(2) Experimental Farm:

The experimental farm is to be arranged next to the Project Office complex so that it will be easily accessible from the Project facilities. It shall face the rural road No.216 and the area road that leads to a school and a church. As people passing by on the roads will be able to see the farm, this location will be effective for exhibiting cropping methods and cropping results.

5-3-2 Basic Design

1. Model Farm

(1) Farm

① Irrigation Method:

Furrow irrigation, sprinkler irrigation, and drop irrigation are a few types of irrigation methods. The latter two systems require special facilities and high water pressure, and their installation and maintenance costs are high; therefore, they are considered inappropriate for use by the Project. Soil in the model field area varies from sandy loam to loam; furrow irrigation is possible in this type of soil. Furrow irrigation is quite a simple method, i.e., water flows into the furrows whenever required. The installation of this system is inexpensive and the necessary maintenance is not difficult to perform. Because of these reasons, the furrow irrigation method was chosen for the Project.

② The Amount of Irrigation Water Required:

a. Crop Water Consumption:

From Chapter 5-2-1, (2), the crop water consumption in the model field is 6.5 mm/day.

b. Irrigation Efficiency:

The irrigation efficiency in the model field is 60% - the same as shown in Chapter 5-2-1, (2).

c. Farm Delivery Requirement (Unit Area Requirement):

The farm delivery requirement (unit area requirement) can be calculated by using the crop water requirement 6.55 mm/day and the irrigation efficiency of the Project area as follows:

$$6.5 \text{ mm/day} \times 10^{-3} \times 10{,}000 \text{ m}^2 \times \frac{1}{24 \times 60 \times 60} \times \frac{1}{0.6}$$

$$= 1.25 \times 10^{-3} \text{ m}^3\text{/sec/ha}$$

$$= 1.25 \text{ l/sec/ha}$$

③ Irrigation Interval Plan and the Irrigation Period:

a. Irrigation Intervals:

The irrigation intervals can be calculated by the following equation:

$$\text{Irrigation Intervals} = \frac{\text{TRAM, or 50\% of TAM, or Dn}}{\text{Daily consumptive use of peak crop growing time}}$$

where, TRAM: Total residual water (mm)

TAM: Total available water (mm)

Dm: One-time application amount (mm)

Dn was used to calculate the irrigation intervals of the Project area.

i) One-time Application Amount Dn

Table 5-10 Application Amount Dn

Soil Layer Group	Layer Thickness D (m)	Crop Consumption Rate (%)	Field Water Content FC (%)	Initial Wilting Point WP (%)
1st Layer	19	40	15	6.5
2nd Layer	19	30	15	6.5
3rd Layer	19	20	15	6.5
4th Layer	19	10	15	6.5

Note: Layer thickness is the depth of the effective root zone of a certain crop which can be obtained from Table 5-11.

Table 5-11 Depth of Effective Root Zone (Eastern United States)

Crop	Depth	Crop	Depth
Alfalfa	0.90 - 1.00	Green Onion	0.45
Green Beans	0.60	Grass Weeds	0.45
Beets	0.60 - 0.90	Clover Mix	0.60
Cabbage	0.45 - 0.60	Groundnuts	0.45
Carrots	0.45 - 0.60	Fruit Trees	0.75
Maize	0.75	Green Peas	0.75
Cotton	1.20	Soybeans	0.60
Grain Crops	0.60 - 0.75	Sweet potatoes	0.90
Grapes	0.90 - 1.20	Tomatos	0.90
Melons	0.75 - 0.90		

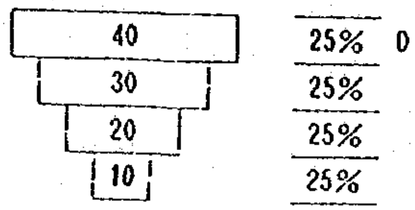
The main crop in the model field will be maize. The depth of the effective root zone of maize is 75 cm. Dividing the depth by four layers, the thickness of one layer becomes:

75 cm/4 = 19 cm.

ii) Crop Consumption Rate:

The crop consumption rate at different depths of root zones for a certain crop can be shown in shown in a figure called SMEP. The SMEP was first used in the United States. The SMEP is shown as follows:

Fig. 5-6 Crop Consumption Percent



iii) Field Capacity (FC):

The field capacity is the moisture content of the soil after free drainage has removed most of the gravity water. The field capacity of sand, loam, and organic soil are 6 - 12%, 18 - 26%, and 27 - 39% respectively (Yutaka Ishibashi Agricultural Hydraulics). Soil in the model field area is sandy loam. Thus,

FC = (12 + 18)/2 = 15%

iv) Initial Wilting Point (Wp)

From Table 5-10 the initial wilting point (Wp) of maize is 6.5%

Table 5-12 Initial Wilting Point

(Unit: %)

Crop \ Soil	Coarse Sand	Fine Sand	Sandy Loam	Loam	Clay Loam
Maize	1.07	3.1	6.5	9.9	15.5
Corn	0.94	3.6	5.9	10.0	14.1
Wheat	0.88	3.3	6.3	10.3	14.5
Green Peas	1.02	3.3	6.9	12.4	16.6
Tomatos	1.11	3.3	6.9	11.7	15.3
Rice	0.96	2.7	5.6	10.1	13.0

Source: Briggs and Shantz 1914

The available water (AM) and consumptive use can be calculated as follows:

Effective Amout (AM) = (FC - Wp) x D/100

Consumptive use = (available water)/(crop consumption rate) x 100 where, D: Soil layer thickness (mm).

Table 5-13 shows the results of the above calculations.

Table 5-13 Calculation of Consumptive Use

Soil Layer	Available Water (mm)	Consumptive Use (mm)
1st Layer	(15 - 6.5 x 190/100 = 16	(16/40) x 100 = 40.0
2nd Layer	"	(16/30) x 100 = 53.3
3rd Layer	"	(16/20) x 100 = 80.0
4th Layer	"	(16/10) x 100 = 160.0

Note: The consumptive use is based on each soil layer.

From the above table, the 1st layer becomes the controlling soil layer for irrigation. Thus, the necessary one-time application amount (Dn) must be 40.0 mm.

Therefore, the necessary irrigation intervals are

40.0 mm/6.5 mm = 6.5 days,

b. Irrigation Period:

During the irrigation season, it is possible to intake water 24 hours a day from the Kaunga River with a gravity flow intake facility. The model field will be irrigated 24 hours a day based on the following reasons:

1. The amount of water for one-time application is fixed as calculated in the previous section. If the irrigation period is shortened, the hourly intake amount shall be increased. As a consequence, it will be required to install larger sized intake facilities, pipelines, and irrigation channels, thus, making installation costs higher.

2. A smaller amount of hourly requires a smaller sized intake facility, and smaller sized pipelines and irrigation channels. The installation costs, in this case, would become lower.

3. A shorter irrigating period would require more operational work.

④ Irrigable Land, River Water, and Rainfall:

a. Irrigable Land after the Rainy Season:

The relationship between the irrigable land and the river water after the rainy season may be expressed by the dissipation curves which were obtained.

The dissipation equations are as follows:

$$Qt_1 = 15.41 \times 0.90^t$$

The relationship between the irrigable land and river water can be expressed as follows:

$$Qt = \frac{A/5 \times 6.5 \times 10^{-3}}{0.6 \times 86{,}400}$$

where, QT: River water Discharge (M^3/sec)
A: Irrigable land (m^2)
Crop water requirement: 6.5 mm/day
Irrigation efficiency: 0.6
Irrigation intervals: 6.5 days

Note: The irrigable land is divided into five equal lots.

Therefore,

$$15.41 \times 0.90t = \frac{A \times 6.5 \times 10^{-3}}{0.6 \times 86{,}400}$$

$$A = 1.229 \times 10^8 \times 0.90^t$$

In the above equation, it is assumed that the estimate river water can be taken for irrigation water. The results of the above calculations are shown in Table 5-14 and Fig. 5-7.

Table 5-14 Irrigable Land after the Rainy Season

(Unit: ha)

Days	10	20	30	40	50	60	70	80	90	100
Irrigable Land	4,285	1,494	521	182	63	22	7.7	2.7	0.9	0.3

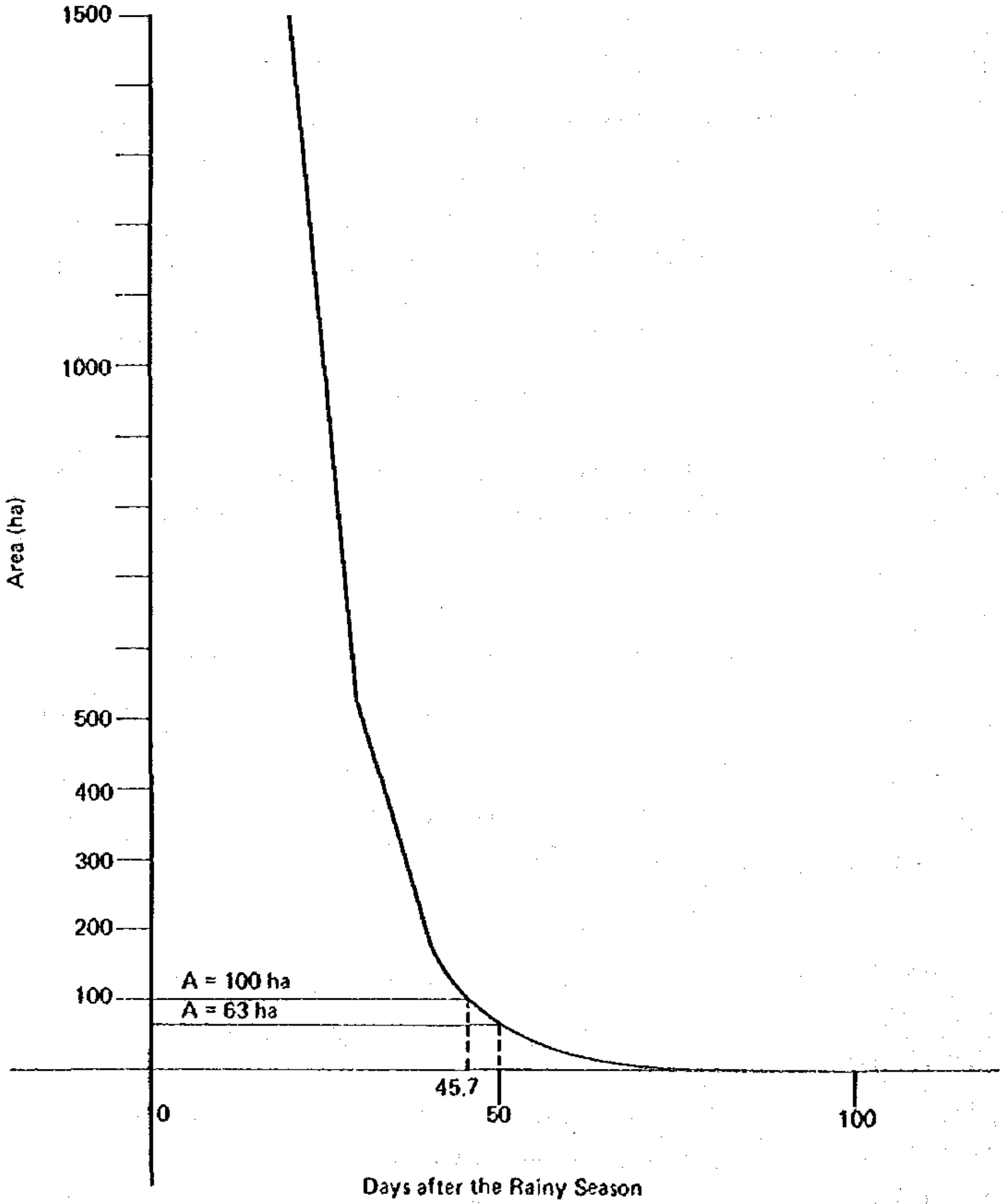


Fig. 5-7 Irrigable Land after the Rainy Season

b. Irrigable Land and Cropping Season:

The main crop in the model field will be maize; it will be seeded during the December - January period and will be harvested during the March - April period. In accordance with the Technical Report of Irrigation and Drainage of FAO, the growing period of maize is 140 days as shown in Table 5-15.

Table 5-15 Growing Period of Crop

Crop	Growing Period	
Maize	Eastern African Plateau, spring sown	30/50/60/40 (180)
	Warm desert climate, warm winter sown	25/40/45/30 (140)
	Southern Spain, sown in early April	30/40/50/3- (150)

Note 1: The Project area belongs to the "warm desert climate, warm winter sown."

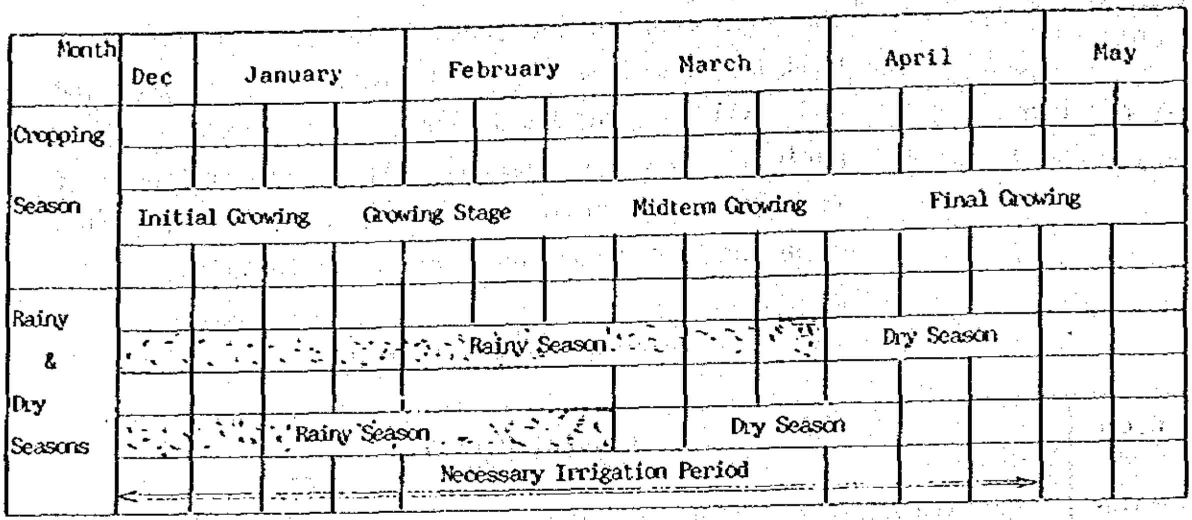
Note 2: The growing period of 140 days is divided into the following four stages:

1 Initial growing stage: 25 days
2 Growing stage: 40 days
3 Midterm growing stage: 45 days
4 Final growing stage: 30 days

Total .... 140 days

In the Project area, sowing starts from the last ten days of December. Fig. 5-8 shows the relationship between the maize growing stages and the rainy season. In this figure, the upper graph of the rainy and dry seasons was the normal seasonal pattern observed during the 1978-80 and 1982-83 seasons. The rainy season is from December to March, and the dry season starts from April. On the other hand, the lower graph of the rainy and dry seasons was the seasonal pattern that occured during the 1981-82 seasons. In this pattern, the rainy season was from December to February, and it was approximately one month shorter than the average rainy season.

Fig. 5-8 Cropping Season and Rainy & Dry Season



In the Project area, the rainfall pattern is not uniform; therefore, in order to increase maize output, it is necessary to continue supplimental irrigation not only throughout the rainy season, but up to crop harvesting time. In normal years, the rainy season lasts until the middle or end of March, and the required irrigation period is approximately 40 to 50 days after its ending. It is estimated that 100 ha of land may continue to be irrigated 40 to 50 days after the ending of the rainy season. This is based on the amount of irrigation water available from the Kaunga River as shown in Table 5-14 and Fig. 5-8. As a result, the Project's field is planned to be 100 ha (50 ha on each bank of the river).

In season of light rainfall - when the rainy season ends one or two months earlier than normal - it will be possible to sufficiently irrigate the crops during their initial growing stage and through their midterm growing stage. However, it will become difficult to supply adequate water from that point on. The condition of crops irrigated in light rain years will almost be equivalent to those in normal years not using irrigation. Therefore, it may be expected that the harvest of crops irrigated in light rain years will be equivalent to the harvest of crops during normal years without the use of irrigation.

⑤ Development of the Model Farm:

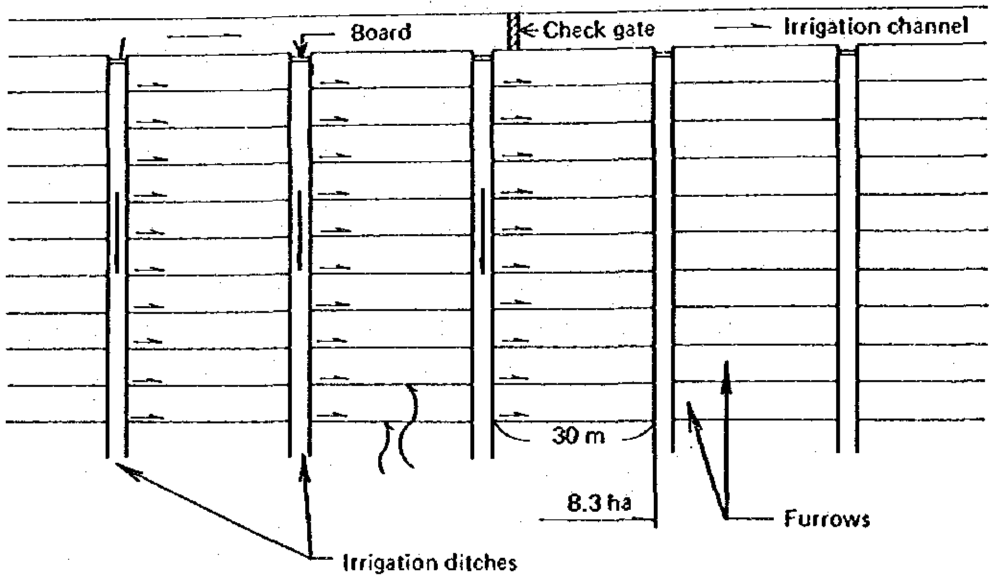
The flat land in the downstream area of the Kaunga River will be developed for the model farm. Soil in the area varies from sand to loam from the upper region to the lower region. The uppermost farmland on the right side of the river is in Chikokora. On the left site of the river the uppermost land is in Mranba. The lower regions of these two areas is suitable for farming. The land along the irrigation water supply pipelines shall be reclaimed to a width of from 100 to 350 meters for use as model fields. The topsoil in the area is relatively thin; therefore, bulldozers, should not be used for land reclamation work. Only tree roots and large rocks shall be removed by machinery. Some villagers have been using trees for fuel and house-building materials; because of this, trees in the area must be retained as much as possible.

