Type |
| Type of Energy Dissipater | End-sill Dissipater |
| 5. Intake Facilities | |
| Type | Orifice |
| Design Maximum Intake Water | 0.74 ($m^3/s$) |

## Table 5.4.2 Evapotranspiration by Penman Method

PROJECT : PROJECT SANTA ANA, TARIJA
ALTITUDE : 1,900 (m)
LATITUDE : 21.5 (°) 1 ( if Northern = 0 , Southern = 1)
LONGITUDE: 64.5 (°)

| Item | | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T mean | °C | 21.0 | 20.4 | 20.3 | 18.3 | 15.6 | 13.5 | 13.8 | 15.0 | 16.9 | 19.0 | 20.1 | 20.8 |
| ea | mbar | 24.9 | 24.0 | 23.9 | 21.0 | 17.7 | 15.6 | 15.9 | 17.0 | 19.3 | 22.0 | 23.6 | 24.6 |
| RHmean | % | 69 | 69 | 70 | 67 | 60 | 54 | 50 | 51 | 52 | 55 | 58 | 65 |
| ed | mbar | 17.2 | 16.6 | 16.7 | 14.1 | 10.6 | 8.4 | 7.9 | 8.7 | 10.0 | 12.1 | 13.7 | 16.0 |
| ea-ed | mbar | 7.7 | 7.4 | 7.2 | 6.9 | 7.1 | 7.2 | 7.9 | 8.3 | 9.3 | 9.9 | 9.9 | 8.6 |
| U | Km/day | 89.44 | 87.75 | 89.91 | 84.41 | 41.23 | 42.53 | 53.21 | 63.34 | 72.2 | 69.84 | 61.31 | 45.75 |
| U2 | Km/day | 53.24 | 50.96 | 53.87 | 59.95 | 55.66 | 57.41 | 71.83 | 85.50 | 97.47 | 94.28 | 82.76 | 61.76 |
| f(u) | | 0.41 | 0.41 | 0.42 | 0.43 | 0.42 | 0.43 | 0.46 | 0.50 | 0.53 | 0.52 | 0.49 | 0.44 |
| (1-W) | | 0.27 | 0.28 | 0.28 | 0.30 | 0.33 | 0.36 | 0.35 | 0.34 | 0.32 | 0.29 | 0.28 | 0.27 |
| W | | 0.73 | 0.72 | 0.72 | 0.70 | 0.67 | 0.64 | 0.65 | 0.66 | 0.68 | 0.71 | 0.72 | 0.73 |
| Ra | mm/day | 17.40 | 16.50 | 14.80 | 12.60 | 10.60 | 9.60 | 10.00 | 11.60 | 13.70 | 15.70 | 17.00 | 17.50 |
| n | | 5.60 | 6.10 | 6.00 | 6.30 | 7.70 | 7.40 | 7.90 | 8.00 | 7.50 | 7.40 | 6.60 | 6.00 |
| N | | 13.20 | 12.80 | 12.30 | 11.70 | 11.20 | 10.90 | 11.00 | 11.50 | 12.00 | 12.60 | 13.10 | 13.30 |
| n/N | | 0.42 | 0.48 | 0.49 | 0.54 | 0.69 | 0.68 | 0.72 | 0.70 | 0.63 | 0.59 | 0.50 | 0.45 |
| (0.25+0.5 n/N) | | 0.46 | 0.49 | 0.49 | 0.52 | 0.59 | 0.59 | 0.61 | 0.60 | 0.56 | 0.54 | 0.50 | 0.48 |
| Rs | mm/day | 8.04 | 8.06 | 7.31 | 6.54 | 6.29 | 5.66 | 6.09 | 6.93 | 7.71 | 8.54 | 8.53 | 8.32 |
| Rns | | 6.03 | 6.04 | 5.48 | 4.91 | 4.72 | 4.24 | 4.57 | 5.20 | 5.78 | 6.40 | 6.40 | 6.24 |
| f(T) | | 14.8 | 14.7 | 14.7 | 14.3 | 13.7 | 13.4 | 13.5 | 13.7 | 14.0 | 14.4 | 14.6 | 14.8 |
| f(ed) | | 0.16 | 0.16 | 0.16 | 0.17 | 0.20 | 0.21 | 0.22 | 0.21 | 0.20 | 0.19 | 0.18 | 0.16 |
| f(n/N) | | 0.48 | 0.53 | 0.54 | 0.58 | 0.72 | 0.71 | 0.75 | 0.73 | 0.66 | 0.63 | 0.55 | 0.51 |
| Rnl | | 1.12 | 1.25 | 1.27 | 1.46 | 1.94 | 2.02 | 2.17 | 2.09 | 1.86 | 1.69 | 1.44 | 1.23 |
| Rn | | 4.91 | 4.79 | 4.22 | 3.45 | 2.78 | 2.22 | 2.40 | 3.12 | 3.92 | 4.71 | 4.96 | 5.02 |
| RHmax (est.) | % | 75.9 | 75.9 | 77.0 | 73.7 | 66.0 | 59.4 | 55.0 | 56.1 | 57.2 | 60.5 | 63.8 | 71.5 |
| Uday (est.) | m/sec | 1.0 | 0.9 | 1.0 | 1.1 | 0.9 | 1.0 | 1.3 | 1.5 | 1.8 | 1.8 | 1.5 | 1.1 |
| Unight (est.) | m/sec | 0.3 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.5 | 0.4 | 0.4 | 0.4 | 0.3 |
| Uday/Unight (est.) | | 3.7 | 4.0 | 3.5 | 3.2 | 2.5 | 2.7 | 4.0 | 3.1 | 4.3 | 4.4 | 3.3 | 3.1 |
| c | | 1.02 | 1.01 | 1.02 | 1.04 | 0.97 | 0.96 | 1.00 | 0.99 | 1.03 | 1.05 | 1.02 | 1.01 |
| ETo | mm/day | 4.53 | 4.35 | 3.95 | 3.45 | 2.76 | 2.41 | 2.85 | 3.44 | 4.37 | 5.09 | 5.04 | 4.72 |
| ETo | mm/month | 140 | 122 | 122 | 103 | 86 | 72 | 88 | 107 | 131 | 158 | 151 | 146 |

Table 5.4.3 Crop Water Requirement

(Unit : mm)

| | Month | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ETo | 158.0 | 151.0 | 146.0 | 140.0 | 122.0 | 122.0 | 103.0 | 86.0 | 72.0 | 88.0 | 107.0 | 131.0 | 1426.0 |
| Crop Coeff. (kc) | GRAPE | 0.60 | 0.70 | 0.70 | 0.65 | 0.55 | 0.45 | 0.35 | | | | 0.25 | 0.45 | |
| | ALFALFA | 0.42 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.42 | | | | | | |
| | WHEAT | | 0.24 | 0.64 | 0.85 | 0.99 | 0.65 | 0.13 | | | | | | |
| | BEANS(1) | | 0.24 | 0.64 | 0.92 | 1.00 | 0.48 | | | | | | | |
| | MIZE | | 0.24 | 0.64 | 0.85 | 0.99 | 0.80 | 0.28 | | | | | | |
| | POTATO | | | | 0.25 | 0.63 | 0.91 | 0.88 | 0.35 | | | | | |
| | ONION | | 0.24 | 0.61 | 0.84 | 0.95 | 0.48 | | 0.30 | 0.69 | 0.87 | 0.95 | 0.48 | |
| | TOMATO | 0.83 | 0.30 | | | 0.26 | 0.78 | 0.83 | 0.30 | | | 0.26 | 0.78 | |
| | GARLIC | | 0.24 | 0.61 | 0.84 | 0.95 | 0.48 | | | | | | | |
| | CARROT | | | | | | | | 0.31 | 0.72 | 0.91 | 0.85 | 0.35 | |
| | BEANS(2) | | | | | | | | 0.31 | 0.73 | 0.95 | 1.00 | 0.48 | |
| Area Factor | GRAPE | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | | | | 0.250 | 0.250 | |
| | ALFALFA | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | | | | | | |
| | WHEAT | | 0.063 | 0.063 | 0.063 | 0.063 | 0.063 | 0.063 | | | | | | |
| | BEANS(1) | | 0.063 | 0.063 | 0.063 | 0.063 | 0.063 | | | | | | | |
| | MIZE | | 0.063 | 0.063 | 0.063 | 0.063 | 0.063 | 0.063 | | | | | | |
| | POTATO | | | | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 | | | | | |
| | ONION | | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | |
| | TOMATO | 0.075 | 0.075 | | | 0.075 | 0.075 | 0.075 | 0.075 | | | 0.075 | 0.075 | |
| | GARLIC | | 0.063 | 0.063 | 0.063 | 0.063 | 0.063 | | | | | | | |
| | CARROT | | | | | | | | 0.063 | 0.063 | 0.063 | 0.063 | 0.063 | |
| | BEANS(2) | | | | | | | | | | | | | |
| | TOTAL | 0.575 | 0.875 | 0.800 | 0.925 | 1.000 | 1.000 | 0.825 | 0.313 | 0.113 | 0.113 | 0.438 | 0.438 | |
| EVAPO-TRANSPI-RATION | GRAPE | 23.7 | 26.4 | 25.6 | 22.8 | 16.8 | 13.7 | 9.0 | | | | 6.7 | 14.7 | 159.4 |
| | ALFALFA | 16.6 | 32.1 | 31.0 | 29.8 | 25.9 | 25.9 | 10.8 | | | | | | 172.1 |
| | WHEAT | | 2.3 | 5.8 | 7.4 | 7.5 | 5.0 | 0.8 | | | | | | 28.9 |
| | BEANS(1) | | 2.3 | 5.8 | 8.1 | 7.6 | 3.7 | | | | | | | 27.4 |
| | MIZE | | 2.3 | 5.8 | 7.4 | 7.5 | 6.1 | 1.8 | | | | | | 31.0 |
| | POTATO | | | | 4.4 | 9.6 | 13.9 | 11.3 | 3.8 | | | | | 43.0 |
| | ONION | | 1.8 | 4.5 | 5.9 | 5.8 | 2.9 | | 1.3 | 2.5 | 3.8 | 5.1 | 3.1 | 36.7 |
| | TOMATO | 9.8 | 3.4 | | | 2.4 | 7.1 | 6.4 | 1.9 | | | 2.1 | 7.7 | 40.8 |
| | GARLIC | | 2.3 | 5.6 | 7.4 | 7.2 | 3.7 | | | | | | | 26.1 |
| | CARROT | | | | | | | | 1.7 | 3.2 | 5.0 | 5.7 | 2.9 | 18.5 |
| | BEANS(2) | | | | | | | | | | | | | |
| | TOTAL | 50.1 | 72.8 | 84.1 | 93.0 | 90.4 | 82.0 | 40.2 | 8.7 | 5.7 | 8.8 | 19.5 | 28.4 | 583.8 |