⑥ Irrigation Method:

Irrigation channels shall be built on the higher elevations of the farm. Depending upon farm divisions, check gate valve shall be installed at proper points. Channel water will flow in the irrigation ditches when check valves are closed and ditch entrance boards are openend. The intaken water will flow into the furrows, then gradually infiltrate into the soil through the sides of the furrows, and then moisten the crops' root zones.

Since the allowable furrow length for sandy loam soil is approximately 30 m to 40 m, the irrigation ditch intervals shall be 30 m. The farm will be irrigated every six days as indicated in the previous chapter. Thus, the area to be irrigated in one day is 50 ha/6 days = 8.3 ha. Fig. 5-9 shows the schematic arrangement of the irrigation channels and ditches.

Fig. 5-9 Arrangement of Irrigation Channels and Ditches



(7) Summary of Model Farm:

Table 5-16 Model Farm

Item	Remarks
Planned Irrigable Farm	Downstream area of the Kaunga River Right bank: Lower region from Chikokora, 50 ha Left bank: Lower region from Mranba, 50 ha Total 100 ha
Required Irrigation Water	0.125 m^3/sec = 10,800 m^3/clay
Irrigable Period	Until two months after the rainy season
Development Method	Remove roots and large rocks

(2) Water Intake Facilities:

① Intake Point:

The intake point shall be selected based upon the following requirements:

- The location where stable water flows close to the river bank on the side where the eater is to be drawn.
- The location where excessive sediment does not flow into the intake water.
- The location where the intake structures do not effect both the upstream and downstream sides.
- The location where stable structures can be built at low cost.
- The location where accessibility for maintenance work is easy.

It is planned to intake water from an upstream point of the Kaunga River and to convey it through a pipeline to the model farm. The intake point is to be decided by giving consideration to the following:

i) Examination from Hydraulic Aspect:

Intake water will be conveyed through a pipeline by gravity flow, so it will be necessary to maintain sufficient head. Thus, it would be preferable to have the water taken from the furthest place upstream. As the intake facility must be installed where the water flow is stable, it would be preferable to locate it where the river becomes narrow and has banks of solid rock. In the area where the river is wide there tends to be an unstable flow of water; this is not a suitable location for the intake facility.

ii) Examination from the Construction Aspect:

From a point further upstream from where a mountain pushes out on the left bank of the river, more rocks appear. Approximately 200 m upstream from where mountains project from both banks, the river becomes narrow and the river bed is covered with large rocks having diameters of 1.0 - 1.5 m and solid rock. This area is not suitable for constructing any type of structure. Thus, the upper limit of the intake structure location is slightly on the downstream side of the area where the river bed is covered with large rocks.

iii) Examination from an Economical Aspect:

Construction and maintenance costs must be taken into consideration prior to the installation of the intake facility. The greatest part of the construction cost will be for the cutoff wall that is to be installed at a point where the river is narrow. From the maintenance aspect, it is preferable to build a stable and safe structure on a hard reliable foundation. For the above reasons, the most economical place to build the intake structure would be at a location where the river is narrowest (approx. 35 m wide) and has mountains projecting n both of its banks.

iv) Examination from Other Aspects:

In the upstream area of the narrowest part of the river, a small amount of surface water flows even at the end of the dry season. It is possible to intake a sufficient amount of water at the narrowest part of the river to last the entire irrigation period. Further upstream from this point, there is no farmland nor houses; the effect of the intake structure here would be nil.

Taking into consideration the aforementioned examinations, the location where the rocky mountains project into the Kaunga River, and where the river itself is narrowest, is the area selected for the water intake point.

② Intake Facilities:

The intake point selected in the above section has rocks projecting from both banks. The river bed material at this point is sand. A test boring indicates the existance of base rock at 2.3 - 2.7 m below the river bed. In accordance with the site survey results, the riverbed elevation at the intake point is +101.95 m. The elevation differences between the riverbed and the pipeline discharge points are 4.95 m on the right bank of the river, and 5.95 m on the left bank of the river. The pipeline route lengths are 3.0 km to the right bank and 2.95 to the left bank. The calculated required head (from head loss calculations) between the intake point and the pipeline discharge points is 4.30 m. Thus, a concrete cutoff wall shall be built about 1.0 m higher than the riverbed, across the river on bed rock in order to secure the intake water head +4.3 m higher than the pipeline discharge points.

For the surface flow intake, the intake mouth shall be located at a higher elevation above the river bed to prevent sand inflow. However, water cannot be drawn through the intake mouth when the river water level becomes lower. During the rainy season, it is impossible to reach the intake point in order to control the level of the intake mouth. Further, the surface water of the river carries a substantial amount of sediment during the rainy season; this sediment would flow into the pipelines. For these reasons, it is preferable to take subsurface water through a perforated culvert. The collected water from the culvert shall be led to collecting box, then the water flows to the model field through a pipeline. The collecting box shall function to collect the sediment contained in the water.

On the downstream side of the cutoff wall, an apron and riverbed protection shall be installed to prevent scouring by overflow water.

Fig. 5-10 Cutoff Wall, Apron and Riverbed Protection

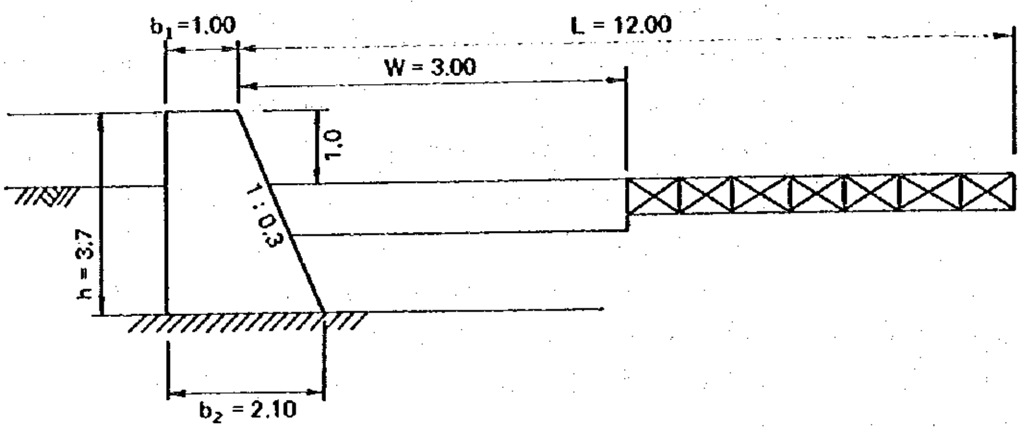
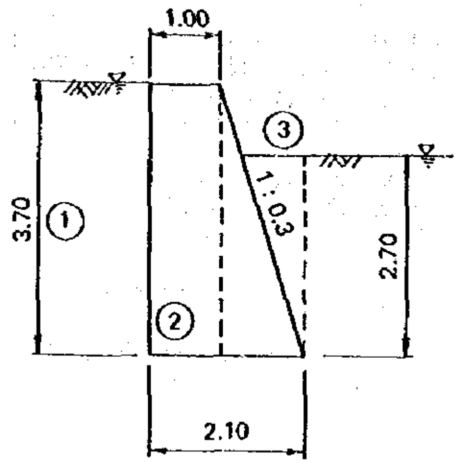


Fig. 5-11 shows the first assumption of the cutoff wall, apron, and riverbed protection dimensions.

i) Cutoff Wall Stability Calculation:

Fig. 5-11 Cutoff Wall



Unit weight of saturated soil with water: $= 2.0 t/m^3$

Unit weight of water: $= 1.0 t/m^3$

Internal friction angle of soil: $\phi = 30^oC$

Unit weight of concrete: $= 2.34\ t/m^3$

Coefficient of active earth pressure: K_A

$$K_A = \frac{\cos^2(\phi-\theta)}{\cos^2 \cdot \cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\phi-\delta)\cdot\sin(\phi-\alpha)}{\cos(\theta+\delta)\cdot\cos(\theta-\alpha)}}\right]^2}$$

Therefore,

$\alpha = \theta = 0, \quad \delta = \phi = 30^o$

Therefore,

$$K_A = \frac{\cos^2 30^o}{\cos 30^o\left[1+\sqrt{\frac{\sin 60^o\cdot\sin 30^o}{\cos 30^o}}\right]^2}$$

Table 5-17 Weight of Cutoff Wall and Soil, and Their Centers of Gravity

No.	Weight	Arm		Moment		Remarks
		x	y	w·y	w·y	
1	1.00x3.70x2.35=8.70	1.60	1.85	13.92	16.10	
2	1.10x3.70x1/2x2.35=4.73	0.73	1.23	3.49	5.88	
3	0.81x2.70x1/2x2.00=2.19	0.27	1.80	0.59	3.94	
Total	15.67 Xo= 18.00 / 15.67 =1.15 yo= 25.92 / 15.67 =1.65			18.00	25.92	

Calculation of Earth Pressure

Normal active earth pressure:

$$Pa = \frac{1}{2} \cdot \gamma \cdot K_A \cdot h^2 = \frac{1}{2} \times 2.0 \times 0.297 \times 3.70^2$$

$$= 4.07 \text{ t/m}$$

$$PaH = Pa \cdot \cos \phi = 4.07 \times 0.866 = 3.52 \text{ t/m}$$

$$PaV = Pa \cdot \sin \phi = 4.07 \times 0.500 = 2.03 \text{ t/m}$$

Stability Calculation:

Table 5-18 Point of Resultant

Load	Vertical	Horizontal	Arm		Moment	
			x	y	V · x	H · y
Weight	15.67	0	1.15	1.65	18.02	0
Earth Pressure	2.03	3.52	2.10	1.23	4.26	4.33
TOTAL	17.70	3.52	-	-	22.28	4.33

$$M_1 = V \cdot X - H \cdot y = 22.28 - 4.33 = 17.95 \text{ t/m}$$

$$X_1 = \frac{M_1}{V} = \frac{17.95}{17.70} = 1.01 \text{ m}$$

Stability for Tipping:

$B/3 = 2.10/3 = 0.70$ m

$X_1 = 1.01$ m $B/3 = 0.70$

Therefore, it is stable against tipping.

Stability against Sliding:

Foundations resisting force against sliding can be calculated using the following equation:

$$Hu = CA \times V \, . \tan \phi B$$

Since the foundation base is bed rock, C = 1, $\tan \phi = 0.7$

$$Hu = 0.7 \times V = 0.7 \times 17.70 = 12.39 \text{ t}$$

The horizontal force is H = 3.52 tons.'

$$Hu/H = 12.39/3.52 = 3.5 > 1.5$$

Thus, its safety factor is larger than 1.5, and the foundation is safe against sliding.

Examination of the Bearing Strength of the Base:

$$P = \frac{V}{B} \, . \, (1 + \frac{6 \cdot e}{B})$$

$$e = \frac{B}{2} - X = \frac{2.10}{2} - 1.01 = 0.04 \text{ m}$$

$$P = \frac{17.70}{2.10} (1 + \frac{6 \times 0.04}{2.10} = 9.39 \text{ t/m}^2 < 60 \text{ t/m}^2$$

Therefore, the ground is strong enough for the structure foundation.

ii) Apron and Riverbed Protection:

The required length of the apron and riverbed protection may be determined based on the empirical method described in the Erosion Control Technical Standard, Design Section I. Thus, the length of the apron shall be 1/4 of the total length of the apron and riverbed protection or shall be two to three times the height of the drop structure. The height of the cutoff wall is 1.0 m.

Therefore,

Apron length: $w = 1.0 \times 3 = 3.0$ m

The length of the apron and the riverbed protection:

$$L = 3.0 \times 4 = 12.0 \text{ m}$$

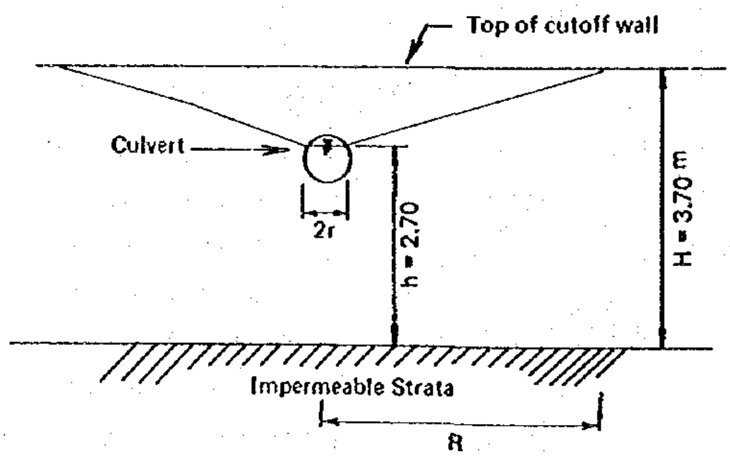
iii) Water Intake Culvert:

Normally, a single water intake culvert is installed paralledl or perpendicular to the subsurface flow direction. For the Project, a cutoff wall is designed to shut off the subsurface flow in the narrow part of the river. Thus, a single water intake culvert shall be installed parallel to the river.

Diameter and Length of the Culvert:

The boring revealed the existence of base rock at a depth of 2.3 to 2.7 meters below the riverbed. The culvert shall be installed at riverbed level. The top of the cutoff wall shall be about 1.0 m higher than the riverbed as shown in Fig. 5-11.

Fig. 5-12 Water Intake Culvert & Cutoff Wall



The water inflow rate into the culvert can be calculated using the following equation:

$$q = \frac{K}{R} \cdot \frac{H^2 - h^2}{\sqrt{\frac{h}{f + 0.5r}} \sqrt[4]{\frac{h}{2h - f}}}$$

$$Q = q \cdot L$$

$$R = (H^2 - h^2)/21 \cdot H$$

where, q: Inflow rate unit length
Q: Total inflow, m^3/sec
R: Effective radius
I: Hydraulic gradient
: Culvert radius
k: Coefficient of permeability
f: Water depth in culvert

Using a 600 mm diameter pipe for the culvert, 2 is 600 mm. Assuming "f" to be 80 percent of the culvert diameter, "f" is then 600 mm x 0.8 = 480 mm. At the water intake point, the river is approximately 32 m wide with rock projecting in from both banks. Since the culvert is to be installed in the middle of the river, the hydraulic gradient becomes:

$$I = \frac{H - h}{16} = \frac{1}{16}$$

The coefficient of permeability of sand (existing riverbed material) is k = 1.0×10^{-2} m/sec.

Therefore, R and q become as follows:

$$R = \frac{H^2 - h^2}{21 \cdot H} = \frac{3.7^2 - 2.7^2}{2 \times \frac{1}{16} \times 3.7} = 13.8 \text{ m}$$

$$q = \frac{K}{R} \cdot \frac{H^2 - h^2}{\sqrt{\frac{h}{f + 0.5r}} \cdot \sqrt[4]{\frac{h}{2h - h}}}$$

$$= \frac{1.0 \times 10^{-2}}{13.8} \times \frac{3.7^2 - 2.7^2}{\sqrt{\frac{2.7}{0.48 + 0.5 \times 0.3}} \times \sqrt[4]{\frac{2.7}{2 \times 2.7 - 0.48}}}$$

$$= 2.60 \times 10^{-3} \text{ m}^3/\text{sec}$$

The required amount of irrigation water is Q = 0.126 m^3/sec.

$Q = 0.126\ m^3/sec = q\ .\ L = 2.60 \times 10^{-3}\ .\ L$

$L = 48.5\ m$

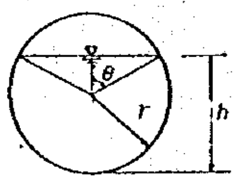
Therefore, the length of the water intake culvert shall be 50 m.

The slope of the culvert installation shall be flat or very mild (1/500). For a culvert with a 1/650 slope, the flow in it can be calculated using the Manning formula as follows:

$$Q = \frac{1}{n} \times r^{8/3} \times I^{1/2} \times \alpha$$

$$V = \frac{1}{n} \times r^{2/3} \times I^{1/2} \times \alpha$$

Table 5-19

h/2r	α	β	Remarks
0.50	0.98954	0.62996	Q: Discharge (m^3/sec)
0.55	1.15917	0.65473	r: Pipe radius (m)
0.60	1.32962	0.67558	n: Roughness coefficient
0.65	1.49699	0.69251	I: Slope
0.70	1.65696	0.70541	V: Velocity (m/sec)
0.75	1.80468	0.71404	
0.80	1.93448	0.71799	
0.85	2.03932	0.71653	
0.90	2.10929	0.70827	
0.95	2.12655	0.68980	
1.00	1.97907	0.62996	

Discharge:

$$Q = \frac{1}{n} \times r^{8/3} \times I^{1/2} \times \alpha$$

$$= \frac{1}{0.013} \times 0.3^{8/3} \times (1/650)^{1/2} \times 1.93448$$

$$= 0.235\ m^3/sec > 0.126\ m^3/sec$$

Velocity:

$$V = \frac{1}{n} \times r^{2/3} \times (1/650)^{1/2} \times 0.71799$$
$$= 0.971 \text{ m/sec} \quad 1.0 \text{ m/sec}$$
(allowable maximum velocity)

As a result of the above calculations, a 50 m long 600 mm diameter culvert will be installed with a 1/650 slope. In order prevent sand intrusion, the entire culvert shall be covered with a 30 to 50 cm layer of 30 to 100 mm in diameter gravel.