# Table 5.4.4 Water Balance

| | | |
|---|---|---|
| Irri. Area (Comb.) | 112 | (ha) |
| Irri. Area (Mono.) | 978 | (ha) |
| Irri. Area (Total) | 1,090 | (ha) |
| Irri. Effe. | 54 | (%) |
| Storage Capa. | 2.9 | (MCM) |

| Year | Item | Unit | JAN. | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1959 | Balance | (MCM) | 0.906 | 2.584 | 0.676 | 0.831 | 0.258 | 0.096 | -0.133 | -0.382 | -0.525 | -0.486 | -0.471 | 3.112 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.743 | 2.335 | 1.782 | 1.268 | 0.776 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1960 | Balance | (MCM) | 5.487 | 5.431 | 3.820 | 1.019 | 0.552 | 0.021 | -0.133 | -0.382 | -0.465 | -0.555 | -0.563 | 2.308 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.743 | 2.335 | 1.841 | 1.258 | 0.674 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1961 | Balance | (MCM) | 1.775 | 5.460 | 4.008 | 4.472 | 1.002 | 0.366 | -0.122 | -0.382 | -0.530 | 0.158 | -0.794 | 0.795 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.754 | 2.346 | 1.787 | 1.918 | 1.099 | 1.874 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1962 | Balance | (MCM) | 0.469 | 2.540 | 1.294 | 1.173 | 0.410 | 0.153 | -0.080 | -0.379 | -0.608 | -0.683 | -0.350 | 0.920 | |
| | Storage | (MCM) | 2.319 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.796 | 2.389 | 1.753 | 1.042 | 0.673 | 1.580 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1963 | Balance | (MCM) | 3.355 | 3.992 | 3.651 | 3.126 | 1.058 | 0.581 | -0.082 | -0.361 | -0.611 | -0.981 | -1.160 | 0.619 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.794 | 2.407 | 1.767 | 0.839 | 0.600 | 1.209 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.935 | 0.000 | 0.935 |
| 1964 | Balance | (MCM) | 3.051 | 3.568 | 2.301 | 0.176 | 0.269 | -0.067 | -0.127 | -0.382 | -0.510 | -0.381 | -0.078 | -0.249 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.814 | 2.663 | 2.255 | 1.717 | 1.309 | 1.210 | 0.948 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1965 | Balance | (MCM) | 2.459 | 2.806 | 2.507 | 0.553 | 0.397 | 0.063 | -0.133 | -0.382 | -0.611 | -0.841 | -1.238 | 0.182 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.743 | 2.335 | 1.696 | 0.827 | 0.600 | 0.772 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.016 | 0.000 | 1.016 |
| 1966 | Balance | (MCM) | 2.454 | 1.599 | 2.884 | 0.181 | 0.656 | 0.065 | -0.063 | -0.382 | -0.611 | -0.856 | -0.566 | 3.436 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.813 | 2.404 | 1.764 | 0.881 | 0.600 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.304 | 0.000 | 0.304 |
| 1967 | Balance | (MCM) | 2.718 | 3.026 | 0.118 | 0.419 | 0.357 | 0.060 | -0.133 | -0.331 | -0.195 | -0.130 | 0.225 | 4.419 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.743 | 2.386 | 2.162 | 2.002 | 2.203 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1968 | Balance | (MCM) | 5.226 | 6.779 | 2.764 | 1.390 | 0.402 | 0.091 | -0.082 | 0.144 | -0.306 | -0.631 | 0.317 | -0.446 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.794 | 2.900 | 2.562 | 1.898 | 2.189 | 1.717 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1969 | Balance | (MCM) | -0.179 | 2.460 | 1.193 | 1.291 | 0.051 | -0.085 | -0.133 | -0.382 | -0.611 | -0.739 | 0.598 | 2.704 | |
| | Storage | (MCM) | 1.515 | 2.900 | 2.900 | 2.900 | 2.900 | 2.876 | 2.720 | 2.312 | 1.673 | 0.907 | 1.487 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1970 | Balance | (MCM) | 4.720 | 3.268 | 4.844 | 2.727 | 1.558 | 0.195 | -0.125 | -0.382 | -0.083 | -0.378 | -1.051 | 0.642 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.752 | 2.343 | 2.232 | 1.823 | 0.747 | 1.377 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1971 | Balance | (MCM) | 2.477 | 5.574 | 3.705 | 1.784 | 0.271 | 0.019 | -0.133 | -0.319 | -0.606 | -0.568 | 0.293 | 1.169 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.743 | 2.398 | 1.763 | 1.167 | 1.440 | 2.586 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1972 | Balance | (MCM) | 2.010 | 2.406 | 2.165 | 0.921 | 0.561 | 0.257 | 0.828 | -0.190 | -0.491 | -0.704 | -0.447 | 0.407 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.682 | 2.160 | 1.426 | 0.957 | 1.345 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1973 | Balance | (MCM) | 2.536 | 2.241 | 4.136 | 1.852 | 1.478 | 0.244 | 0.028 | -0.305 | -0.600 | -0.744 | -1.097 | -0.238 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.567 | 1.936 | 1.165 | 0.600 | 0.589 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.554 | 0.238 | 0.791 |
| 1974 | Balance | (MCM) | 0.348 | 2.993 | 2.995 | 3.118 | 0.828 | 0.361 | -0.133 | -0.382 | -0.611 | -0.657 | -1.052 | 1.638 | |
| | Storage | (MCM) | 0.927 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.743 | 2.335 | 1.696 | 1.011 | 0.600 | 2.227 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.661 | 0.000 | 0.661 |
| 1975 | Balance | (MCM) | 4.528 | 5.197 | 2.423 | 0.403 | 0.113 | 0.029 | -0.133 | -0.382 | -0.201 | -0.671 | -0.010 | 1.744 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.743 | 2.335 | 2.105 | 1.405 | 1.372 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1976 | Balance | (MCM) | 3.773 | 2.552 | 2.640 | 0.280 | 0.566 | -0.072 | -0.127 | -0.293 | -0.452 | -0.951 | -0.160 | 0.293 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.889 | 2.658 | 2.339 | 1.858 | 0.878 | 0.704 | 0.984 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1977 | Balance | (MCM) | 2.825 | -0.547 | 2.615 | 0.923 | 0.771 | 0.493 | -0.031 | -0.343 | -0.373 | -0.426 | -0.843 | 1.089 | |
| | Storage | (MCM) | 2.900 | 2.325 | 2.900 | 2.900 | 2.900 | 2.900 | 2.845 | 2.475 | 2.073 | 1.617 | 0.751 | 1.828 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1978 | Balance | (MCM) | 1.125 | 12.891 | 0.110 | 1.172 | 0.488 | 0.594 | 0.044 | -0.409 | -0.575 | -0.683 | -0.423 | 2.978 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.464 | 1.860 | 1.148 | 0.704 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1979 | Balance | (MCM) | 8.223 | 2.193 | 4.512 | -0.178 | 0.258 | 0.277 | 0.090 | -0.358 | -0.632 | 0.198 | -0.641 | 3.992 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.697 | 2.900 | 2.900 | 2.900 | 2.515 | 1.853 | 2.023 | 1.357 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1980 | Balance | (MCM) | 5.058 | 2.714 | 2.224 | 1.796 | 0.776 | -0.023 | -0.125 | -0.395 | -0.543 | -0.240 | -1.271 | -0.983 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.856 | 2.710 | 2.288 | 1.717 | 1.458 | 0.600 | 0.589 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.444 | 0.983 | 1.428 |
| 1981 | Balance | (MCM) | 7.505 | 8.402 | 0.798 | 0.791 | 0.067 | 0.011 | -0.095 | -0.328 | -0.634 | -0.833 | 0.158 | -0.081 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.892 | 2.773 | 2.418 | 1.755 | 0.895 | 1.034 | 0.934 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1982 | Balance | (MCM) | 2.196 | 8.317 | 4.311 | 0.935 | 0.134 | -0.023 | -0.133 | -0.409 | -0.035 | -0.404 | -0.875 | 1.367 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.858 | 2.702 | 2.267 | 2.204 | 1.769 | 0.869 | 2.222 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1983 | Balance | (MCM) | 0.002 | -0.138 | -1.578 | -0.767 | -0.158 | -0.103 | -0.159 | -0.409 | -0.637 | -0.987 | -0.116 | -0.563 | |
| | Storage | (MCM) | 2.198 | 2.036 | 0.608 | 0.592 | 0.584 | 0.577 | 0.569 | 0.560 | 0.549 | 0.537 | 0.526 | 0.516 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.166 | 0.767 | 0.158 | 0.103 | 0.159 | 0.409 | 0.637 | 0.907 | 0.116 | 0.563 | 3.984 |
| 1984 | Balance | (MCM) | 9.503 | 8.722 | 7.484 | 1.654 | 0.700 | 0.063 | -0.159 | 0.171 | -0.637 | -0.260 | -0.666 | 0.253 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.717 | 2.862 | 2.193 | 1.902 | 1.211 | 1.444 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1985 | Balance | (MCM) | 2.797 | 8.832 | 1.164 | 1.369 | -0.024 | 0.153 | -0.098 | -0.207 | -0.452 | -0.528 | 0.041 | 2.299 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.854 | 2.900 | 2.778 | 2.545 | 2.063 | 1.586 | 1.524 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1986 | Balance | (MCM) | 1.481 | 9.679 | 4.533 | 1.707 | -0.144 | 0.091 | -0.042 | -0.409 | -0.514 | -0.823 | 0.357 | 5.455 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.733 | 2.807 | 2.742 | 2.306 | 1.764 | 0.913 | 1.252 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1987 | Balance | (MCM) | 7.675 | 2.449 | -0.151 | 0.110 | 0.047 | -0.062 | -0.151 | -0.409 | -0.637 | -0.720 | 1.273 | 3.972 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.719 | 2.805 | 2.830 | 2.750 | 2.575 | 2.141 | 1.477 | 0.731 | 1.992 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1988 | Balance | (MCM) | 7.850 | 7.748 | 9.463 | 3.990 | 0.490 | 0.238 | 0.088 | -0.299 | -0.540 | -0.912 | 0.214 | 3.867 | |
| | Storage | (MCM) | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.900 | 2.573 | 2.003 | 1.062 | 1.256 | 2.900 | |
| | Shortage | (MCM) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