③ Summary of Intake Facilities:

Table 5-20 Intake Facilities

Facilities	Description
Cutoff Wall	Mass concrete 32 m long, spillway width: 1.0 m Height: 1 m above the riverbed Foundation: Fixed on base rock
Apron	Mass concrete 3.0 m long, 28 m wide, 60 cm thick
Riverbed Protection	Wired mattresses (groyne) 9 m long, 28 m wide
Intake Water Collecting Culvert	600 mm diameter 50 m long
Water Collecting Box	Reinforced concrete 2.40 m x 1.80 m x 4.50 m
Water Intake Amount	0.126 m^3/sec

(3) Pipeline:

① Selection of the Pipe

The pipeline can be built with various types of pipes, i.e., ductile cast-iron pipes, steel pipes, asbestos cement pipes, polyvinyl chloride pipes, etc. The comparisons of these pipes are shown in Table 5-21.

Table 5-21 Comparison of Pipes

Aspect \ Pipe	1 Ductile cast-iron Pipe	2 Steel Pipe	3 Asbestos Cement Pipe	4 Polyvinyl Chloride Pipe
1. Structure	Strong to external and internal forces. Strong corrosion resistance.	Strong to external external force, and impact loads. Durable.	Chemical-proof. Strong to impact loads. Prefer to relatively strong internal force.	Not suitable for strong external and internal force.
2. Installation	Heavy material. Not suitable in soft ground.	Welding is for joining pipes, and the welding work must be done under dry conditions.	Requires careful handling. Easy to crack during transportation and installation.	Light material. Easy to handle and to install. Suitable in soft soft ground.
3. Economy	Expensive	Relatively expensive	Low cost	Low cost

Pipe type shall be selected by examining the above pipe and the Project area conditions. Based on the area survey and data collected by the study team, the following aspects were examined:

i) Intake water will be conveyed by gravity flow. The internal force will be small. No roads cross the planned pipeline route, and the external forces on the pipe will be comparatively small.

ii) Soil along the pipeline route is sand; it has enough strength to support a pipeline. There will be no uneven land settlement.

iii) One of the policies of the Project is to install irrigation facilities at low cost and by using available technical skills. The irrigation facilities in the model field shall be of such a type as is applicable to other areas in the southern provinces.

Taking into consideration the above examinations, ductile cast-iron pipes and steel pipes are not applicable for use in the Project area, mainly for economical reasons. Polyvinyl chloride pipes are easier to install than asbestos cement pipes; however, in Zambia, polyvinyl chloride pipe is not manufactured. Considering the possibility of installing irrigation facilities in other parts of the country with locally available techniques, it is preferable to use asbestos cement pipes which are presently available in Zambia. From the aspect of future repair and maintenance work, it is preferable to use locally available pipe. In Zambia, asbestos cement piping is widely used at the present time; therefore, there will be no difficult problems using asbestos cement pipe for the model field. Thus, it has been decided to use asbestos cement pipes for the Project's model field pipeline.

② Pipe Diameter:

The Hazen-Williams formula is used for the hydraulic calculation of the pipeline. The basic equation of the formula is as follows:

$$V = 0.84935\ C\ R^{0.63}\ I^{0.54}$$

From this equation, the following equation can be derived to determine the flow in a pipe:

$$V = 0.35464\ C\ D^{0.63}\ I^{0.54}$$

$$Q = 0.27853\ C\ D^{2.63}\ I^{0.54}$$

$$D = 1.6258\ C^{-0.38}\ Q^{0.38}\ I^{-0.205}$$

$$I = h_f/L = 10.666\ C^{-1.85}\ D^{-4.87}\ Q^{1.85}$$

where,
- V: Average velocity of flow (m/sec)
- C: Hazen-Williams roughness coefficient (see Table 5-)
- R: Hydraulic radius
- I: Energy slope
- D: Diameter of pipe (m)
- h_f: Head loss (m)
- Q: Discharge (m^2/sec)
- L: Pipe Length (m)

Table 5-22 Values of C in Hazen-William Formula

Type of Pipe (inside)	Values of C		
	Max values	Max values	Max values
Asbestos Cement Pipe	160	140	140
Hard Polyvinyl Chloride Pipe	160	140	150
Polyethylene Pipe	170	130	150
Strengthened Plastic Composite Pipe and Cenntrifugal Force Strengthened Plastic Composite Pipe	160	-	150

Source: Use C = 140 for a pipe less than 150 mm in diameter.

The necessary amount of irrigation water for the Project can be calculated by using previously obtained figures as follows:

Crop water requirement: ET crop = 6.5 mm/day

Irrigable Land: S = 100 ha (50 ha on left bank; 50 ha on right bank)

Irrigable efficiency: 60%

Irrigating period: 24 hr

Thus, Q becomes as follows:

$$Q = 6.5 \text{ mm/day} \times 10^{-3} \times 50 \text{ ha} \times 10^4 \times \frac{1}{0.6} \times \frac{1}{60x60x24}$$

$$= 0.063 \text{ m}^3/\text{sec}$$

The energy slope can be obtained by dividing the head difference between the intake point and the discharge point of the pipeline (h = 4.95 m) with the pipeline length (3.0 km):

$$I = \frac{4.95}{3,000} = 1.6 ‰.$$

The roughness coefficient of an asbestos cement pipe is C = 140 from Table 5-22. Therefore, the necessary pipe diameter of the pipeline is as follows:

$$D = 1.6258\ C^{-0.8}\ Q^{0.38}\ I^{-0.205}$$

$$= 1.6258 \times 140^{-0.38} \times 0.063^{0.38} \times 0.00165^{-0.205}$$

$$= 0.323 \text{ m}$$

Thus, the pipe diameter of the pipeline shall be 350 mm

.

The allowable maximum average velocity in an asbestos cement pipe is 3.0 m/sec. The minimum average velocity of 0.3 m/sec should be maintained to prevent sediment deposits in the pipe.

The velocity in the 350 mm diameter pipeline will be as follows:

$$I = 10.666\ C^{-1.85}\ D^{-4.87}\ Q^{1.85}$$

$$= 10.666 \times 140^{-1.85} \times 0.35^{-4.87} \times 0.0063^{1.85}$$

$$= 1.140 ‰.$$

$$V = 0.35464 \cdot C \cdot D^{0.63} \cdot I^{0.59}$$

$$= 0.35464 \times 140 \times 0.35^{0.63} \times 0.001140^{0.59}$$

$$= 0.660 \text{ m/sec}$$

In order to convey the required amount of water, the slope of the pipeline must be equal or larger than the energy grade line of the flow. It is desirable for the head difference between the intake point and the discharge point of the pipeline to be larger than the head loss plus 0.5 m.

The friction loss in the pipeline is as follows:

h_f = L . I = 3,000 x 1.140 ‰ = 3.42 m

Other loss = friction loss x 10% = 3.42 x 0.10 = 0.34 m

Therefore, the required head difference is:

3.42 + 0.34 + 0.50 = 4.26

The elevation differences between the intake point to the discharge points of the pipeline are 4.95 m on the right bank of the river and 5.95 m on the left bank. Thus, it is possible to convey the required amount of water through the pipeline.

(3) Appurtenances for the Pipeline:

For the safety and maintenance of the pipeline, it is required to install air-relief valves, control valves, sediment flushing facilities, and river-crossing structures.

1) Air-relief Valve:

An air-relief valve shall be installed at each of the following points:

a. Where mild pipeline slopes become steep downward slopes.

b. Immediately downstream of a control valve in a pipeline having a downward slope.

c. Immediately upstream of a control valve in a pipeline having and upward slope.

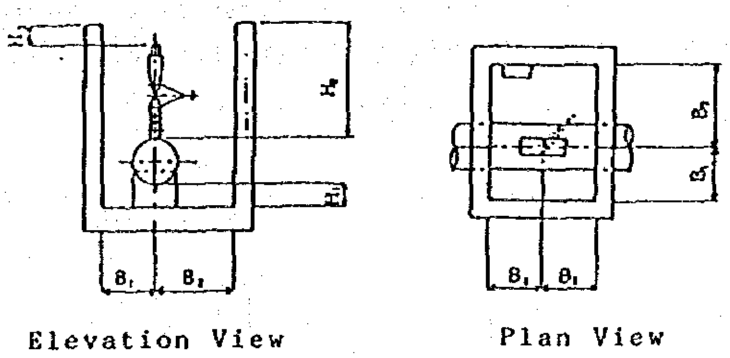
d. At the highest point of a pipeline.

e. Where there is a change in the downward slope and an engineer deems it necessary to install the valve.

f. At 400 m intervals in pipelines having long, very mild slopes.

The Project pipeline route is in relatively flat areas; conditions "d" and "f" above will be applicable. Thus, a total of six air-relief valves are planned to be installed: 3 each on both banks of the river. The necessary air-relief pipe size is normally 1/5 to 1/8 times the diameter of the pipeline -75 mm diameter air-relief valves are planned for the Project pipeline. The air-relief valves shall be installed as shown in Fig. 5-12.

Fig. 5-12 Air-relief Valve Protector



The air-relief valve protector shall be built with cast-in-place concrete.

Height of the Protector:

The allowance height (H_1), from the base plate of the protector to the bottom of the pipe, shall be 250 mm to 300 mm. H_2, the height from the pipe top to the top of the protector, shall be sufficient to contain a tee joint for the air-relief valve installation, a cutoff valve, an air-relief valve, and a 100 mm to 200 mm allowance (H_3) from the top of the air-relief valve to the top of the protector wall.

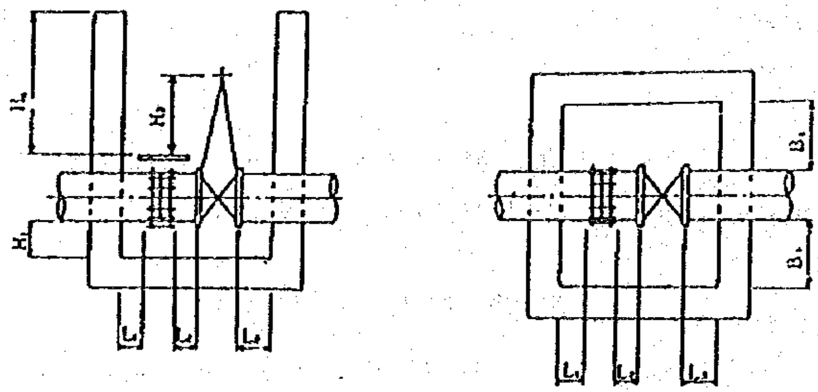
The plan dimensions of the protector:

The distance between the air-relief valve center and three of the walls shall be 600 mm, allowing sufficient space for maintenance work. The distance from the air-relief valve center to the remaining wall shall be 900 mm, allowing enough space for cutoff valve operation.

ii) Control Valves:

Three control valves shall be installed at the upstream sides of the three river-crossing points for flow cutoff, sediment flushing, and pipe draining purposes. For the Project pipeline, as it will not be necessary to control water discharge, gate valves will be used. The valve chamber is shown in Fig. 5-13.

Fig. 5-13 Valve Protecting Chamber



Elevation View Plan View

Chamber Height:

H_1, the allowance between the chamber base and the bottom of the pipe, shall be 250 to 300 mm to allow sufficient working space. H_3, the height from the valve top cover to the valve handle, shall be 1,000 to 1,200 mm (approximately the chest height of an average person). H_4, the height from the valve top cover to the top of the chamber, shall be higher than 1,600 mm to permit a person to turn the valve handle from a kneeling position.

Chamber length (inside dimension parallel to the pipe):

L_1, the allowance between the chamber wall to the expansion joint, shall be 200 mm to provide adequate working space. L_2, the clearance between the expansion joint and the valve flange, shall be 100 mm. L_3, the clearance between the valve flange and the chamber wall shall be 400 to 500 mm.

Chamber width (inside dimension perpendicular to the pipeline):

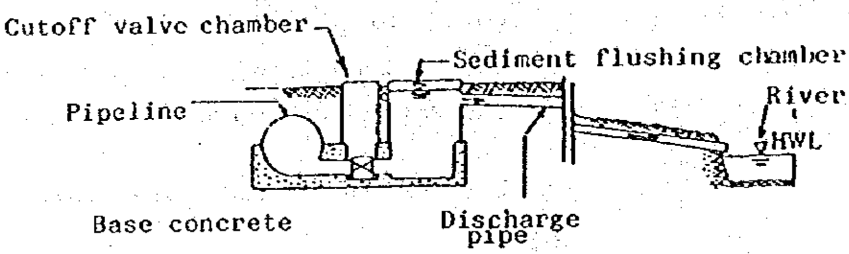
The clearance between the chamber wall and the pipe surface shall be 600 mm to permit adequate working space.

iii) Sediment Flushing Facilities:

For the operation and maintenance of the pipelines, sediment flushing facilities shall be installed so that water can be completely drained at the pipelines lowest elevation in the vicinity of a river-crossing point.

There will be one pipeline on each bank of the river. Each pipeline will cross the river three times. At these crossing points sediment flushing facilities will be required. The sediment flushing chambers will be large enough to be accessible for operation. Normally, the chamber size is larger than 1.5 m. Fig. 5-14 shows the sediment flushing facilities.

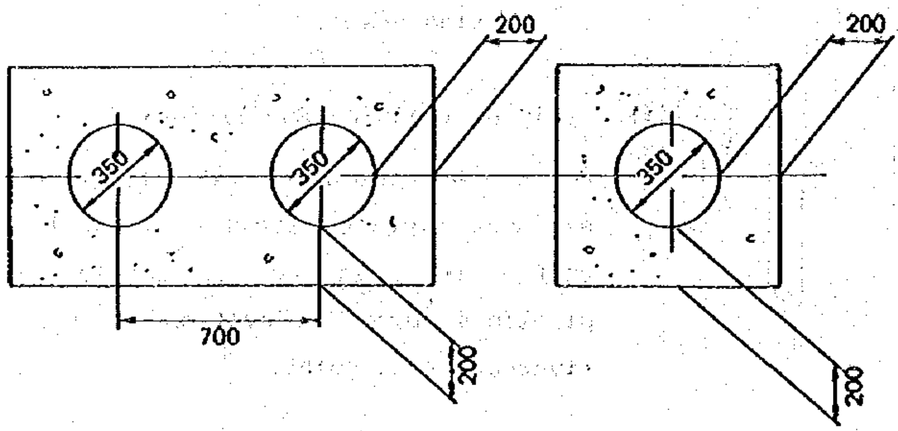
Fig. 5-14 Sediment Flushing Facilities



iv) River-crossings:

At river-crossing points, the pipelines shall be installed lower than the riverbed and protected with 20 cm thick concrete. Doing so, will prevent disturbance to the river flow. There are a total of four river-crossings: two upstream from the pipeline's diverting point, and one for each pipeline downstream of the diverting point.

Fig. 5-15 Pipeline Protection



④ Summary of Water Conveyance Facilities

Table 5-23 Water Conveyance Facilities

Facility	Description
Pipeline	Asbestos cement pipe Length: 3,000 m on right bank 2,900 m on left bank
Air-relief Valves	75 mm diameter, 6 on right bank pipeline 6 on left bank pipeline Total: 12
Control Valves	Control Valves: 3 in right bank pipeline 3 in left bank pipeline Total: 6
Sediment Flushing Facility	3 on right bank pipeline 3 on left bank pipeline Total: 6
River Cross Cross	2 places upstream of diverting point 2 places downstream of diverting point Total: 4

⑤ Irrigation Channels:

The discharge from the pipeline is $Q = 0.063\ m^2/sec$. In order to distribute the irrigation water to each model field, it is planned to install soil-cement lining open channels. The Manning formula is used to perform the hydraulic calculations of the open channel:

$$A = A \cdot V$$

where, Q: Discharge (m^3/sec)

A: Cross section of flow (m^2)

V: Average flow velocity (m/sec)

$$V = \frac{1}{n} \cdot R^{2/3} \cdot I^{1/2}$$

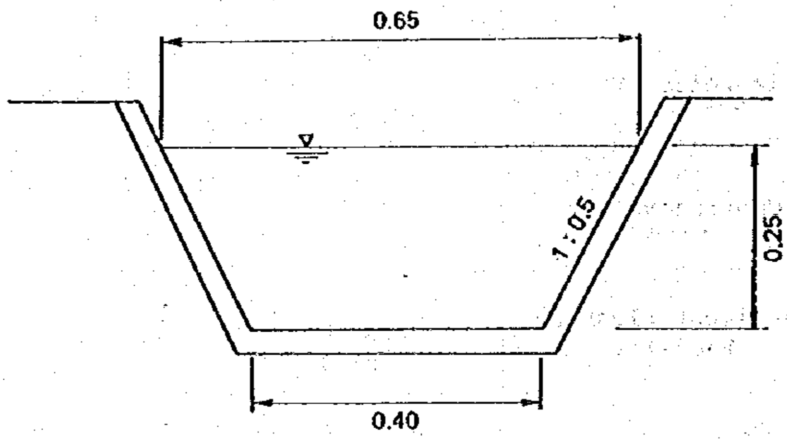
where, n: Manning's roughness coefficient (0.015 for cement lining)

R: Hydraulic radius

I: Slope of the energy grade line

The average minimum velocity in the open channel shall be 0.45 m/sec to prevent sediment deposits in the channel. The allowable maximum average velocity in the soil-cement lining channel shall be 1.5 m/sec. The required channel cross section is assumed as follows:

Fig. 5-16 Plan of Open Channel



$Qa = 0.063\ m^3/sec$ (planned discharge)

$I = 1/1,300$ (Average channel slope in the field)

$A = (0.40 + 0.65) \times 1/2 \times 0.25 - 0.131\ m^2$

$P = (0.28 \times 2 + 0.40) = 0.960\ m$

$R = A/P = 0.136,\ R^{2.3} = 0.265$

Therefore, the velocity and discharge in the channel are:

$V = 1/0.015 \times 0.265 \times (1/1,300)^{1/2} = 0.490\ m/sec$

$Q = A \cdot V = 0.131 \times 0.490 = 0.064\ m^3/sec \quad Q_a = 0.063\ m^3/sec$

The freeboard of the channel may be calculated by using the following equation:

$Fb = 0.0d + h_v + (0.05\ to\ 0.15)$

where, Fb: Freeboard (m)

b: Flow depth (m)

h_v: Velocity head = $V^2/2g$ (m)

g: Acceleration of gravity (9.8)

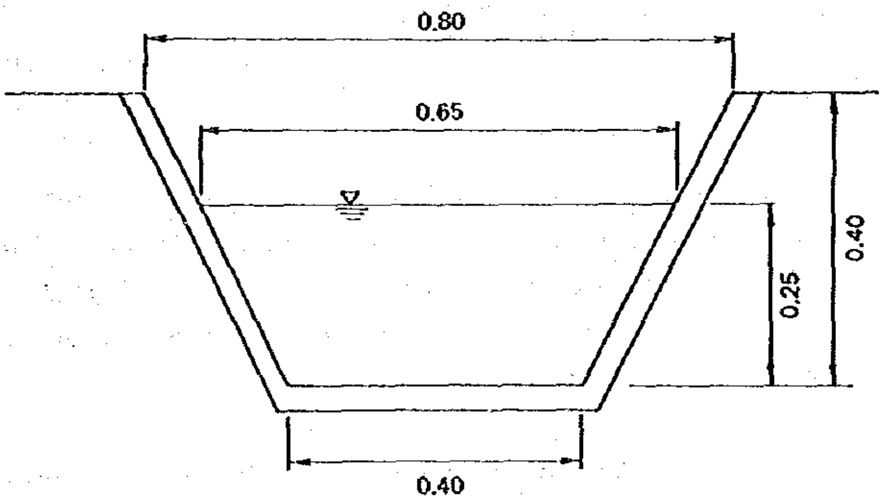
Therefore,

$$Fb = 0.05 \times 0.25 + \frac{0.490^2}{2 \times 9.8} + (0.05 \text{ to } 0.15)$$
$$= 0.01 + 0.01 = (0.05 \text{ to } 0.15)$$
$$= 0.07 \text{ to } 0.17$$

Thus, Fb shall be 0.15 m.

The irrigation channel shall have the following cross section:

Fig. 5-17 Cross Section of Open Channel



The planned model field areas are to be in the lower regions of Chikokora, which is on the right bank of the river, and Mranba, which is on the left bank. Therefore, the irrigation channels shall be installed from Chikokora to Mpona on the right bank, and from Mranba to Chitowa on the left bank. 50 ha of farmland shall be developed each irrigation channel. The total lengths of the channels are 3,735 m on teh right bank and 2,262 on the left bank. Since the irrigation intervals are six days, each channel shall be divided into six sections and, by operating the installed check valves, irrigation water will flow into the irrigation ditches during those times. Water intake points from the channels shall be installed at 30 m intervals.

Table 5-24 Irrigation Channel

Item	Description
Irrigation Channel	Cross section: 0.40 m (base) x 0.8 m (top width) x 0.40 (height) Length: 3,735 m on right bank 2,262 m on left bank
Check Gate	6 on right bank 6 on left bank Total: 12 each
Intake Mouth	One every 30 m

(5) Distribution Pond:

A distribution pond shall be installed near each village along the irrigation channel for the villagers' domestic use. The size of the pond shall be decided upon in accordance with the size of the village population.

According to the World Health Organization (WHO) report, domestic eater supplies, per capita, during 1973 in rural areas of the world were as follows:

Domestic Water Supplies per Capita in Rural Areas

(Unit: Liter/person/day)

Africa:	13 - 35
Southeast Asia:	30 - 70
Western Pacific Regions:	30 - 75
East Coast of the Mediterranean:	40 - 85
Latin America & Caribbean Sea Regions:	70 - 190
Average of all underdeveloped countries:	35 - 90

Feachem, et al., reported the 1972 statistics of domestic daily water consumption using different water supply methods in rural areas of underdeveloped countries as follows:

Average Daily Water Use per Capita (liter/person/day)

Water Supply Condition	Average Daily Use	Daily Use Range
No Pipe Supply:	15	5 - 25
Stand Pipe:	30	10 - 50
Pipe Supply:		
Single Faucet	50	10 - 100
Multiple Faucets	150	50 - 300

Based on the above statistics, domestic water use from the distribution pond is estimated to be 15 liters/person/day.

There are eight villages in the Project area: Sipopa, Chikkola, Balakasau, and Mpona are on the right bank of the Kaunga River; Mulanba, Mkando, Kanaventi, and Chitowa are on teh left bank. The villages of Sipopa and Chikokola, and Chitowa and Kanaventi are located very close to each other. Thus, only one distribution pond will be installed for each of those two village groups.

From August to October there will be no water inflow to the distribution pond. Therefore, it will be necessary to store enough water for tuse during that period. Table 5-25 lists the calculated necessary distribution pond capacities for each village.

Table 5-25 Distribution Pond Capacities for Villages

Village	Number of Homes	Size of Work Force	Population	Necessary Water (m^3)	Pond Capacity	Remraks
Sipopa Chikokola	31 21	88	173	234	240m^3	
Balakasau	13	21	41	55	60m^3	
Mpona	44	71	139	188	190m^3	
Mlanba	11	18	35	47	50m^3	
Mkando	23	41	80	108	110m^3	
Chitowa Kanaventi	7 14	37	73	99	100m^3	
Terminal Point of Channles					1,000m^3	One on each bank

Note: Work forces are comprised of people whose ages are over 15 years old (51% of the entire population).

2. The Project Office and Experimental Farm

(1) Facilities of the Project Office

1 Floor Plans for the Buildings:

The floor plans for the buildings were made considering the work process and work flow of the Project. further, considering the minimal use of reinforcing steel bars and cement material, flat type buildings were chosen for the Project. Building floor areas were decided based upon the standards of the Department of Public Works and the Department of Agriculture of Zambia by referencing the Japan Society of Architects' (JAS) Manual of Facility Design Criteria. The floor plans for the Project are shown in Table 5-5.

Table 5-5 Required Floor Area per Person

Classifications	Japanese Standard (JAS)	Zambian Specifications	This Project
Office Room	7.5 m^2/person	6.0 m^2/person	6.0 m^2/person
Training (Class) Room	1.5-2 m^2/person	1.5 m^2/person	1.5 m^2/person
Conference Room	4.0 m^2/person	3.0 m^2/person	3.0 m^2/person
Sanitary Room	One/15 people	One/15 people	One/15 people

i) Size of Building:

1) Management Office Building		130.0m^2
Name of Room	Floor Plan Standard and Reason	Planned Area
Manager's Office	Manager: One 7.5 m^2 For Vistor: 6.0 m^2	13.5m^2
Researcher's	No experimental work - desk work only, Standard is 5.2m^2/person, but little allowance is given due to two persons in each room (total 3 rooms): 5.2 x 2 = 10.4m^2, say 13.5m^2/ea	

i) Size of Buildings:

Table 5-6 Planning for Facilities

1) Operation and Management Office Building		130.0m^2
Name of Room	Floor Plan Standard and Reason	Planned Area
Farm Manager's Office	Farm Manager: One 7.5 m^2 For Vistor: 6.0 m^2	13.5m^2
Engineers's Office	No experimental work - desk work only. Standard is 5.2m^2/person, but little allowance is given due to two persons in each room (total 3 rooms): 5.2 x 2 = 10.4 m^2, say 13.5 m^2/ea	13.5 x 3 = 40.5m^2
Administration Office Room	5 persons 6.0 x 5 = 30.2 m^2	30.0m^2
Conference Room	10 persons per meeting 3.0 x 10 = 30.0 m^2	30.0m^2
Hallway & Sanitary Room		16.0m^2
2) Training Center Building		100.0m^2
Training Room	50 Farmers Seminar: 15-20 people x 2.0 m^2 Seminar: 50 people x 1.5 m^2 Seminar: 80 people x 0.8 m^2 50 x 1.5 m^2 = 75.0 m^2 Control Space: 12.0 m^2	87.0m^2 87.0m^2
Sanitary Space	Assuming that the numbers of male and female attendees are equal (total 50 attendees). To install one each water closet and urinal per 15 people. 25/15 = 1.6, say 2 units For males: 2 water closets, 2 urinals, 1 sink = 7.2 m^2 For females: 2 water closets, 2 sinks = 6.0 m^2	13.0m^2
3) Garage and Repair Shop		275.25m^2
Garage Space	5 vehicles Space for one vehicle: 2.75m(W) x 6.0m(L) = 16.5 m^2 16.5m^2 x 5 = 82.5m^2, adding wall space:	86.25m^2
Parts Stowage	(2.75 m x 6.0 m)	16.5m^2

Name of Room	Floor Plan Standard and Reason	Planned Area
Tool Stowage	5.75 m x 6.0 m	34.5m^2
Repair Shop	Inspection and repair space: 1.0m(W) x 7.0m(L) x 1.2m deep pit 69m^2 Work Space 60m^2	134.5m^2
4) Stowage Building		129.6m^2
Seeds and Fertilizer	5.4 m x 3.6 m	19.44m^2
Agricultural Medicine	1.8 m x 3.6 m	6.48m^2
Parts Stowage	4.5 m x 3.6 m	16.20m^2
Tool Stowage	3.6 m x 2.7 m	9.72m^2
Stowage Space for Agricultural Machinery	Tractor (large) 2 ea Discplouch 2 ea Discharrow 2 ea Tractor (small) 2 ea Cultivator 2 ea Mini-backhoe 1 ea Trailer 1 ea Powered Sprayer 1 ea (7.2 m x 10.8 m)	77.76m^2
5) Lodging Facilities		239.9m^2
Bedroom Living & Dining Room Bathroom & Kitchen	2.7 m x 4.2 m x 2 rooms 22.68m^2 4.8 m x 4.44 m 22.312m^2 3.6 m x 4.44 m 15.984m^2 Total one building 59.976m^2 59.976 x 4 buildings	239.9m^2
6) Power Generator		60.0m^2
Generator House	20 Kva 2 ea 240 V 37 Kva 1 ea 380 V	60.0m^2
TOTAL		934.75m^2

2 Building Plan

i) Plan:

a. Operation and Management Office Building

This building will be the center of operation, management and research activities of the Project. All office rooms, manager's office, and conference room are arranged on both sides of the building entrance. Since the researcher's offices will be local site offices, the rooms are designed to accommodate two persons each, with a space of 13.5 m^2.

b. Farmers' Training Center Building:

This building will be used as the training site to instruct farmers in irrigational farming methods. The building, having four entrances/exits, is to be located close to the experimental farm so that farmers can come and go the farm quickly and easily. Assuming that the number of male and female attendees are the same, segregated sanitary facilities are necessary. The floor space of the building was calculated by alloting 1.5 m^2 per each attendee and adding 12 m^2 for control space.

c. Garage and Repair Shop:

Vehicles will be used for extension activities and for inspection trips to the experimental farm and the model field. The location of the garage puts it relatively close to the management office building. It will be so situated as to prevent vehicular traffic from interferring with the movement of agricultural equipment. There will be a pit in the repair shop that can be used for the repair and inspection of vehicles. There will also be a space for the storage of spare parts and tools.

d. Storage Building:

The storage building will be divided into five sections for seeds and fertilizers, agricultural medicines, parts, tools, and agricultural machinery. Seed and fertilizer will be in the same room because they are seasonal items requiring frequent issue and replenishment. The section for agricultural medicines, in order to protect it from direct sunlight, will have no windows. Parts and tools stowage places will be separate because they are easy to control.

e. Lodging Facilities:

The room sizes for the lodging facilities were determined based upon the middle class dwelling standards of the Department of Water Development of Zambia. The kitchen is designed to use propane gas, charcoal or kerosene for fuel. As the winter temperatures are moderate, the bathrooms will be equipped with electric hot water heaters. These facilities were also designed to accommodate visiting Japanese technical advisors.

f. Power Generator:

Three diesel generator units are planned to be installed in the power generating house. It will be designed to have the necessary space for the generator units, a repair and maintenance area, and a fenced in area for fuel storage. Electric fans will provide ventilation when the generators are in operation.

ii) Three-dimentional Plan

For the three-dimensional plans of buildings, and the formative art of the Project complex, the architectural design shall be such that all facilities will be suitable to the Zambian climate and will meet Zambian testes as outlined in the Basic Design Policy.

From a functional view, long eaves shall be installed as protection against strong sunlight and to prevent rain from blowing in. The walls of living quarters and offices shall have large windows to permit fresh air to enter.

iii) Buildings' Cross Section Plan:

The cross section plans are to meet the requirements of preventing rain from blowing into the buildings, and providing the buildings protection against strong sunlight and strong winds.

Roofs will have long eaves, and the other walls of living quarters and offices will have large openings. Sloped roofs shall be installed to allow rain water to drain quickly. There will be ventilation spaces the roofs.

Ceilings will be installed to insulate rooms against heat. To permit proper air circulation, 24 m will the minimum allowable ceiling height. Rooms that are to be used by many people at one time will have ceilings of maximum possible height.

The spaces for cable and pipe installation shall be of sufficient size of allow for future changes or expansion, and must be readily accessible for maintenance and repair work.

iv) Structural Plan:

In Zambia, lightweight concrete block structures are commonly used as the most rational and economical construction method. For the structural plan of the Project, lightweight concrete structures will be used for building construction. Zambian specifications will be used for selecting the design loads of buildings and design criteria.

a. Ground base:

Soil in the Project Office area (soil sampling location No. 9, Fig. 3-5) is sandy loam having 27% sand (see Fig. 3-7). The bearing strength of the ground is suitable for the construction of flat lightweight concrete-block building. For the foundations of the Project Office buildings, direct foundation types will be used and will have depths of -0.7 m below ground level and bearing strengths of 5.0 tons/m^2. This type of foundation is generally used in the area.

b. Structure design:

Building structures will be lightweight concrete types. Rooms shall be separated by lightweight concrete block walls. Roofs shall be supported by lattice structures.

As for design criteria, British Standards (BS) is used in Zambia. The following criteria shall be used in the building design of the Project:

Dead load and active load	:	BS 6399 Part 1 (1984)
Wind load	:	BS CP 3 Chapter V (1972).
Lightweight concrete-block structures	:	The Standards of Japan's Society of Architects.
Reinforced concrete structure	:	The Standards of Japan's Society of Architects.

Table 5-7 lists the main active loads for the design of the Project Office building. The design wind load shall be based on winds of 35 m/sec (approximately 75 miles/hr) which is classified as tropical monsoon zone winds in the BS CP 3. No seismic load will be considered for structure design as earthquakes have never been recorded in Zambia.

Table 5-7 Active Loads for Building Design

Name of Room	Active Load (Kg/m^2)
Office	225
Research Room	306
Laboratory	306
Training Room	306
Conference Room	510
Hallways & Balcony	306

Source: BS 6399 Part 1, 1984

v) Facility Plan:

a. Electric Facility Plan:

Electricity will be generated by diesel engines. The following items are required for the facility:

Generator equipment
Main power distribution lines
Lighting fixture and outlets

- Generator equipment:

The generator equipment is designed to supply sufficient amounts of power to Project facilities. The specifications of the generator equipment are as follows:

Output:	77 Kva
Voltage:	3 ph. 380 V
Cycles:	50 Hz
Engine:	Diesel engine
Cooling Method:	Air-cooled, indoor type

- Main power distribution:

Main power distribution lines shall be installed from the power generating station to each building and facility.

- Lighting fixtures and outlets:

The lighting fixtures shall be fluorescent tubes and, in a few cases, incandescent light bulbs. A light switch shall be installed in each room in close proximity to its entrance. Outlets shall be for 220-240 V based on the British Standards.

Table 5-8 shows the lighting standards for the Project Office building.

Table 5-8 Lighting Standards

Standard Lighting (Lux)	Name of Room
100	Sanitary Room, Storage Room, Power Generating House
150	Hallway, Bathroom, Agricultural Machinery Storeroom
200	Bathroom, Kitchen
240	Living & Dining Room
300	Training Room, Repair Shop
400	Manager's room, Offices, Conference Room

- Cable conduit:

Electric cables shall be installed in conduits. In the buildings, steel conduits shall basically be installed above the ceilings. Outside of the buildings, hard pipes of polyvinyl chloride shall be installed for cabling.

- Grounding work:

One grounding plate shall be installed in the power generating house for grounding the generator unit. One grounding rod shall be installed for each building.