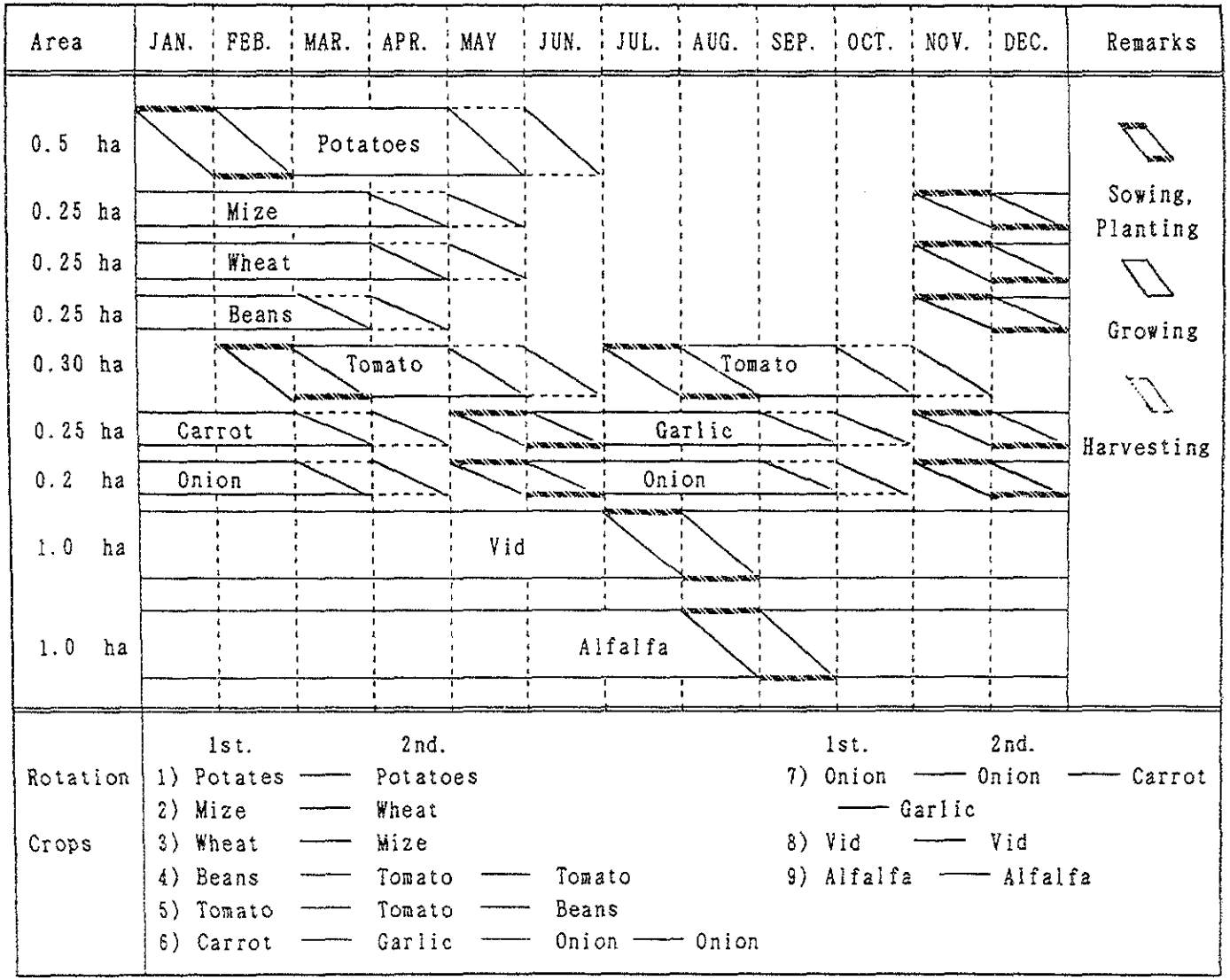



Figure 5.2.1 Proposed Cropping Pattern

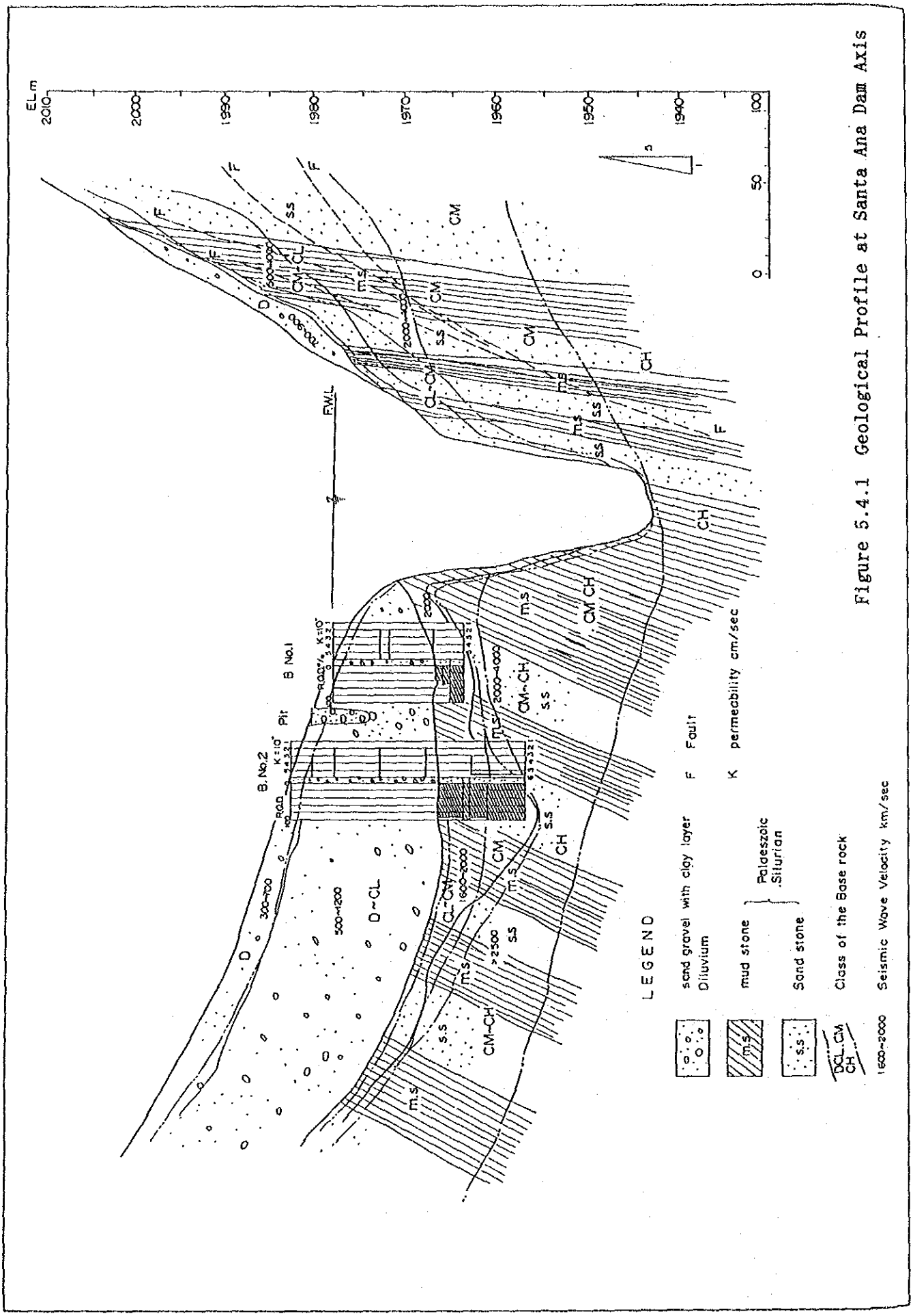



Figure 5.4.1 Geological Profile at Santa Ana Dam Axis

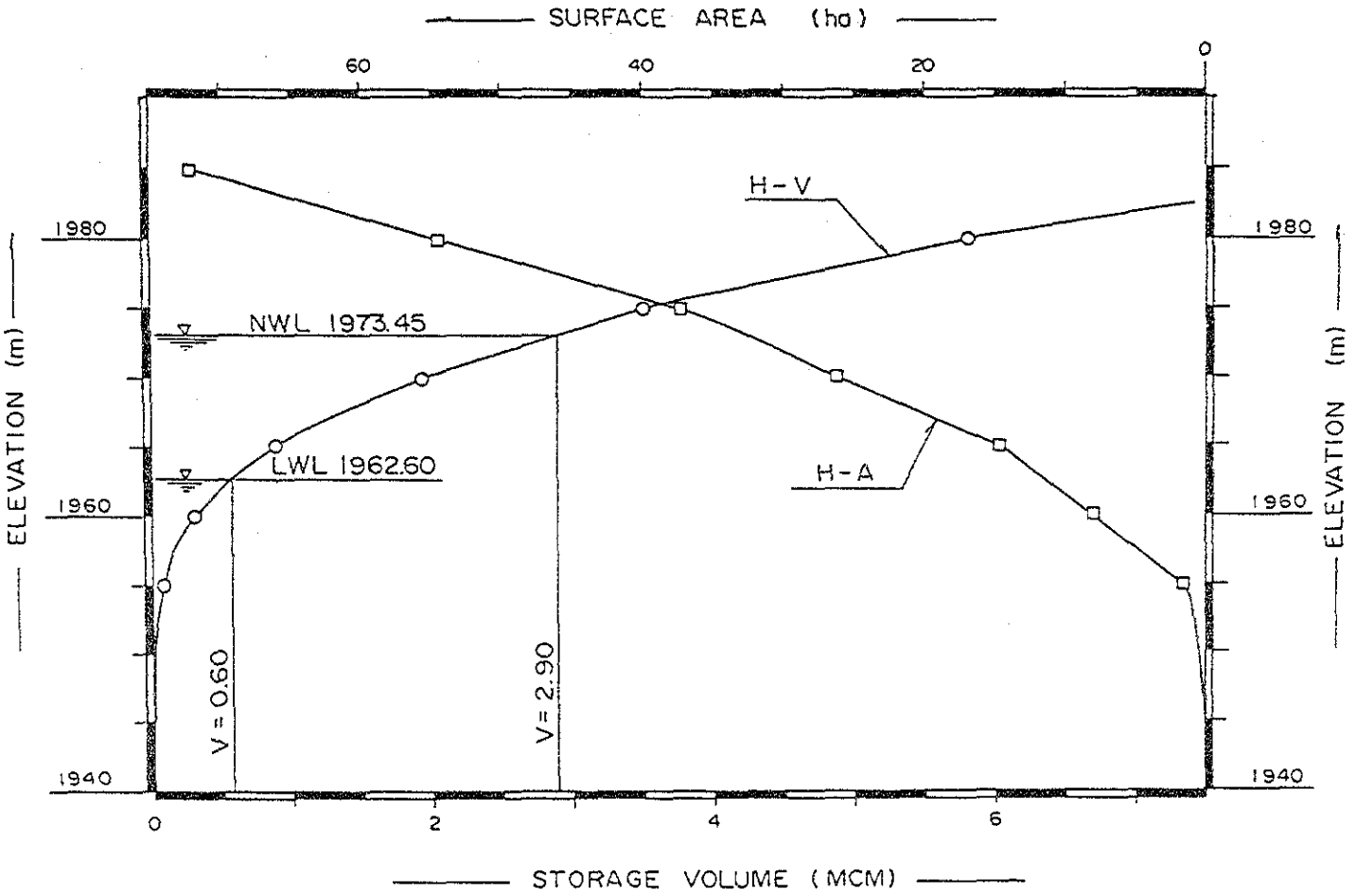



Figure 5.4.2 Reservoir Area-Capacity Curve

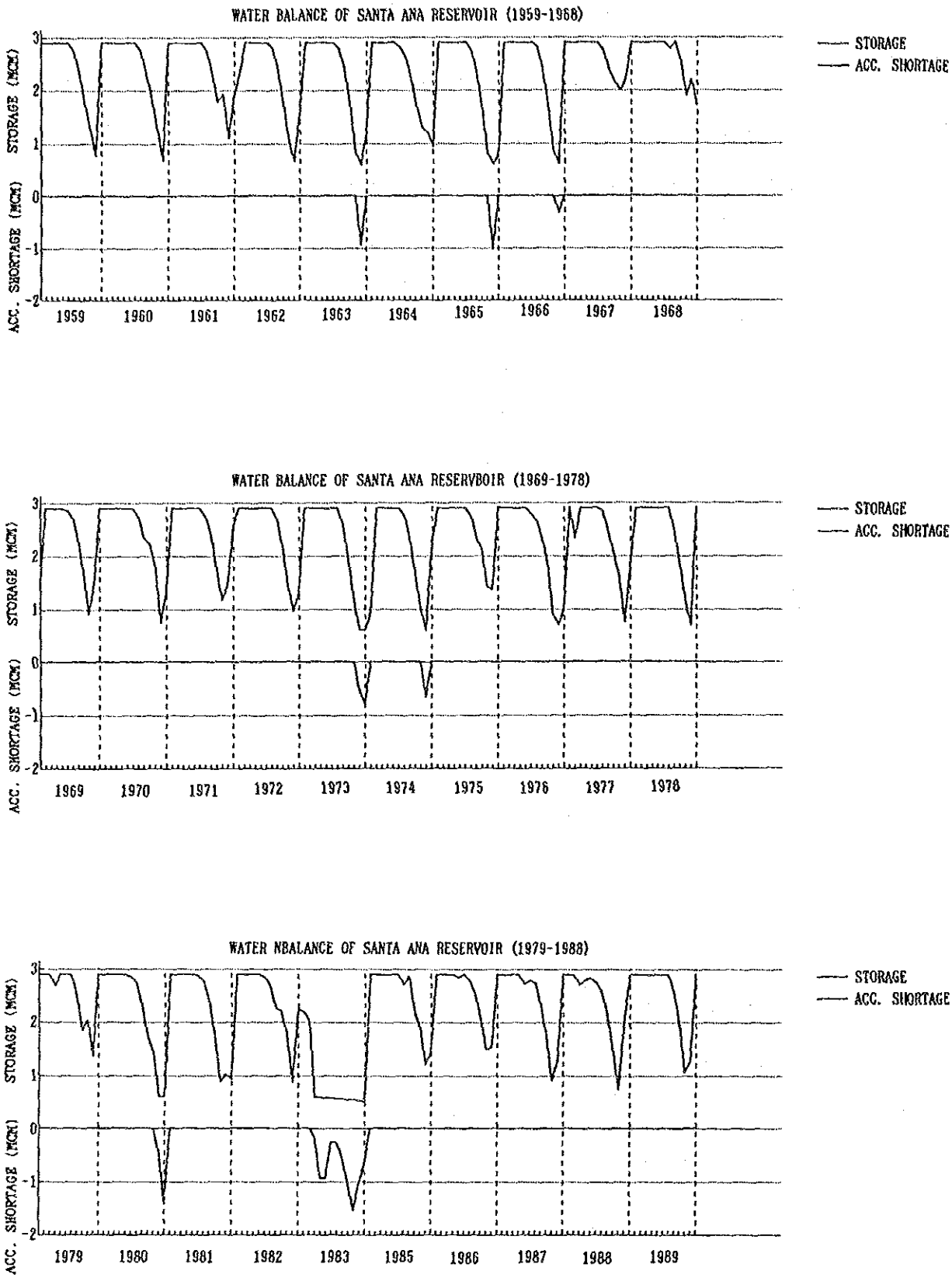



Fig. 5.4.3 Water Balance of Santa Ana Reservoir

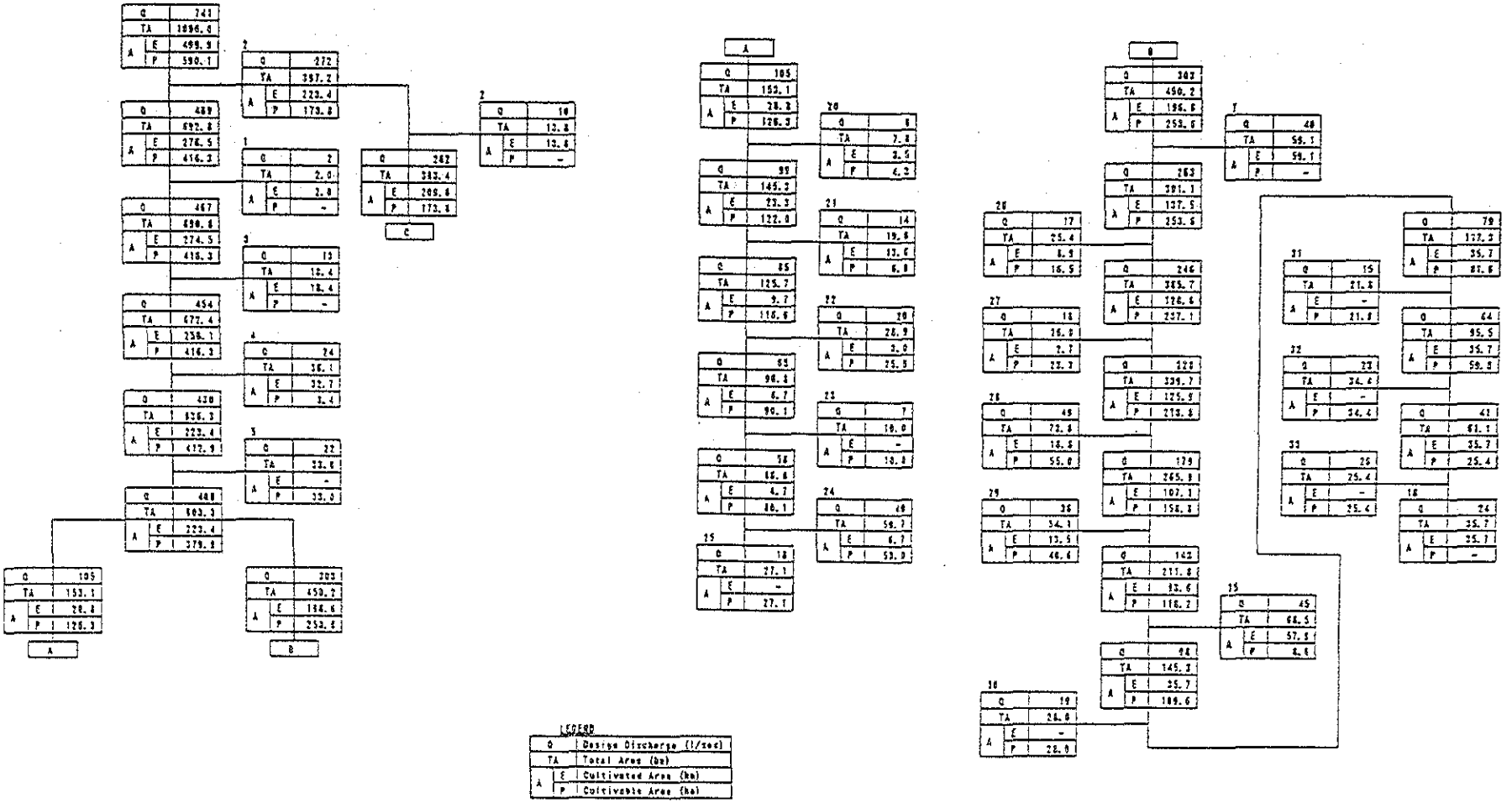



Fig. 5.4.4 Irrigation System

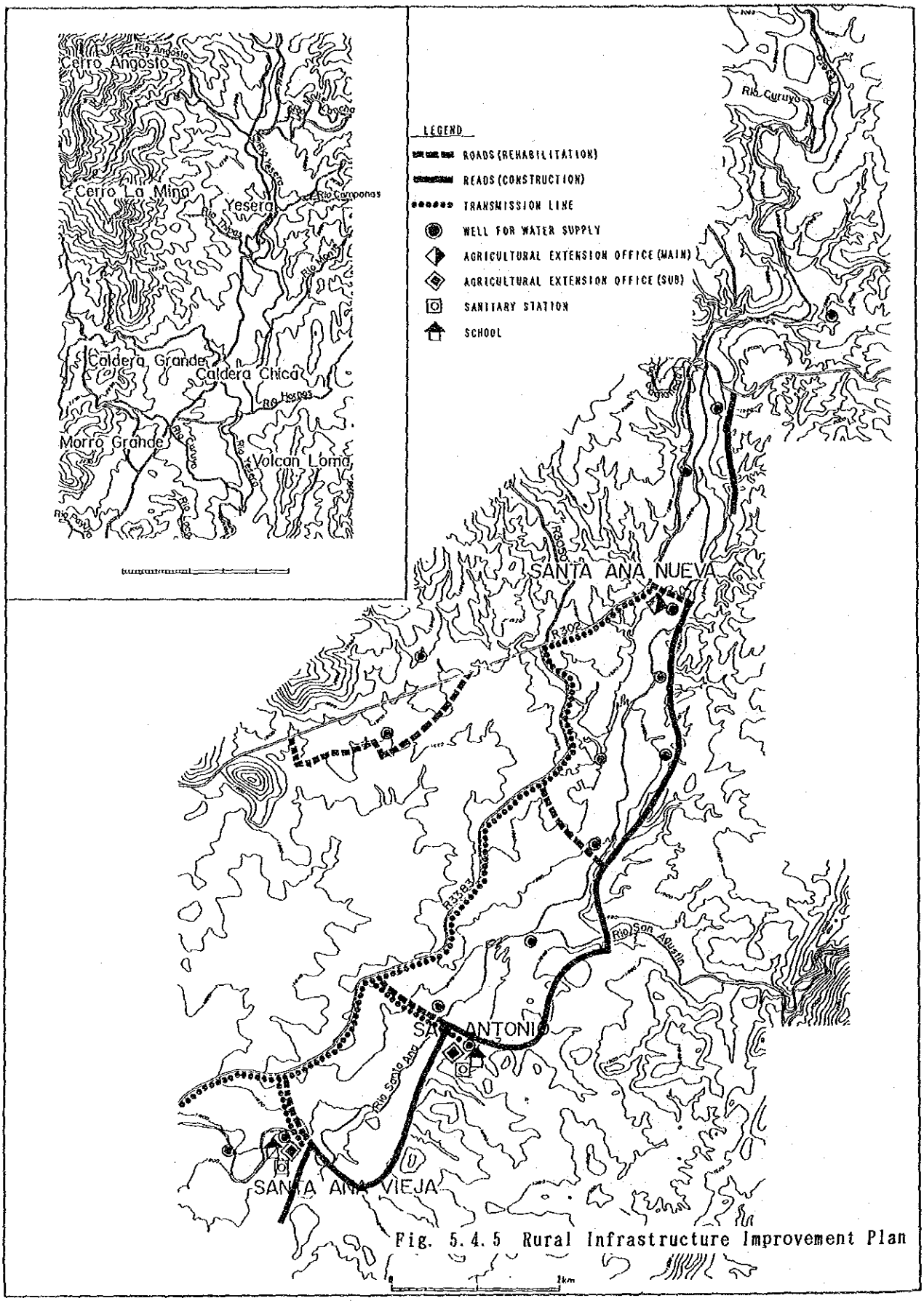



Fig. 5.4.5 Rural Infrastructure Improvement Plan

# CHAPTER 6 PROJECT IMPLEMENTATION AND OPERATION AND MAINTENANCE PLAN

# CHAPTER 6 PROJECT IMPLEMENTATION AND OPERATION AND MAINTENANCE PLAN

## 6. 1 Project Implementation Plan

### 6.1.1 Organization for Project Implementation

In Bolivia, the Ministry of Planning and Co-ordination (MPC) co-ordinates the financing from a foreign country of a project and the participation of authorities concerned in the carrying-out of the project at national level. The administrative agency of the project will be the Regional Development Corporation of Tarija (CODETAR) and the Agricultural and Stockbreeding Department, which is one of departments in CODETAR, will give the technical support.

The facilities which are constructed under the responsibility of the CODETAR are dam, main and secondary canals, and their related structures. On the other hand, civil works such as tertiary canal and terminal facilities are carried out by farmer themselves under the guidance of CODETAR.

The Project is carried out on the premise that the agricultural technique with irrigation will be extended. Therefore, the farmers' organization and supporting service are indispensable items and the well-balanced development and improvement with improvement of rural infrastructure are important. Then, a closer cooperation with the related authorities is necessary in implementing the project. The operation and maintenance for the facilities after completion of the project are carried out by the Santa Ana Development Office established in CODETAR.

### 6.1.2 Project Implementation

(1) Budgetary allocation

The foreign currency portion of the project cost will be financed by the international financing institute, while the local currency portion will be provided by the Bolivian Government.

(2) Construction work

A qualified contractor will be selected by international competitive bidding to construct the civil works of the project. The tertiary canal and on-farm facilities will be made by the farmers or farmers' association under the technical guidance of CODETAR.

(3) Administration office

CODETAR will establish a Santa Ana Project Implementation office

which consists of an administrative, engineering and agricultural development sections. The contents of the major work are preparation of the tender document, appraisal of the detailed design, tendering of construction work, land acquisition & compensation, supervision of works, design & technical guidance for tertiary canal and on-farm facilities and guidance of agricultural technique. The organization of Santa Ana Project Implementation office is proposed as shown in Fig. 6.1.1.

Furthermore, the Santa Ana Project Implementation office plays a role for a operation and maintenance office after completion of the construction work.

### 6.1.3 Implementation Schedule of the Project

The Project will be completed in the course of four years, namely the detailed design period of one and half years and the construction period of two and half years as shown in Fig. 6.1.2. The detailed design period includes the financing procedure of half a year and the detailed design of one year. The construction period needs half a year for the land acquisition and two years for the construction works. The tertiary canal and on-farm facilities will be constructed during the construction period of the major facilities.

(1) Detailed design

The detailed topographic survey of the right-of-way for the proposed major structures such as dam, reservoir and etc. and the route surveys including profile and cross-section of canal and roads will be carried out. Detailed design will be carried out taking the surveyed results. Tender documents of the project will be prepared together with construction cost estimate.

(2) Land acquisition

The land acquisition for construction of the facilities and structures such as dam, reservoirs, canals, roads and etc. should be acquired by the CODETAR prior to commencement of the construction works. The compensation for the lands and houses which are submerged by the construction of dam and reservoir should be carried out.

(3) Contract

The contractor will be employed through international competitive bidding. The machinery and equipment required for the construction works are to be prepared by the contractor. The construction materials are to be procured form domestic and/or international market under the responsibility of the contractor.

(4) Construction works

Construction works will start in the second year after the commencement of the project. Works are to be performed in the following order unless otherwise specified.

Dam -- Sedimentation Dam -- Irrigation Canal -- Tertiary Canal & On farm Facilities -- Rural Infrastructure

The construction works of dam and sedimentation dam are to be carried out during the dry season, when the discharge is little and the temperature is relatively low, and the construction works of irrigation canal mainly during the rainy season.

## 6.1.4 Construction Planning

(1) General

Major facilities constructed by the project are,one dam for water source, five sedimentation dams constructed upstream of the Dam, main and secondary irrigation canals, small-scale reservoirs along the canal and rural infrastructure such as schools, sanitary, wells and roads.

(2) Basic item

- Construction period
  The construction of the major works will be completed within about two years including the preparation period. Dam works will be mainly carried out during the dry season when rainfall is little and temperature is relatively low. Other works will be carried out all the year round.

- Workable days and hours

  The construction works are planned to be carried out in one shift with net working hour of 8.0 hr per day and 25 days per month in the dry season (May to October) and 20 days per month in the rainy season (November to April).

- Preparation work