- Standards of electric facility:

  Generators, lighting fixtures, grounding rods, electric cables shall be in conformity with the Japanese Industrial Standards (JIS). JEC, and JEM. Outlet and switch units shall be in accordance with Zambian Standards (BS).

  Temperature conditions:

Outdoors:	Max. 40°C
Indoors:	Max. 40°C
Underground:	Max. 40°C
Humidity:	Max. 85%

b. Water Supply and Sewage Systems:

- Water shall be supplied from a 250 mm diameter, 70 m deep well. A 3 m^3 capacity water storage tank shall be installed at a height of 5.0 m above ground level. The well and storage tank are arranged to be installed at the highest point in the Project site in order to maintain high static water pressure.

- Drainage system:

  Sewer and drain water shall be treated in septic and infiltration tanks. The specifications for the infiltration tank shall be based on the British Standards.

c. Fueling station:

- The fueling station shall have a 4,000 liter capacity gasoline tank and a 4,000 liter capacity diesel fuel tank. The gasoline tank shall be installed underground. The diesel fuel tank shall be installed above ground. Fueling shall be conducted by means of hand pumps.

  Three service tanks for the diesel generator units shall be installed in the power generating house.

vi) Building Materials and Exterior and Interior Finishes

- Building materials:

Local material shall be used as much as possible. Only material that is not locally available shall be Japanese made.

Cement:	Ordinary Portland cement (mass concrete with local cement, finish work with Japanese cement)
Coarse aggregate:	Local crushed stone
Fine aggregate:	Local river sand

- Concrete:

The concrete mixture shall be of ordinary Zambian Portland cement. Its design strength shall be 180 kg /cm^2. The slump of concrete shall be in the range of 10 - 15 cm. Cncrete materials shall be mixed with "volume mix."

- Reinforcing bars:

Japanese made, or equivalent, material shall be used. The quality of the bars shall be in conformance with SD 30 and SD 24 (JIS). The joints of the reinforcing bars shall be lap joints. The bars are to be round with diameters of 6 - 13 mm; those with larger diameters shall be deformed bars.

- Wood material:

Zambian wood will be used for wooden structures and finishing material.

- Building methods:

- Roof:

Roofs shall be waterproof types that are durable and can withstand strong sunlight and heavy rains. There shall be a ventilation space between the roof and the room below for the purpose of preventing heat radiation.

Good quality asbestos corrugated plate is available in Zambia. It is desirable to use this material in roof construction.

Eave lengths should be as long as possible to provide protection against rain and heat.

- Outer wall:

Outer walls are subjected to strong sunlight and rain. The wall material shall have a heat insulation effect. Thus, the external walls will be built with lightweight concrete blocks "W200", and the interior walls will be finished with white cement mortar. Sash windows will be installed in the walls to allow natural air ventilation within the rooms.

- Floor:

During the rainy season, there are occasional high intensity rainfalls that cause flooding in the area. Therefore, the height of building floors must receive careful consideration.

Terazzo tiles will be used on building floors. Floors are to designed to be 60 mm higher than the terrace elevation to prevent rainwater damage.

- Ceiling:

In order to have a ventilation space below the roof it will be essential for the room below to have a ceiling. This ventilation space will help to prevent heat radiation. Locally available tapboard installed with steel T-bars will be used for ceilings.

- Finish Work:

Exterior:

Walls: Lightweight hollow concrete blocks W200 mm, decorative piling, white cement spray finish.

Roofs:	Asbestos corrugated plate covering, truss and spiral-truss structures (steel)
Windows:	Steel sash with O.P. fly screen, burglar bar installation
Porch & Terrace:	Motor steel trowel joint finish
Entrances:	Wooden flush doors, O.P. finish

Interior:

Walls:	Mortar steel trowel finish, VP finish
Floors:	Motar base, PVC tile finish
Baseboard:	Motar base, PVC H 100mm
Ceilings:	Slate board 6 (tapboard) EP 600 x 600

Toilet & bathroom:

Floor:	Mozaic tile or OVC tile finish
Walls:	Tile finish up to the door height, 150, White. Higher areas with mortar, steel trowel, white paint finish.

vii) Yard Plan:

The following four facilities shall be constructed in the Project Office area:

- Roads in the Project Office area.
- Drying area: 15 m x 30 m = 450 m^2.
- Weather observation area: 6m x 8m = $48m^2$.
- Wind direction and speed gage tower: Steel lattice tower, h = 10.0m 3 platforms.
- Fuel station area: Concrete pavement, 150 mm thick.

(2) Experimental Farm with Irrigation Facilities

① Experimental Farm:

Many different types of crops will be planted at the experimental farm for research and test cropping purposes. In order to conduct the research and test cropping in accordance with a variety of themes and crops, a large area of land and many research personnel and workers will be required for the Project. In the Project, research personnel will carry out their research work and will also participate in extension activities teaching farming methods and informing neighboring farmers of the crops most suitable to grown in their areas. It is planned to have six researchers working in six different fields: general farming, dry field farming, agricultural civil engineering, irrigation facilities, agricultural equipment, and extension work.

In general, the land necessary for efficient research work by one researcher is approximately 0.5 ha. The area of the experimental farm is based on that figure. That is, 0.5 ha x 6 persons = 3 ha.

The Project area is relatively flat with a mild downward slope to the southwestward. It is assumed that the ground water follows a similar slope as it flows towards the Kaunga and Luangwa rivers.

It is planned to locate the Project Office one hectare complex next to the school and the church and along and access road that connects to rural road No. 216. This area is very accessible; it will be easy to contact village people from here. Two blocks of the experimental farm will be facing the road, while another block will be to the rear. With this arrangement the experimental farm can be effectively demonstrated (see Section 5-3-3 of Basic Design Drawing).

The main road, including drainage ditches, in the Project area shall be 10 meters wide. This road will be wide enough to allow agricultural machines to pass one and other. Branch roads shall be six meters wide to permit safe transit of pedestrians and agricultural machinery.

The two blocks of the experimental farm that are alongside the access road will use furrow irrigation systems. These blocks will be subdivided into 20 m x 50 m lots. Each lot will be used for a single purpose of research. A 150 mm diameter pipe will convey irrigation water to these lots. On discharge plug with a water gage shall be installed at each lot.

The remaining block of the experimental farm will be equipped with a sprinkler and drip irrigation system. This block will be used to compare crops' growth rates using different irrigation methods.

i) Furrow Irrigation Farm:

In order to measure the amount of irrigation water for each test cropping, it is planned to install 150 mm diameter water supply pipes with a gate valve and a water meter at each outlet. The outlets shall be installed at intervals of 1.0 m so that furrows can be properly spaced for the crop being planted. Two water supply pipelines shall be installed in parallel, 50m apart, in each experimental lot.

ii) Sprinkler Irrigation Farm:

The sprinkler irrigation farm shall be divided into 50 m x 100 m lots. There are sprinkler heads designed for installation at 6 m, 12 m, 18 m, and 24 m intervals. For this farm, sprinkler heads designed for 12 m intervals will be used. Thus the arrangement of the sprinkler heads in each farming lot shall made to have eight rows (12 m x 8 rows = 96 m), each row having four sprinkler heads (12 m x 4 sets = 48 m). The amount of irrigation water required by each type of test cropping can be changed by adjusting the intervals of the sprinkler heads.

iii) Dripping Irrigation Farm:

The dripping irrigation farm is to be located next to the sprinkler irrigation farm. It shall divided into 50 m x 100 m lots. Judging from the themes of test croppings and the lot length, fourty rows of 16 mm diameter pipes with dripper intervals of 0.5 m shall be installed with lengths being 95 m with 1.0 m intervals.

② Irrigation

Necessary irrigation water can be calculated based on the figures obtained in Chapter 5-2-1, (2).

Crop water requirement: 6.5 mm/day
Irrigation efficiency:
Furrow irrigation: 60%
Sprinkler irrigation: 80%
Dripping irrigation: 90%

Therefore, the amount of necessary irrigation water is as follows:

For furrow irrigation:

$$Q_1 = 6.55 \text{ mm/day} \times \frac{1}{0.6} \times 2.0 \text{ ha} = 217 \text{ m}^3\text{/day}$$

For sprinkler irrigation:

$$Q_2 = 6.5 \text{ mm/day} \times \frac{1}{0.8} \times 0.6 \text{ ha} = 41 \text{ m}^3\text{/day}$$

For dripping irrigation:

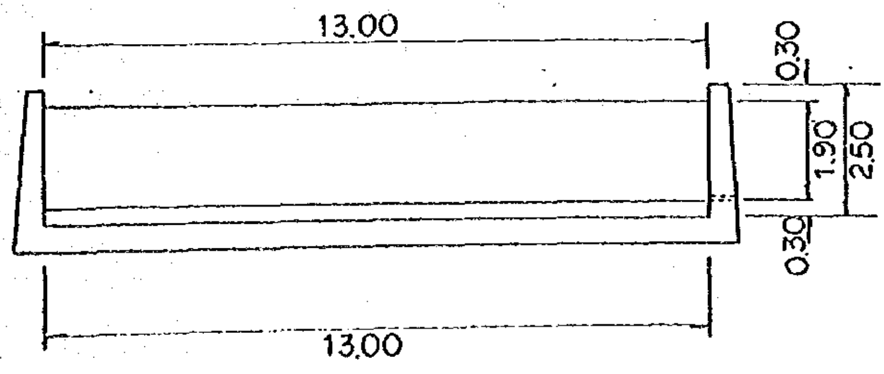
$$Q_3 = 6.5 \text{ mm/day} \times \frac{1}{0.9} \times 0.5 \text{ ha} = 36 \text{ m}^3\text{/day}$$

Total requirement: $217 + 41 + 36 = 294 \text{ m}^3\text{/day}$

Irrigation water shall be pumped up from a well to a water storage tank. It shall then be distributed to each experimental cropping area by the use of a booster pump. The capacity of the booster pump shall be decided upon as the one-time irrigation period becomes less than ten hours. The size of the water storage tank shall be adequate for holding enough water for one day's irrigation use. The amount of irrigation water used in one day is 294 m^3 as derived from the above calculation. Including a ten percent additional allowance for the one day use, the arrived at storage tank capacity is 323 m^3 (294 x 1.10).

Storage tank dimensions were determined by establishing its minimum water depth at 0.3 m, with a top clearance of 0.3 m as shown in Fig. 5-4.

Fig. 5.4 Storage Tank



③ Well and Pump Capacities:

It is planned to use well water for irrigating the experimental farm. Existing wells in the neighboring villages are from 9 m to 18 m deep. Some wells yield saline water. In order to avoid drawing water from the same aquifers of the existing wells, and to secure a sufficient amount of irrigation water, it is planned to dig a 60 m deep well.

It will be required to pump up 323 m^3/day. Assuming that the pump runs eleven hours a day, the pumping rate shall be as follows:

$$\frac{323 \times 10^3}{11 \text{ hr} \times 60 \text{ min}} = 489 \text{ liters/min}$$

Test pumping at the Project site showed 12 ldsiter/sec = 720 liter/min from a 27 m deep well, Thus it will be possible to pump up to 490 liters/min from the well.

A pump capacity larger than 490 liters/min shall be selected. The pump motor and the diameter of the suction pipe shall be determined based on the pump selected.

④ Summary of the Experimental Farm Facilities:

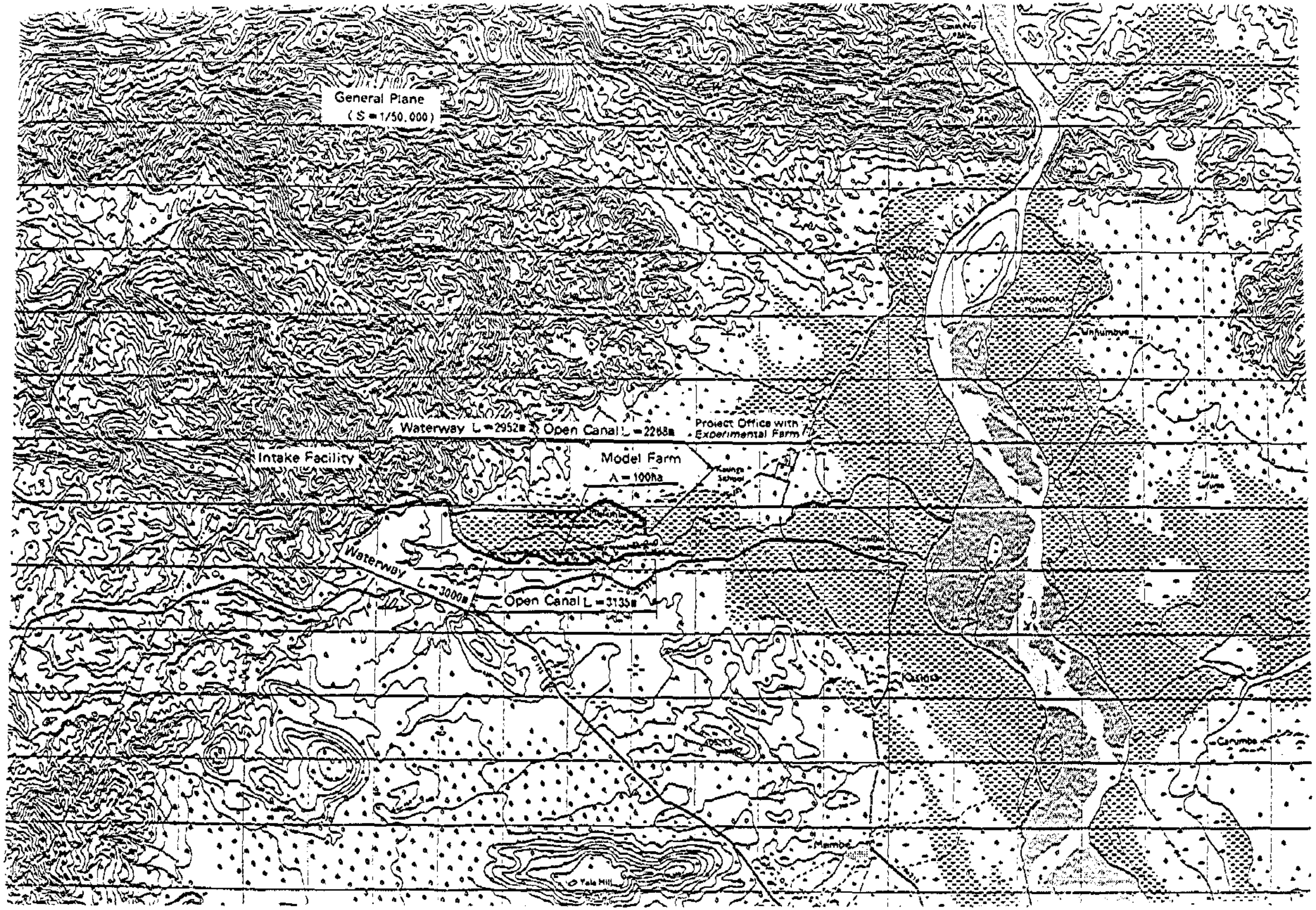
Table 5-9 Experimental Farm Facilities

Item	Facility	Description
Irrigation Farm	Furrow Irrigation Farm	2 ha Pipes with gate valves 1.0 m outlet intervals 4 water supply pipelines
	Sprinkler Irrigation Farm	0.5 ha 12.0 m sprinkler head intervals 4 sprinkler heads on each row
	Drip Irrigation Farm	0.5 ha 0.5 m dripper intervals Twenty 95 m long pipelines
Irrigation	Water Storage Tank	Reinforced concrete structure 13.0 m (L) x 13.0 m (W) x 2.5 m (H)
	Well	60 m deep
	Pump capacity	Large than 490 liters/min

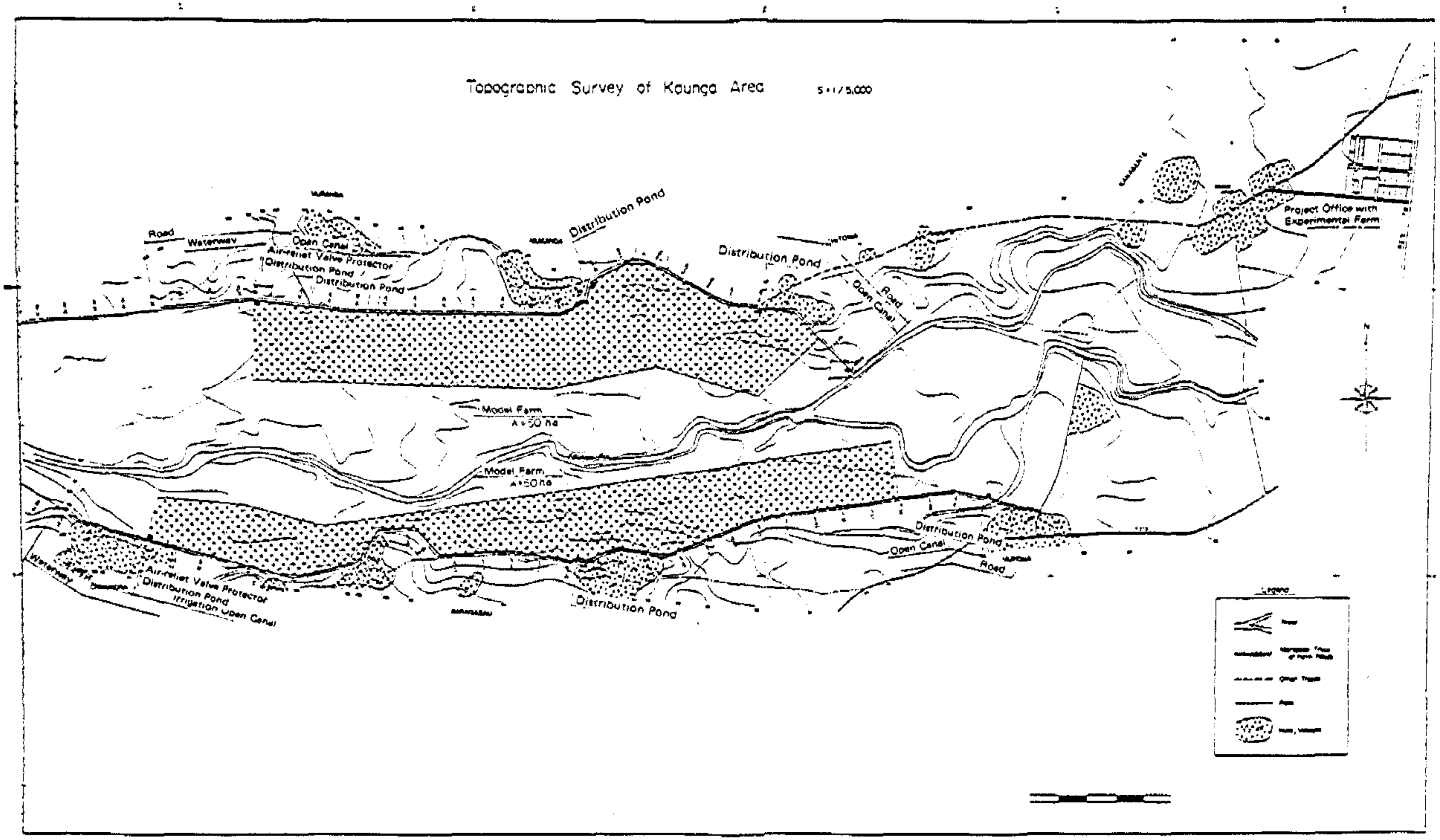
5-3-3 Basic Design Drawings

1. Area Plan
2. Model Farm Plan
3. Experimental Farm Plan
4. Arrangement of Project Office Complex
5. Operation and Management Office Building
6. Lodging Facilities
7. Stowage and Agricultural Machinery Building
8. Training Center Building
9. Garage and Repair Shop Building
10. Power Generating House
11. Elevation Profile (1)
    - Pipelines on Both Banks and Open Channel on Right Bank
12. Elevation Profile (2)
    - Open Channel on Right Bank
13. Elevation Profile (3)
    - Pipeline on Left Bank and Open Channel on Left Bank
14. Intake Facilities
15. Pipeline Route
16. Irrigation Cannels
17. Distribution Ponds

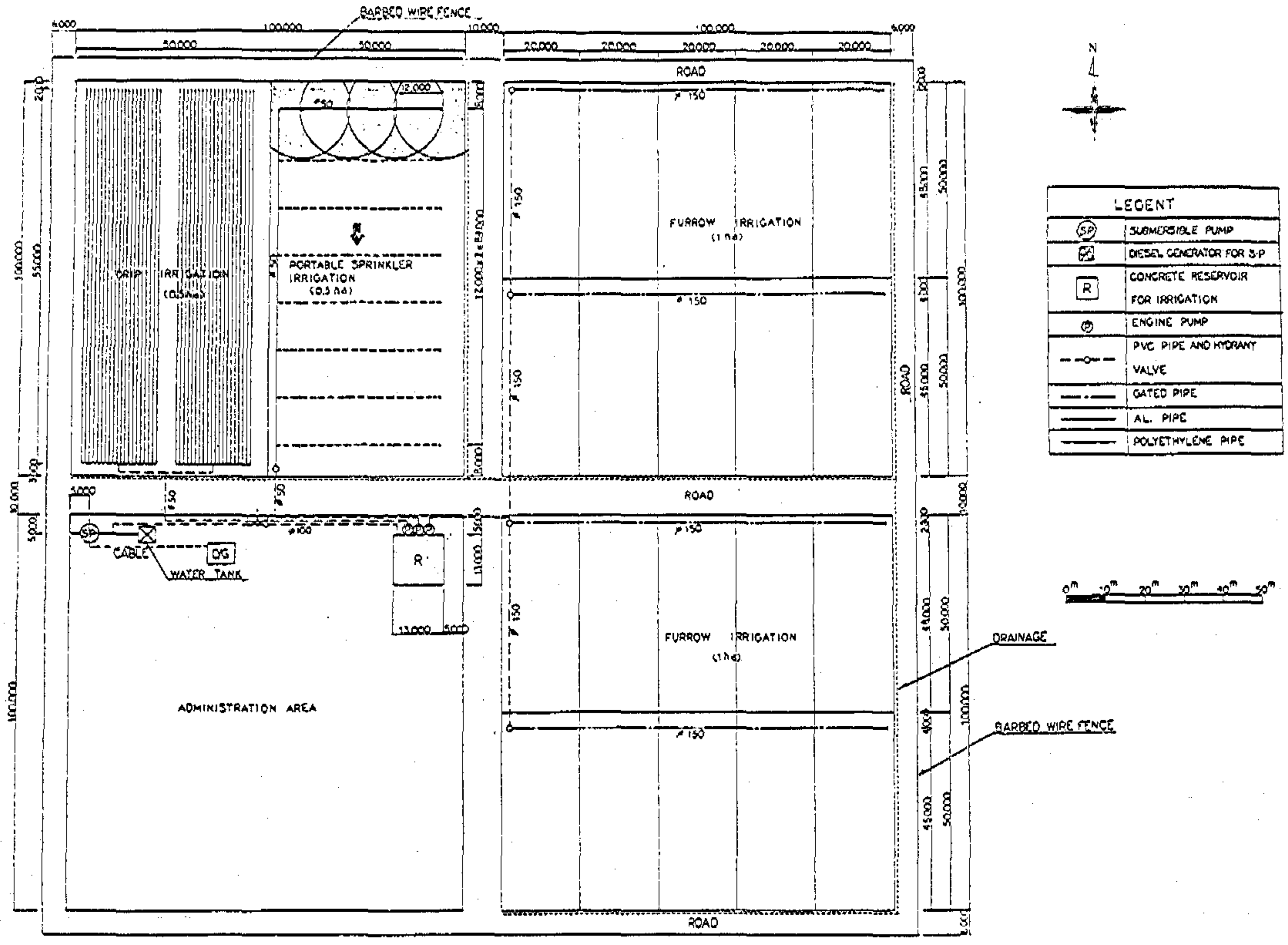
1. Area Plan


General Plane
(S = 1/50,000)
Waterway L = 2952m
Open Canal L = 2268m
Project Office with Experimental Farm
Intake Facility
Model Farm
A = 100ha
Waterway L = 3000m
Open Canal L = 3133m
Unkumbwe
Kasisa
Carumbe
Mambo
Yala Hill

2. Model Farm Plan

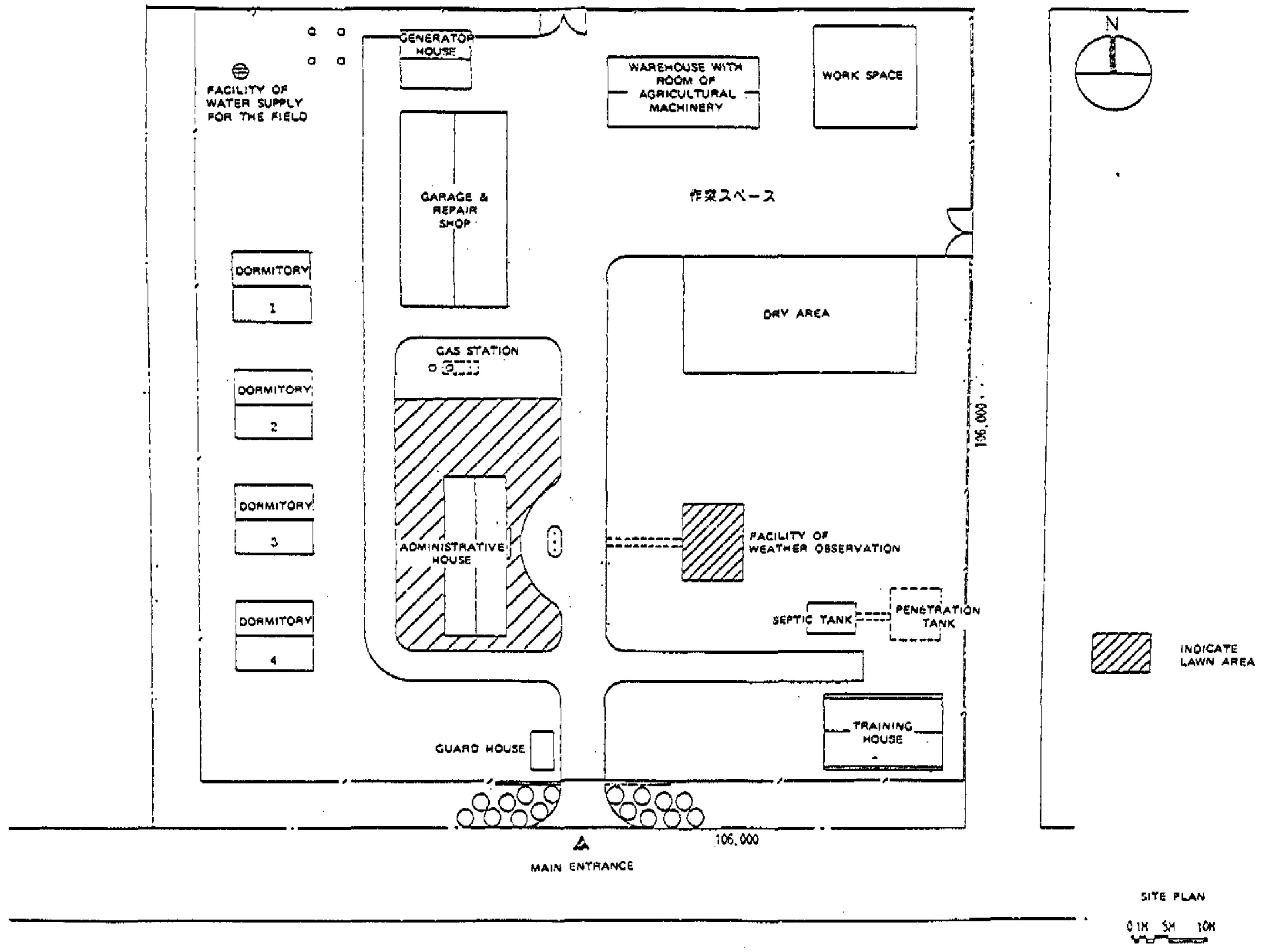


3. Experimental Farm Plan

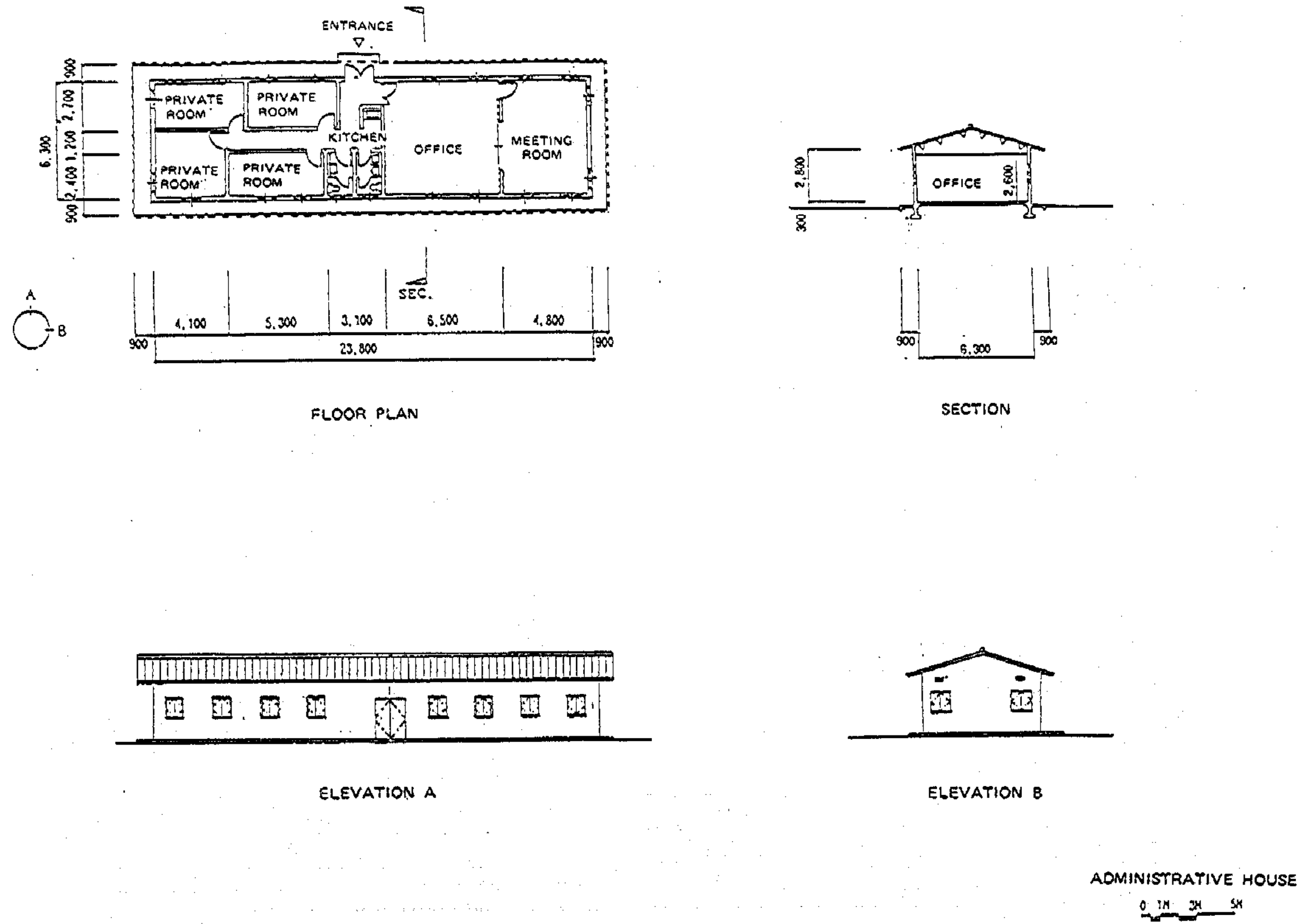


IRRIGATION SYSTEM LAYOUT

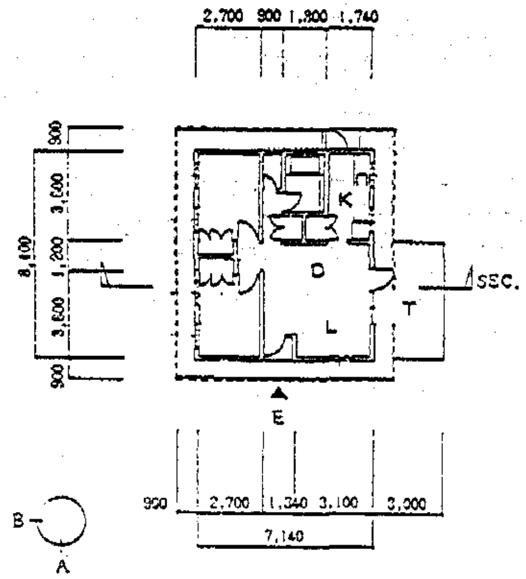
4. Arrangement of Project Office Complex



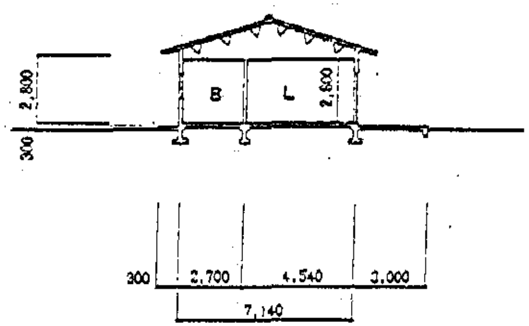
5. Operation and Management Office Building



6. Lodging Facilities

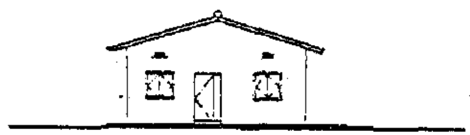


FLOOR PLAN

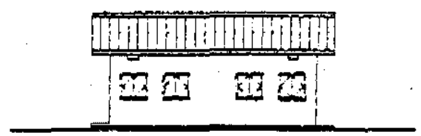


SECTION

E: ENTRANCE
L: LIVING ROOM
D: DINING ROOM
K: KITCHEN
B: BED ROOM
T: TERRACE



ELEVATION B

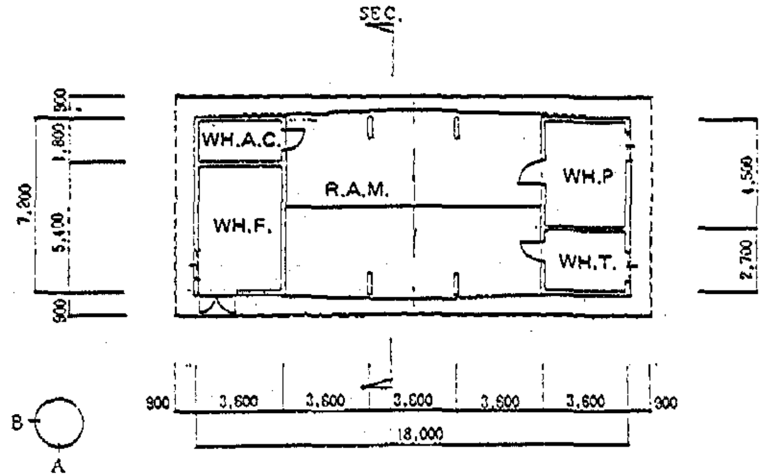


ELEVATION A

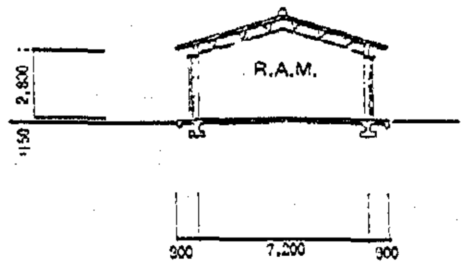
DORMITORY

0 1M 3M 5M

7. Stowage and Agricultural Machinery Building



FLOOR PLAN



SECTION

WH.A.C. : WAREHOUSE FOR AGRICULTURAL CHEMICAL
WH.F. : WAREHOUSE FOR FERTILIZER
WH.P. : WAREHOUSE FOR PARTS
WH.T. : WAREHOUSE FOR TOOLS
R.A.M. : ROOM OF AGRICULTURAL MACHINERY