  Preceding the construction works, it is necessary to establish and secure roads for carrying machinery and heavy equipment and materials, as well as the facilities for power source under dam construction, water supply, communication service. Among these, the early stages to be constructed would be the road for transporting necessary materials from the nearest place with convenient transportation to the construction site. The power

supply facilities for construction must ensure enough power required prior to commencement on temporary drainage channel, and water supply facilities must be completed before commencement of dam construction.

Re-inforcement work should be carried out on two bridges which are built in the provincial road passing through the projected area from the Pan-American Highway. At present, an power transmission line is laid as far as San Miguel, but it can not be used for power source of the dam construction because of the power shortage. Since electric power of about 2,000 KVA will be necessary, a transmission line from near the Pan-American Highway to the proposed dam site will be planned. After completion of dam works, transmission line will be used for the rural electrification of the project.

- Materials for concrete and concrete

Sand and gravel, which are material for concrete, are gathered from the river bed 400 m upstream of the dam site and stored in stockyard of the dam site. Ready mixed concrete prepared at the concrete plant is to be transported to each construction site by a mixing truck.

The kind of concrete is classified into as follows based on the purpose of the utilization.

| Class | 4-week compression stress ($kg/cm^2$) | Use |
|---|---|---|
| H-100 | 100 | Base concrete |
| H-150 | 150 | Plain concrete |
| H-225 | 225 | Reinforced concrete |
| H-225a | 225 | Dam concrete |

(3) Dam construction

- Temporary road

The road existing on the left bank of the river is available for the access road from the provincial road. At the right bank, a construction road which links the concrete plant with an existing road will be planned. Dimensions of the temporary road are as follows, taking the scale and frequency of traffic vehicle into consideration

| | |
|---|---|
| Total width | 7.0 m |
| Effective width | 5.5 m |
| Maximum gradient | 8 % |
| Minimum radius | 50 m |

Also, bulldozer (11 ton class) will be used for the construction.

- Scale of concrete casting

The casting of concrete is planned for one lift of 1.5 m taking into account the capacity of the concrete plant (200-300 $m^3$/day) and temperature control of cast-in-place concrete.

- Temporary facilities

Water supply facilities must be able to supply to the amount of water necessary with the pressure, to supply the water required for construction works, i.e., cleaning of the surface of base rock, curing and cooling of concrete, cleaning the poured surface, as well as cleaning and cooling construction machinery, and the water required for the construction workers' living purpose. In this plan, water is to be taken from Yesera River by two water pumps (100mm, 18.5kw). The pumps will be place in locations where can be pumped even during the dry season.