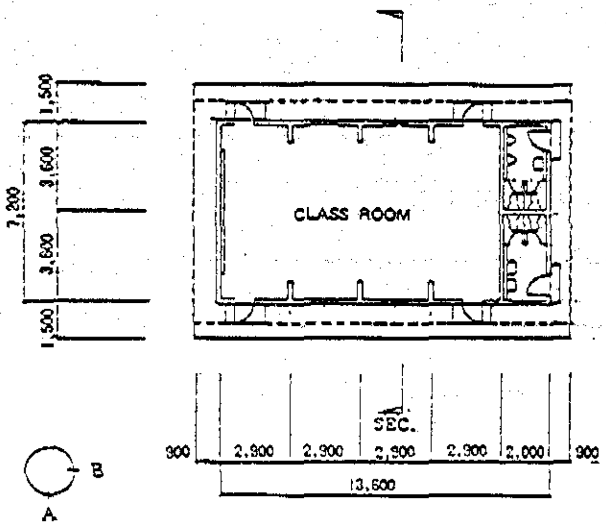
ELEVATION A

ELEVATION B

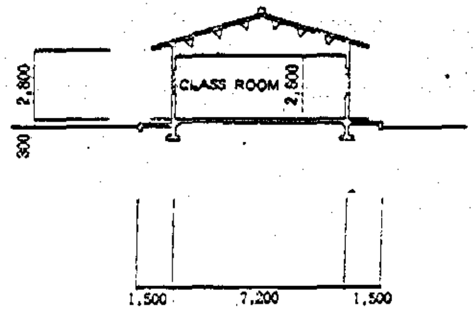
WAREHOUSE WITH ROOM OF AGRICULTURAL MACHINERY