- Cofferdam

Considering the small discharge of the river in the dry season (0.08 - 0.185$m^3$/s) and the reduction of construction costs, the river discharge under construction will be drained by the temporary closure of half of the river and a temporary drainage channel constructed in the dam body without a diversion tunnel.

- Major quantity

Major quantity accompanied with dam construction is as follows.

| | |
|---|---|
| Excavation (Rock) | 14,400 $m^3$ |
| Excavation (earth) | 9,600 $m^3$ |
| Curtain grouting | 3,300 m |
| Consolidation grouting | 3,000 m |
| Dam concrete | 28,700 $m^3$ |
| Other concrete | 2,800 $m^3$ |

(4) Sedimentation dam

Sedimentation dam is classified into two structure types. One is wet masonry, and others are concrete. The dam of concrete type will be constructed by the same method as the dam for water source facility and the ready mixed concrete is transported from the concrete plant installed at the Santa Ana dam site. The dam of wet masonry type will be constructed of the materials gathered near the site.

Major quantity accompanied with sedimentation dam construction is as follows.

| Item | Unit | No.1 | No.2 | No.3 | No.4 | No.5 | Total |
|---|---|---|---|---|---|---|---|
| Excavation (rock) | $m^3$ | 820 | 900 | 1,300 | 1,040 | 1,240 | 5,300 |
| Excavation (earth) | $m^3$ | 550 | 600 | 870 | 690 | 830 | 3,540 |
| Dam concrete | $m^3$ | - | 3,900 | 5,100 | - | 5,600 | 14,600 |
| Wet masonry | $m^3$ | 2,040 | - | - | 2,700 | - | 4,740 |

(5) Irrigation Canal

The irrigation canals consist of the main and secondary canals. The main canal will be constructed with a concrete lining and the secondary canal with wet masonry. The canal construction works is divided into 11 construction sections; the main canal (5.4km) is divided into 2 sections, the secondary canal on the left bank (16.4km) into 5 sections, the secondary canal No.1 on the right bank (3.7km) and the secondary canal No.2 on the right bank (7.3km) into 3 sections, and they will be constructed along with the related structures. The construction works of the road which is planned on the left bank of Santa Ana River in the rural infrastructure improvement will precede the construction works the secondary canals of the left bank, so it can be used as a access road at that time.

Major quantity required for the construction of these facilities is as follows.

(Unit: $m^3$)

| Item | Principal canal | Secondary canal | | | Total |
|---|---|---|---|---|---|
| | | left bank | right No.1 | right No.2 | |
| Excavation | 21,700 | 28,000 | 7,600 | 15,000 | 72,300 |
| Filling | 9,700 | 7,400 | 2,100 | 4,000 | 23,200 |
| Concrete | 2,700 | - | - | - | 2,700 |
| wet masonry | - | 5,800 | 1,600 | 3,100 | 10,500 |

(6) Reservoirs

Reservoirs will be constructed at the site where the irrigation canal crosses a small stream. The central part of the embankment will be filled and compacted with cohesive soil which can be gathered near the site. Moreover, the upstream and downstream slopes will be protected by rock gathered near the site. Embankment and compaction will be carried out by bulldozer of 21 ton class, for a thickness of 30 cm per one lift and compaction of 4 times each.

Major quantity of the facilities is as follows.

Total number of reservoir 14 sites
Total amount of embankment 84,200 $m^3$

(7) Rural infrastructure

Rural infrastructures consist of construction or rehabilitation of roads in the area (20.2 km) and the improvement of the basic rural infrastructure such as wells for drinking water supply (15 places), rural electrification used a transmission line which is installed by the dam construction, rehabilitation of school houses (2 places), construction of public health centers and agricultural extension offices (3 places). These works will be carried out taking the construction schedule of the related works such as canal works into consideration.

(8) Construction schedule

The required period of the construction works of the project is half a year for the land acquisition and two years for the construction works. Details are shown in Table 6.1.2.

## 6. 2 Project Cost

The project cost is composed of the construction cost, land acquisition cost, procurement cost of O&M equipment, administration cost, cost for consulting services and physical contingency allowance.

### 6.2.1 Method of Cost Estimate

The project cost has been estimated on the following conditions. The cost divides into foreign and local currencies, and indicate using the United States dollars.

(1) Form of contract

Civil engineering works will be executed by contractors on a contract basis. The machinery and equipment required for construction works will be provided by contractors. Accordingly, the required expenses on construction machinery and equipment will be estimated depreciation cost basis.

(2) Basic rate

Unit prices such as wages, materials and equipment applied for project cost estimation are market prices prevailing in the Tarija City. The major prices are as follows.

| Item | Unit | Price | Remarks |
|---|---|---|---|
| Laborer | US$/day | 2.53 | |
| Electrician | US$/day | 6.05 | |
| Driver | US$/day | 4.45 | |
| Operator | US$/day | 7.04 | |
| Carpenter | US$/day | 8.72 | |
| Plumber | US$/day | 6.96 | |
| Assistant | US$/day | 2.53 | |
| Mechanic | US$/day | 6.05 | |
| Gasoline | US$/l | 0.30 | |
| Right oil | US$/l | 0.30 | |
| Sand | US$/$m^3$ | 4.66 | |
| Coarse aggregate | US$/$m^3$ | 7.66 | |
| Cement | US$/50kg | 3.50 | |
| Reinforcement bar | US$/ton | 1,061.00 | |

(3) Unit Cost

Unit cost of construction works is calculated according to the proposed items which are classified by the construction method. Since the construction works are carried out on the contract basis, the overhead and profit of 33% against the direct unit cost is considered.

(4) Foreign exchange rate

The exchange rate between Bolivian and U.S. dollar is fixed with the official rate of US$1.00 = Bs. 3.00 as of January 1990.

(5) Contingency allowance

Physical contingency allowance is set at 10% for civil engineering works and 5% for other works. Price escalation is set at 3%.

### 6.2.2 Project Cost

(1) Construction cost

Major civil works are dam works, sedimentation dam works, irrigation canal works, on-farm works and rural infrastructure works. the total construction cost required for these works is estimated at US$13,886,000 which is divided into foreign and local currency portions amounting to US$7,072,000 and US$6,814,000, respectively.

(2) Cost for land acquisition

The costs for land acquisition and compensation required for constructing reservoirs, irrigation canals and roads are estimated to be US$31,000, totally represented by local currency.

(3) Cost for procurement of O/M equipment

The procurement costs of the equipment required for the operation and maintenance of dam, canals and related facilities are estimated to be US$ 443,000 which is divided into foreign and local currency portions amounting to US$ 421,000 and US$ 22,000. They will be procured by the executing agency at the first year of the construction period.

(4) Administration costs

The administration costs required for the project implementation such as preparation of office, procurement of office supplies, salaries and wages of personnel, miscellaneous expenses, etc. are estimated to be US$ 465,000 which is divided into foreign and local currency portions amounting to US$ 45,000 and US$ 420,000, respectively.

(5) Cost for consulting services

The cost for consulting services including topographic and geological surveys is estimated to be US$ 385,000 during the detailed design period and to be US$ 470,000 during the construction periods, which is divided into foreign and local currency portions amounting to US$ 673,000 and US$ 182,000.

(6) Contingency allowance

The physical contingency allowance for all facilities is estimated to be US$ 1,299,000 which is divided into foreign and local currency portions amounting to US$ 650,000 and US$ 649,000.

(7) Project cost

The project cost to be implemented by CODETAR is estimated to be US$ 14,917,000. Out of it, the foreign currency portion is US$ 7,515,000 which is equivalent to 51% of the total cost and the local currency portion is US$ 7,402,000 which is equivalent to 49% of the total cost. And also, the total construction costs of on-farm facilities which are carried out by farmers is estimated to be US$ 268,000. The content of project cost is shown in Table 6.2.1. The disbursement of the project cost will be made in 4 years and the annual disbursement schedule is shown in Table 6.2.2.

## 6. 3 Operation and Maintenance Plan

In order to operate and maintain the facilities, so that they sufficiently fulfill their function after completion of the project implementation, it is ideal that the irrigation association which is composed of its beneficiary would be organized and they would administer the

facilities of themselves. However, the farmers in the area have no experience of operation and maintenance of the large-scale irrigation facilities. Since the CODETAR carries out the closer agricultural supporting service to the area, the Santa Ana Project Implementation office which carries out the administration works of the project will continuously carry out the operation and maintenance of the facilities. And also, the office will operate and maintain the facilities in cooperation with the producers' association which is organized by the farmers in the area.

Out of the facilities which are constructed on the Project, the irrigation and the agricultural facilities are placed under the charge of the Santa Ana office and other facilities under their appropriate authorities.

### 6.3.1 Organization for Operation and Maintenance

The Santa Ana development office which will operate and maintain the facilities after completion of the project implementation is organized as following Fig. 6.3.1. The roles of the its department are as follows.

- Engineering section : Operation of irrigation facilities
  Preparation of operation manual
- Administrative section: Decision of water charge
  General administration

### 6.3.2 Equipment and Machinery of Operation and Maintenance

The equipment and machinery required for the operation and maintenance for dam, canals, roads and etc. after completion of the project are selected as follows.

| Equipment | Capacity | required Quantity | Purpose |
|---|---|---|---|
| Bulldozer | 11 ton | 1 | Repair of road and canal |
| Tractor shovel | 0.6 $m^3$ | 1 | Exca. & loading |
| Back hoe | 0.3 $m^3$ | 1 | Exca. & loading |
| Dump truck | 4 ton | 1 | Transport of earth sludge |

### 6.3.3 Operation and Maintenance Cost

Operation and maintenance costs consists of the administration cost for the office, the maintenance cost of the irrigation facilities and administration cost for the producers' association and are estimated to be US$ 73,800 per year. The O/M costs are collected similarly as the water charges from the appropriate farmers. The details of the O/M cost is described in Annex I.

## Table 6.2.1 Project Cost

(Unit: US$1,000)

| ITEM | PROJECT COST | | | REMARK |
|---|---|---|---|---|
| | F. C | L. C | TOTAL | |
| Irrigation Facilities | | | | |
| 1. Dam | 3,148 | 2,734 | 5,882 | |
| 2. Sabo Dams | 1,141 | 1,403 | 2,544 | |
| 3. Canal | 873 | 885 | 1,758 | |
| 4. Reservoir | 447 | 433 | 880 | |
| 5. On Farm | 188 | 55 | 243 | Execusion by farmers |
| Sub-Total | 5,797 | 5,510 | 11,307 | |
| Rural Infrastructure Improvement | | | | |
| 6. Center Facilities | 10 | 93 | 103 | |
| 7. Road | 65 | 436 | 501 | |
| 8. Electricitiy | 13 | 51 | 64 | |
| 9. Water Supply | 14 | 3 | 17 | |
| 10. Sanitary Facilities | 29 | 21 | 50 | |
| 11. Educational Facilities | 5 | 45 | 50 | |
| Sub-Total | 136 | 649 | 785 | |
| 12. Land Aqui. & Compen. Cost | 0 | 31 | 31 | |
| 13. O/M Cost | 421 | 22 | 443 | |
| 14. Consulting Sevices Cost | 673 | 182 | 855 | |
| 15. Adominstration Cost | 45 | 420 | 465 | |
| Sub-Total | 1,139 | 655 | 1,794 | |
| Total | 7,072 | 6,814 | 13,886 | |
| 16. Physical Contingency | 650 | 649 | 1,299 | |
| Ground Total | 7,722 | 7,463 | 15,185 | |
| (Percentage) | 51% | 49% | 100% | |

Table 6.2.2 Annual Disbursement Schedule

(Unit: US$1,000)

| ITEM | 1 st | | | 2 nd | | | 3 rd | | | 4 th | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F/C | L/C | Total | F/C | L/C | Total | F/C | L/C | Total | F/C | L/C | Total | F/C | L/C | Total |
| 1. Dam | | | | 944 | 820 | 1,764 | 1,731 | 1,504 | 3,235 | 473 | 410 | 883 | 3,148 | 2,734 | 5,882 |
| 2. Sabo-Dam | | | | | | | 685 | 842 | 1,527 | 456 | 561 | 1,017 | 1,141 | 1,403 | 2,544 |
| 3. Canal | | | | | | | 437 | 443 | 880 | 436 | 442 | 878 | 873 | 885 | 1,758 |
| 4. Reservoir | | | | | | | 224 | 217 | 441 | 223 | 216 | 439 | 447 | 433 | 880 |
| Sub-Total | 0 | 0 | 0 | 944 | 820 | 1,764 | 3,077 | 3,006 | 6,083 | 1,588 | 1,629 | 3,217 | 5,609 | 5,455 | 11,064 |
| 5. Agricaltural Facilities | | | | | | | 5 | 47 | 52 | 5 | 46 | 51 | 10 | 93 | 103 |
| 6. Road | | | | | | | 33 | 218 | 251 | 32 | 218 | 250 | 65 | 436 | 501 |
| 7. Electricitiy | | | | | | | 6 | 26 | 32 | 7 | 25 | 32 | 13 | 51 | 64 |
| 8. Water Supply | | | | | | | 4 | 2 | 6 | 10 | 1 | 11 | 14 | 3 | 17 |
| 9. Sanitary Facilities | | | | | | | 15 | 11 | 26 | 14 | 10 | 24 | 29 | 21 | 50 |
| 10. Educational Facilities | | | | | | | 3 | 23 | 26 | 2 | 22 | 24 | 5 | 45 | 50 |
| Sub-Total | 0 | 0 | 0 | 0 | 0 | 0 | 66 | 327 | 393 | 70 | 322 | 392 | 136 | 649 | 785 |
| 11. Land Aqui. & Comsa. | | | | 0 | 31 | 31 | | | | | | | 0 | 31 | 31 |
| 12. O/M Equipment | | | | 421 | 22 | 443 | | | | | | | 421 | 22 | 443 |
| 13. Consulting Sevices | 269 | 73 | 342 | 135 | 36 | 171 | 135 | 36 | 171 | 134 | 37 | 171 | 673 | 182 | 855 |
| 14. Adoministration Cost | 15 | 112 | 127 | 0 | 109 | 109 | 15 | 111 | 126 | 15 | 88 | 103 | 45 | 420 | 465 |
| Sub-Total | 284 | 185 | 469 | 556 | 198 | 754 | 150 | 147 | 297 | 149 | 125 | 274 | 1,139 | 655 | 1,794 |
| Total | 284 | 185 | 469 | 1,500 | 1,018 | 2,518 | 3,293 | 3,480 | 6,773 | 1,807 | 2,076 | 3,883 | 6,884 | 6,759 | 13,643 |
| 15. Physical Contingency | 14 | 9 | 23 | 122 | 92 | 214 | 322 | 341 | 662 | 173 | 201 | 375 | 631 | 643 | 1,274 |
| 16. Price Escalation | 9 | 6 | 15 | 97 | 67 | 164 | 325 | 344 | 669 | 238 | 273 | 511 | 669 | 690 | 1,359 |
| Sub-Total | 23 | 15 | 38 | 219 | 159 | 378 | 647 | 685 | 1,331 | 411 | 474 | 886 | 1,300 | 1,333 | 2,633 |
| Ground Total | 307 | 200 | 507 | 1,719 | 1,177 | 2,896 | 3,940 | 4,165 | 8,104 | 2,218 | 2,550 | 4,769 | 8,184 | 8,092 | 16,276 |

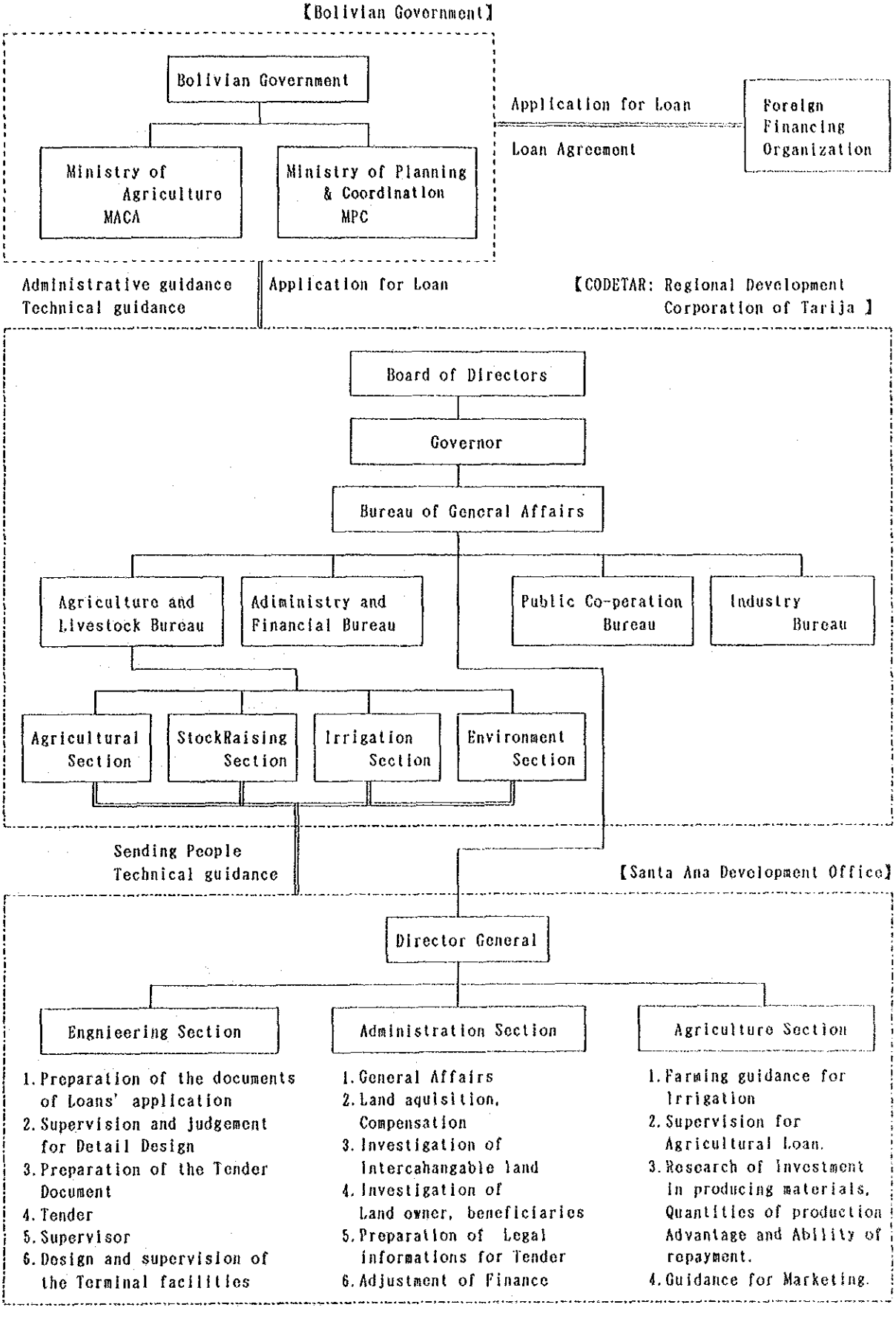



Fig. 6.1.1 Organization of the Project Execution

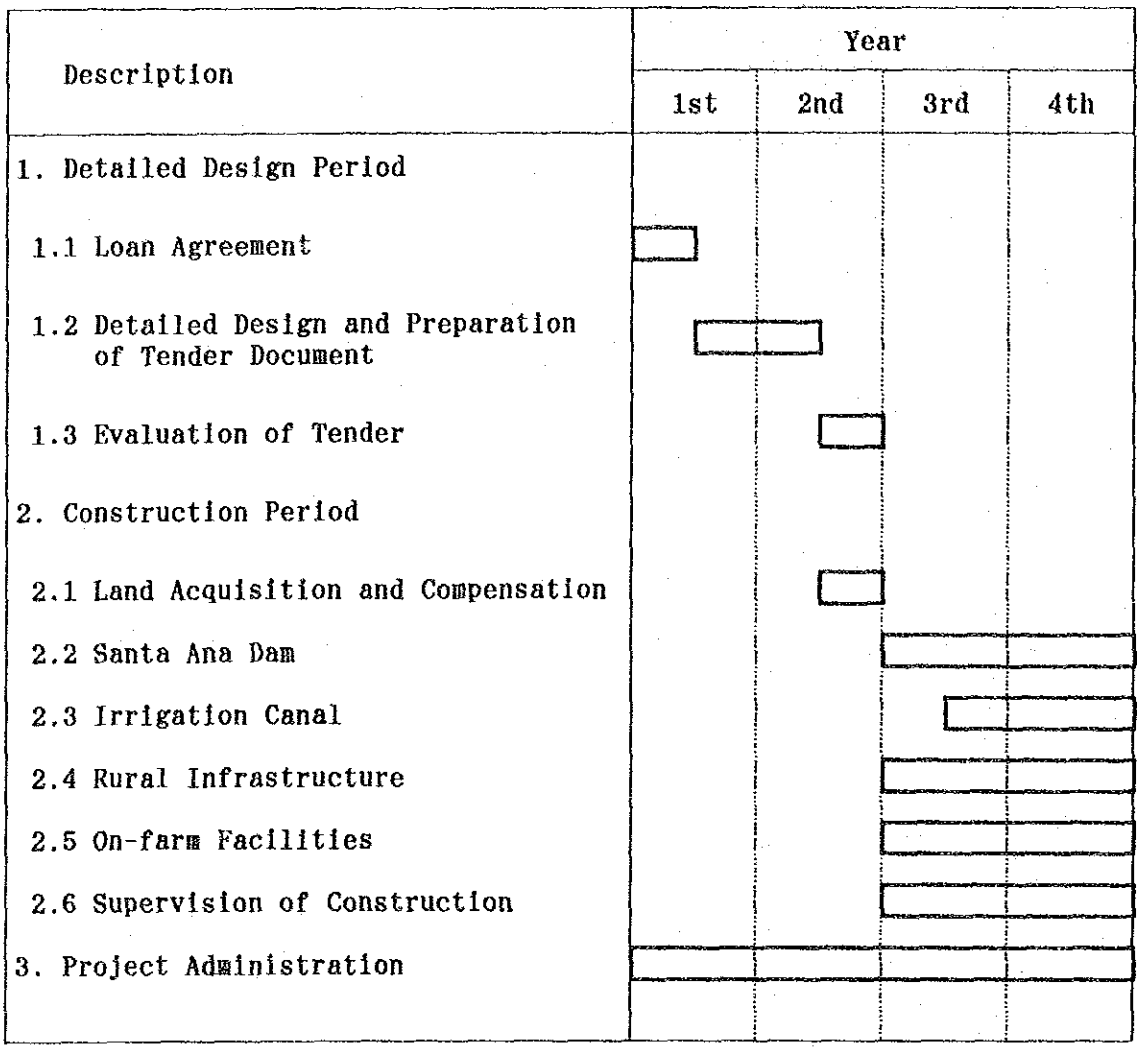



Fig. 6.1.2 Project Implementation Schedule

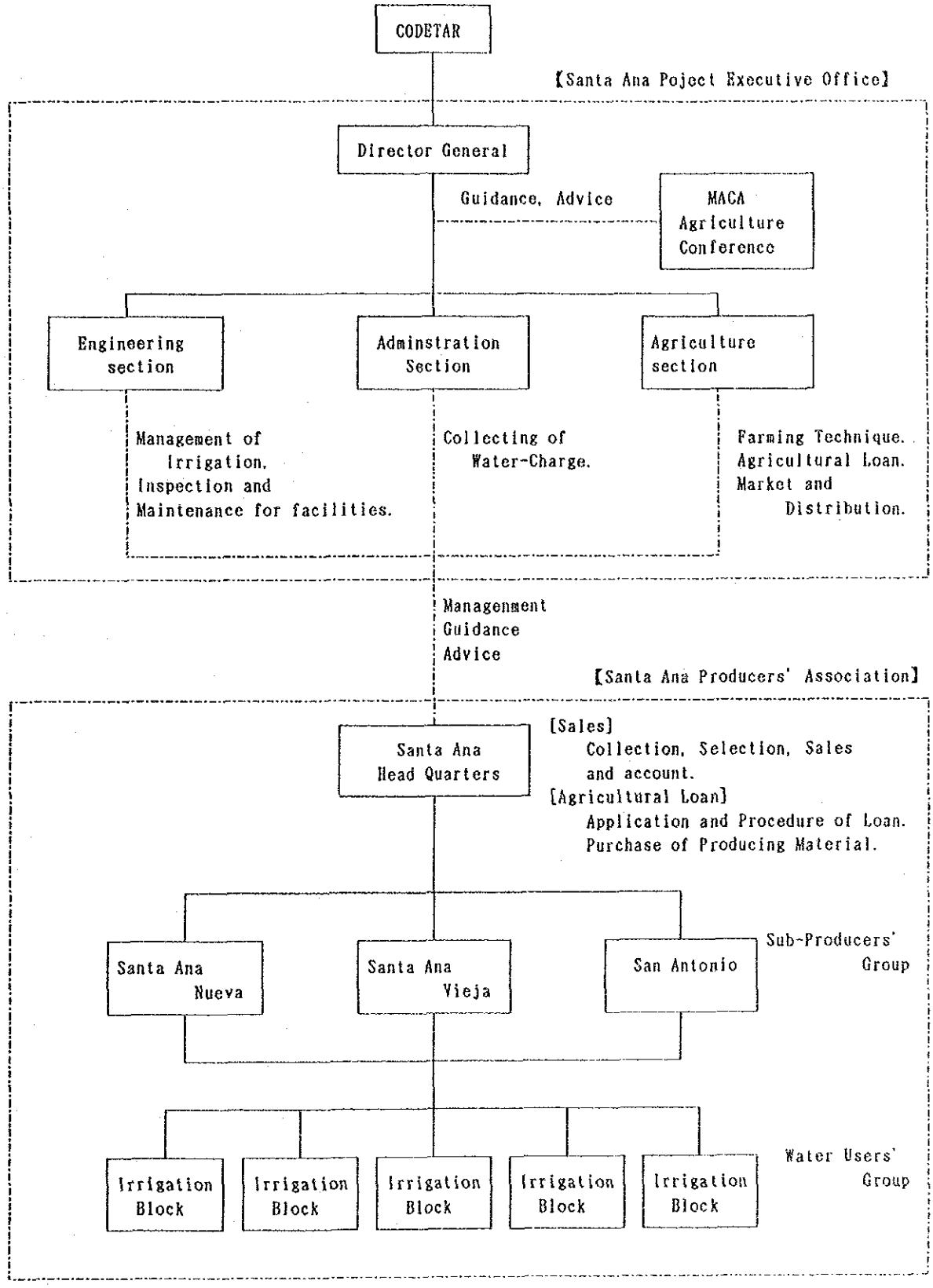



Fig. 6.3.1 Organization of Operation and Maintenance

# CHAPTER 7 PROJECT EVALUATION

# CHAPTER 7 PROJECT EVALUATION

## 7.1 Conditions of the Project Evaluation

The project aims at regional agriculture and rural developments. The project evaluation,therefore, is made on financial and economic aspects since project components is intensely given weight in public interest in the objective areas. In the financial analysis, fund raising of farmers households is mainly verified. The following conditions are assumed in the evaluation:

a. As the foreign exchange rate, US$ 1=B.S 3.0 is applied, (similar to the case of the cost estimation).

b. In the economic evaluation, opportunity cost is employed for an estimate of the project cost. 0.8 is used for conversion factor from the financial cost to the economic cost.

c. Since difference between the market price of agricultural products and their economic price is small, the farmgate prices are principally employed (refer to Annex J).

d. The project life is set up 50 years including the detailed design and the construction period.

## 7. 2 Financial Evaluation

### 7.2.1 Project Benefits

The benefits of the project is represented by the difference of net return between with project conditions and without conditions. Out of these, direct benefits which are possible to estimate quantitatively with carrying out of the project is as follows:

a. Benefits due to increase of agricultural produce.

b. Reduction of transportation cost for agricultural production materials and produce due to improvement of the road network in the project area.

c. Erosion control due to land reclamation and installation of small reservoir.

(1) Benefits of agricultural produce

As shown in the agricultural management improvement plan, agricultural productivity is improved by the supply and efficient

utilization of irrigation water. The expected result is an increased yield of agricultural produce. Comparison of agricultural produce and production costs between the with project conditions and the without conditions is as follows and the benefit of the increased agricultural produce is estimated at US$ 1,982,000.

Unit: US$ 1,000

| Item | With project | Without Project | Increment |
|---|---|---|---|
| Agricultural production amount | 2,970 | 375 | 2,595 |
| Agricultural production cost | 670 | 57 | 613 |
| Benefit | 2,300 | 318 | 1,982 |

Taking into account the widespread cultivation techniques of general farm products and the growth period from newly-cultivated vines to matured crops, a quantitative steady state to yield agricultural production benefits is defined as the second year for annual crop and the fourth year for vine crop, after the completion of the construction works of the project. As a result, increased in the agricultural production with elapsed year are estimated as shown below. The detailed explanation of each case is shown in ANNEX J.

unit: US$ 1,000

| Fiscal year | Annual crop 1(%) | | Vine crop 1(%) | | Increased produce 2(%) | |
|---|---|---|---|---|---|---|
| After completion of the project | | | | | | |
| 1st year | 253 | 20 | - | 0 | 253 | 10 |
| 2nd year | 807 | 70 | - | 0 | 807 | 30 |
| 3rd year | 1,184 | 100 | 846 | 60 | 2,030 | 80 |
| 4th year | 1,184 | 100 | 1,414 | 100 | 2,595 | 100 |

1(%): Achieved percentage of projected yield
2(%): Achieved percentage of projected production

(2) Reduction of transportation cost due to road improvement

Accompanied by the implementation of the project, the total amounts of agricultural products shipped in the projected areas are about 26,000 tons/year. The amount of productive materials purchased (fertilizer, agricultural chemical, etc.) is cumulatively estimated to be about 6,200 tons/year. Large-sized trucks are available for transportation of agricultural produce and productive materials because of the improvement of farm roads which enables reduction of expenses of the transportation to Tarija City which is a major agricultural produce market. Furthermore, reduction of loaded damages for fruit and vegetables can be expected. The benefits due to improvement and repair of farm roads is estimated to be US$ 8,370 per year (refer to ANNEX J).

(3) Inhibitory effect on soil erosion

Estimation of the benefit due to the erosion control by the land reclamation and the installation of small reservoir is defined as the reduced amount of damage caused by erosion. The loss amount of farm per unit area in the projected area caused by the soil erosion is estimated