0 1M 3M 5M

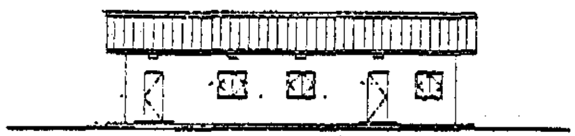
8. Training Center Building



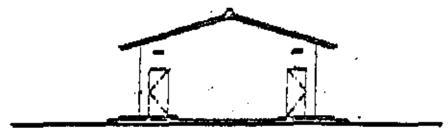
FLOOR PLAN



SECTION



ELEVATION A

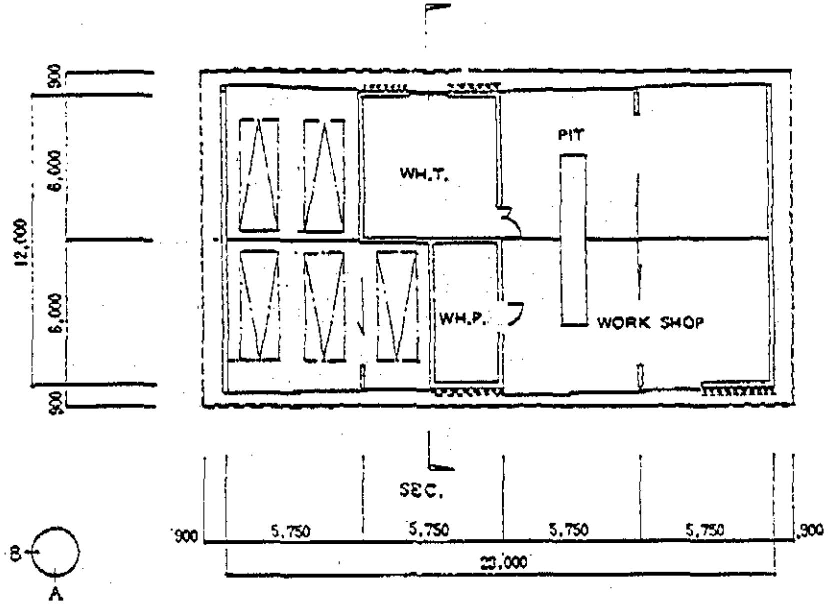


ELEVATION B

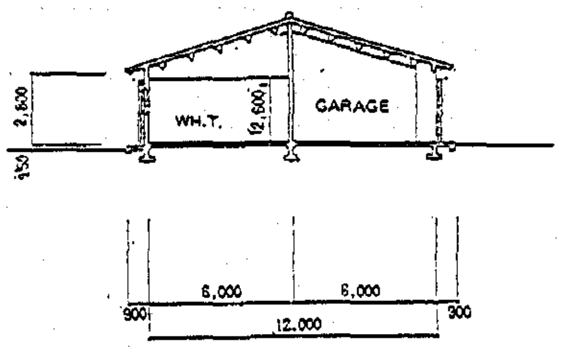
TRAINING HOUSE

0 1M 2M 5M

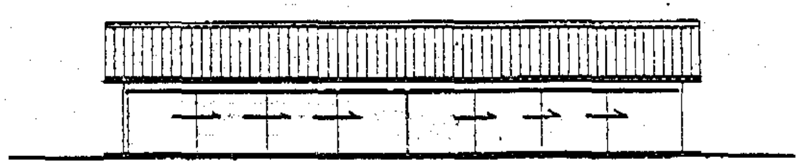
9. Garage and Repair Shop Building



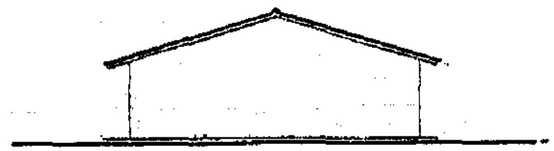
FLOOR PLAN



SECTION



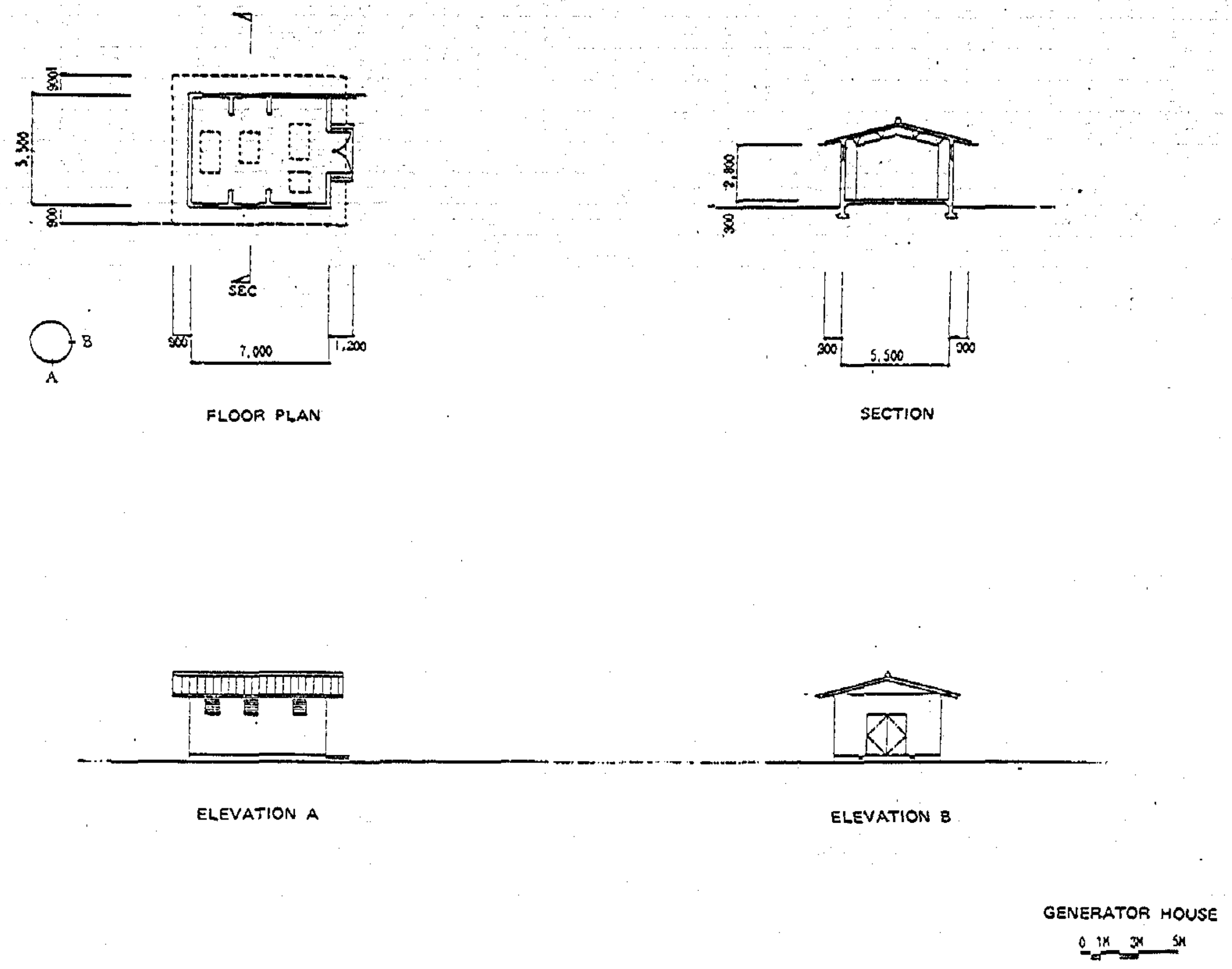
ELEVATION A



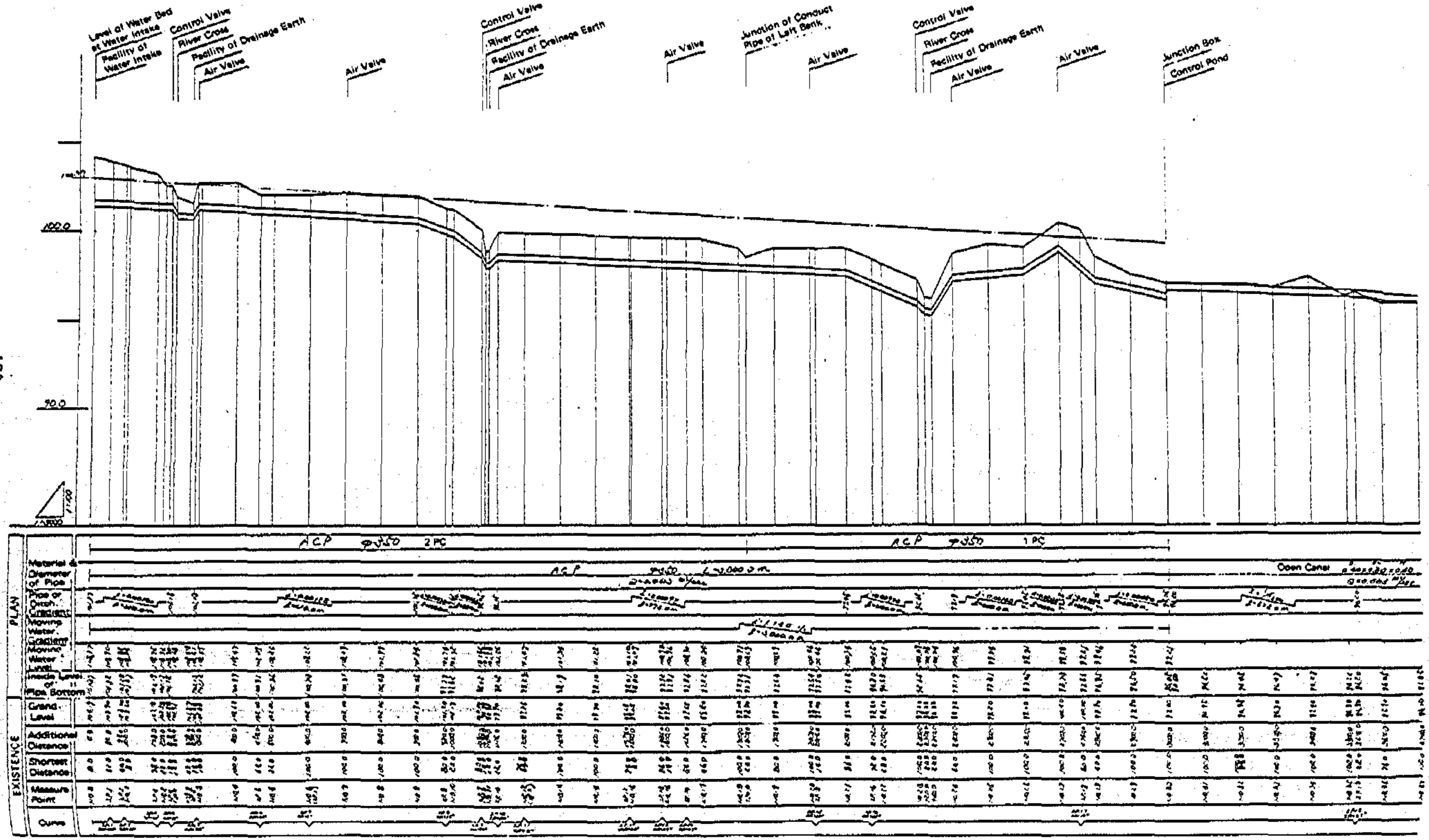
ELEVATION B

GARAGE & REPAIR
HOUSE

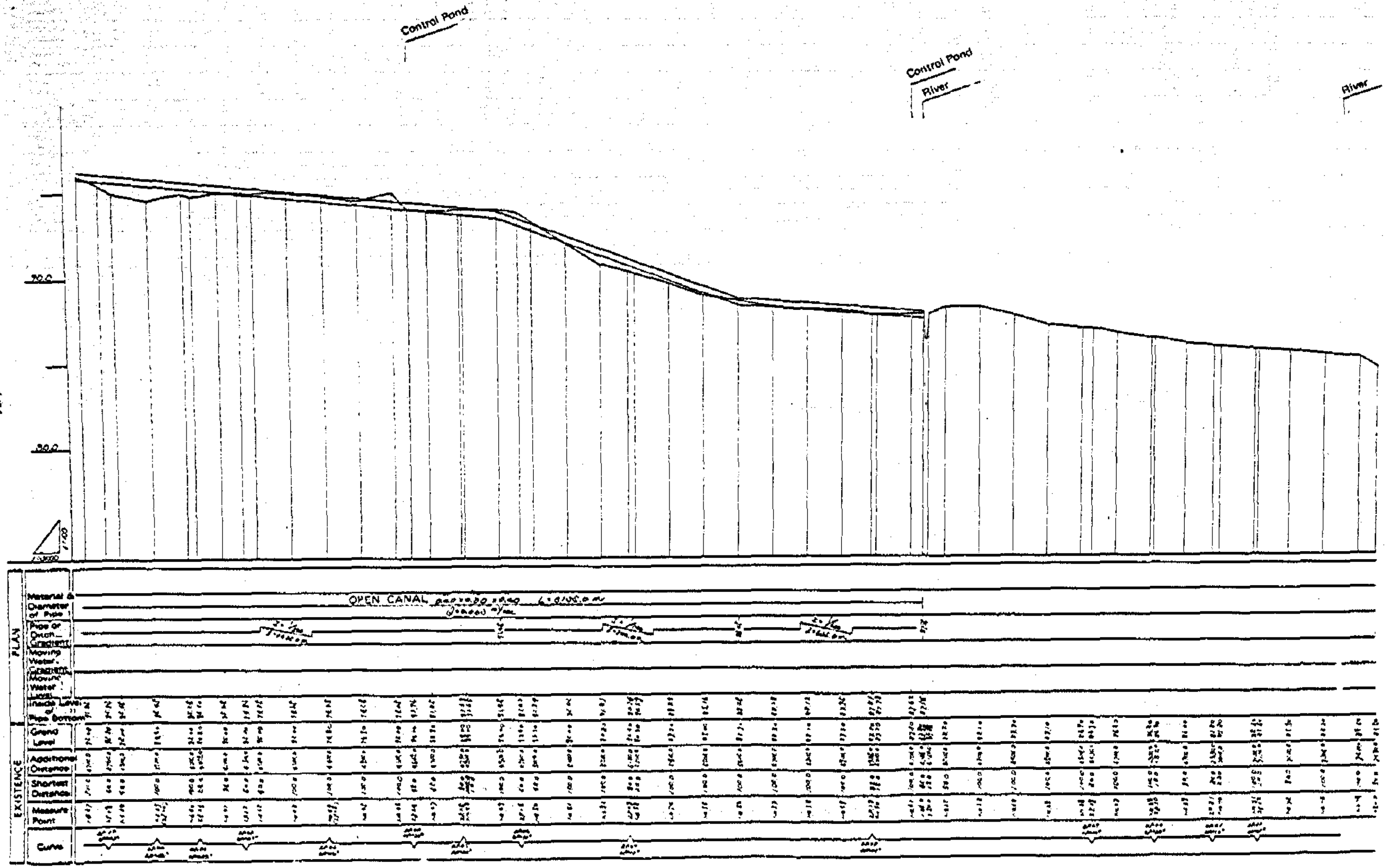
10. Power Generating House



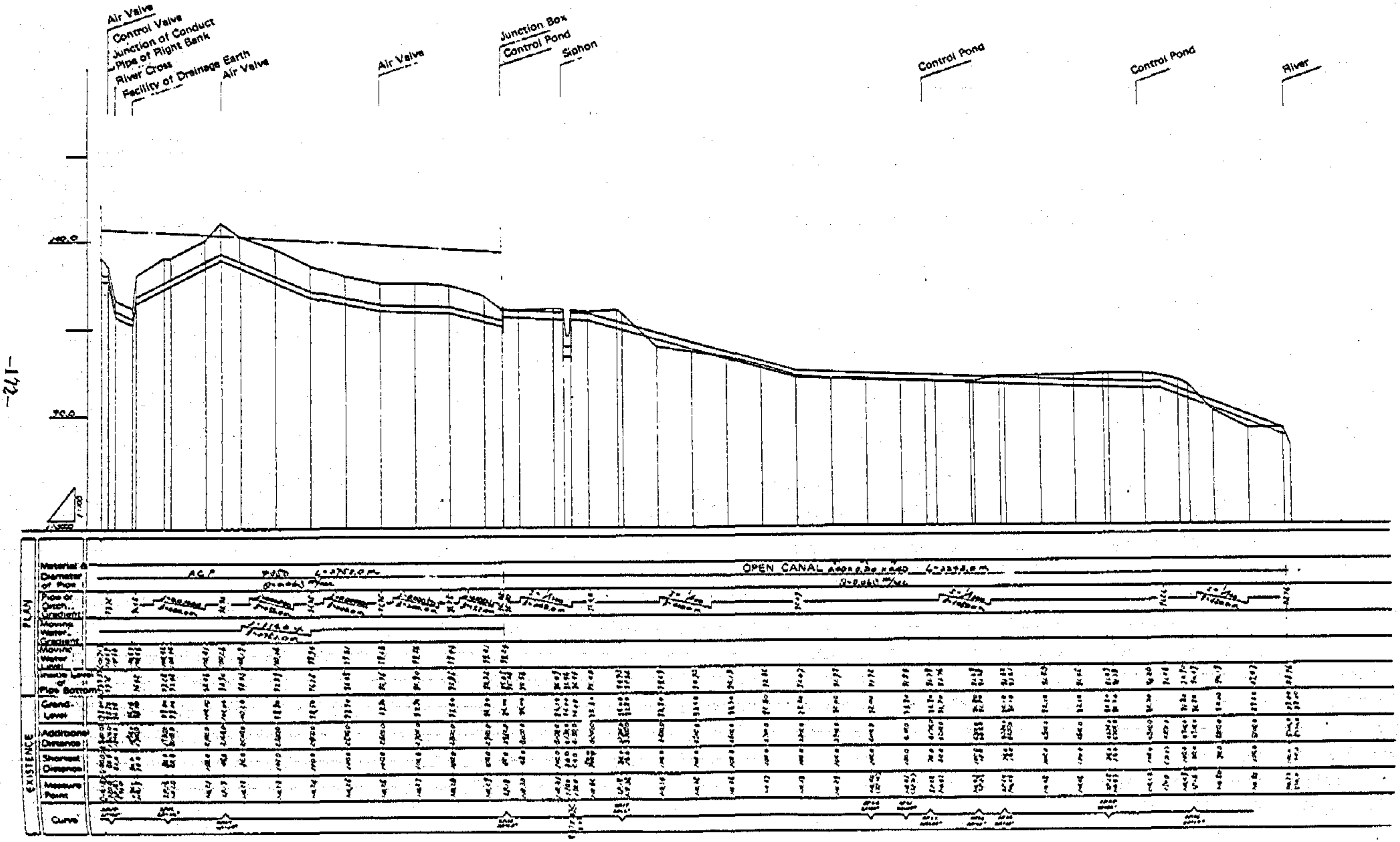
11. Elevation Profile (1) - Pipelines on Both Banks and Open Channel on Right Bank



12. Elevation Profile (2) - Open Channel on Right Bank

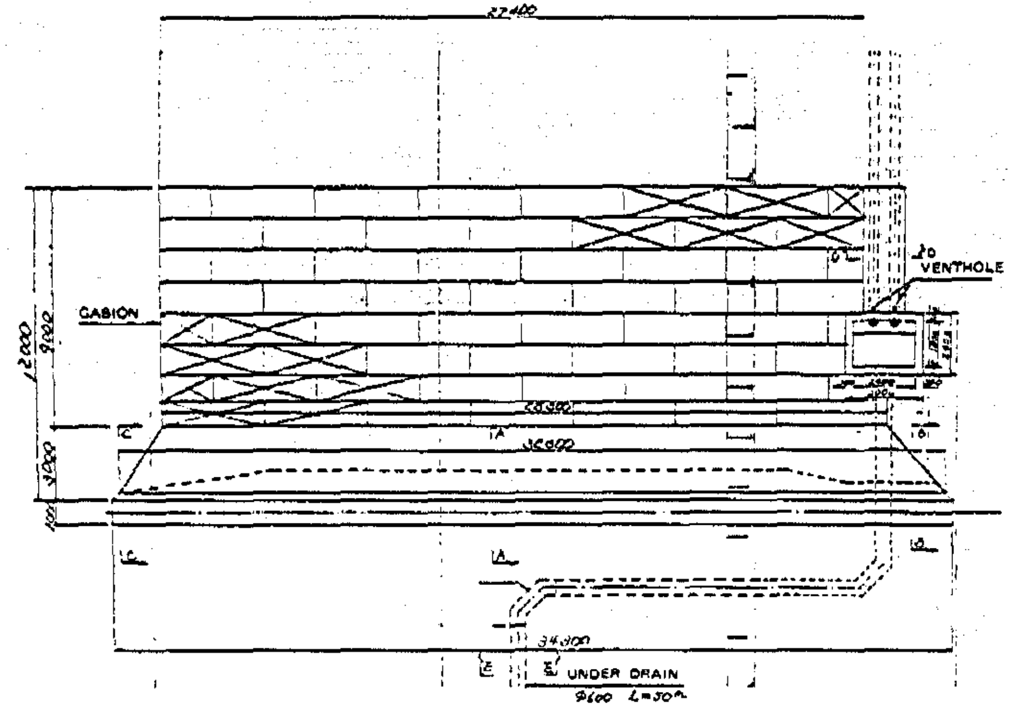


13. Elevation Profile (3) - Pipeline on Left Bank and Open Channel on Left Bank

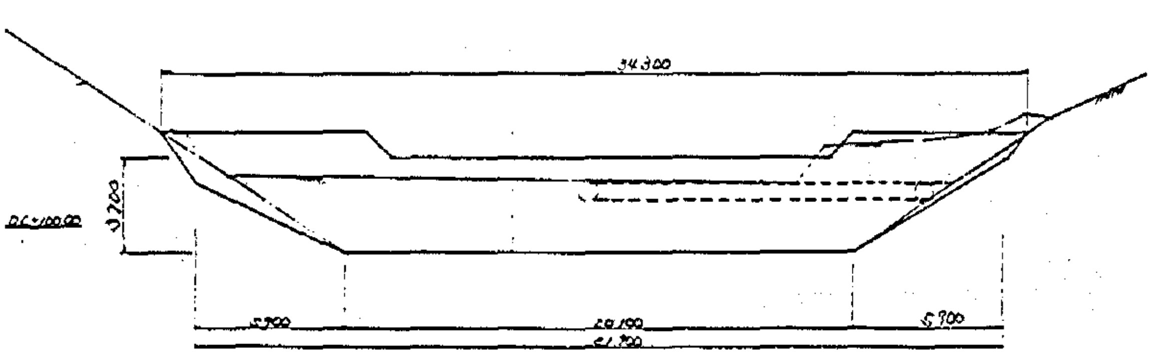


14. Intake Facilities

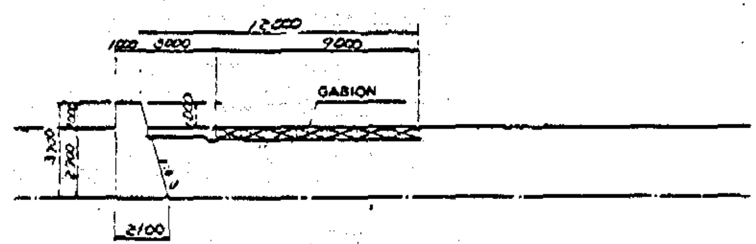
FLOOR PLAN



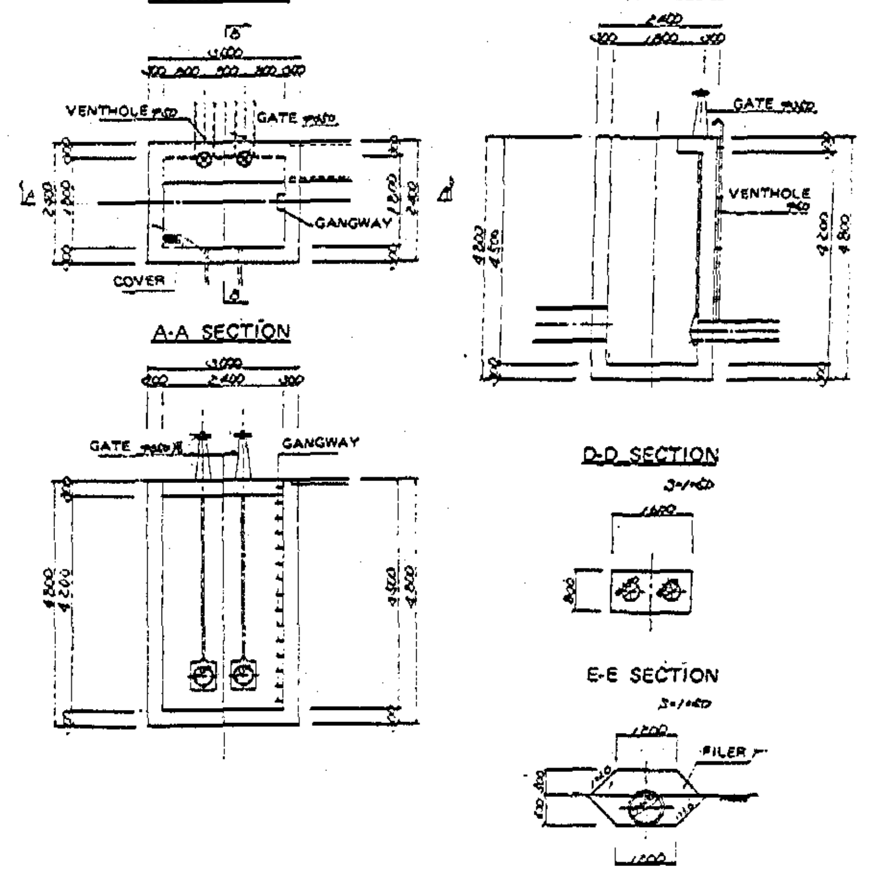
CROSS SECTION



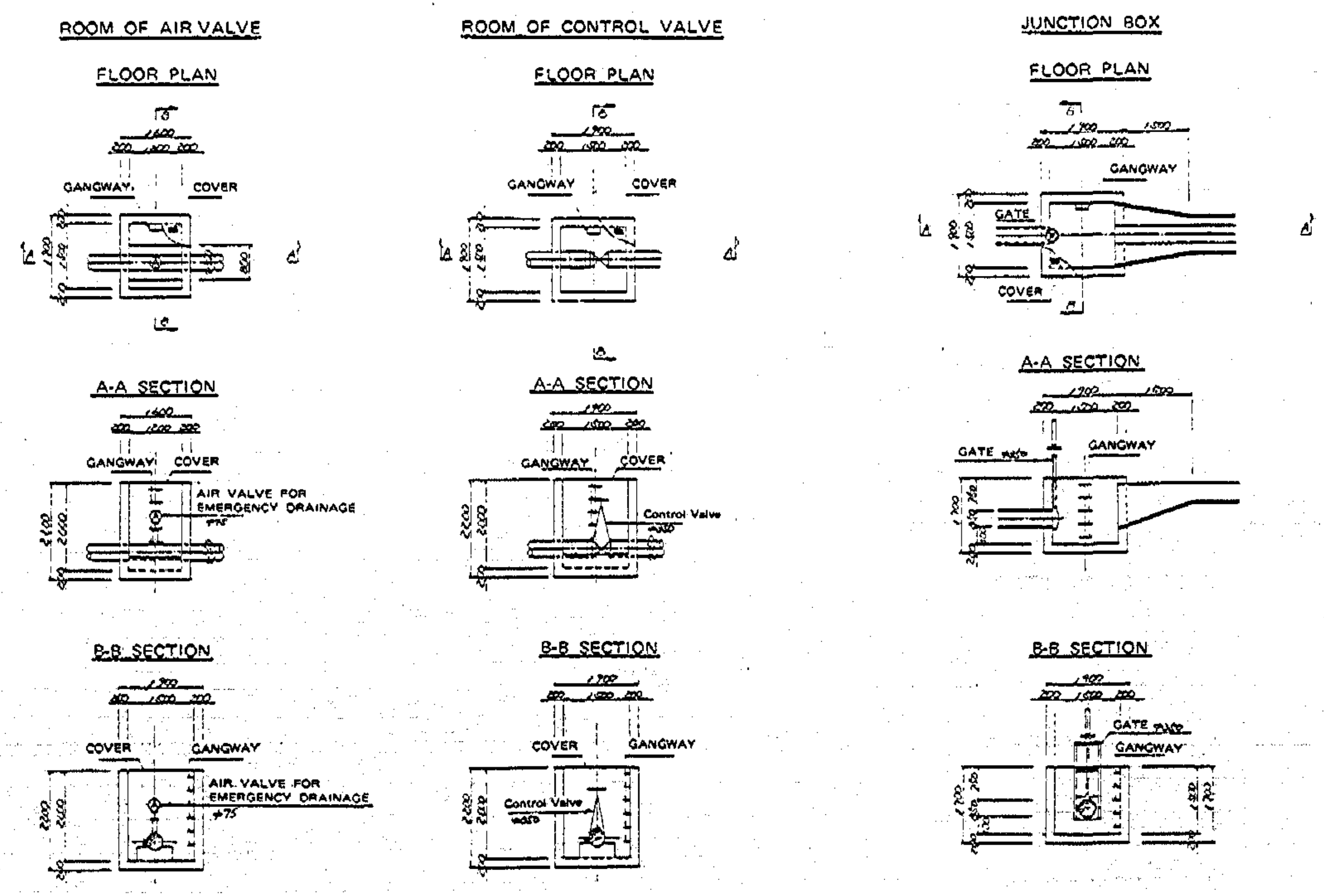
LONGITUDINAL SECTION



BOX OF WATER INTAKE

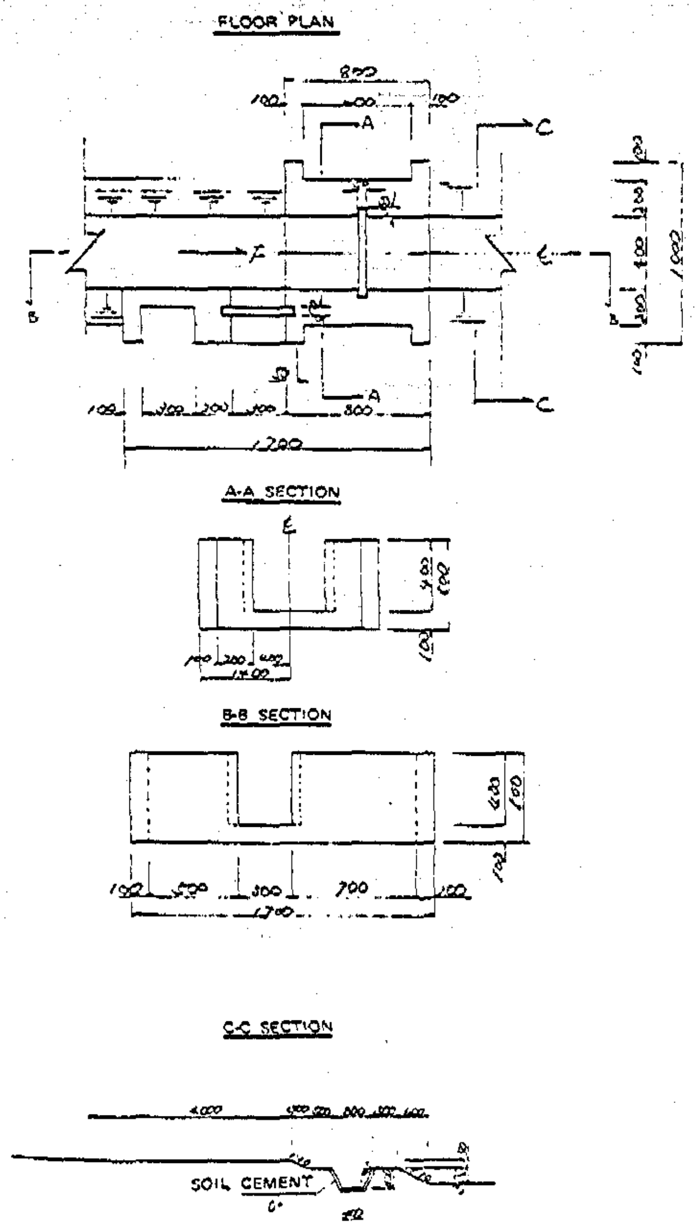


15. Pipeline Route

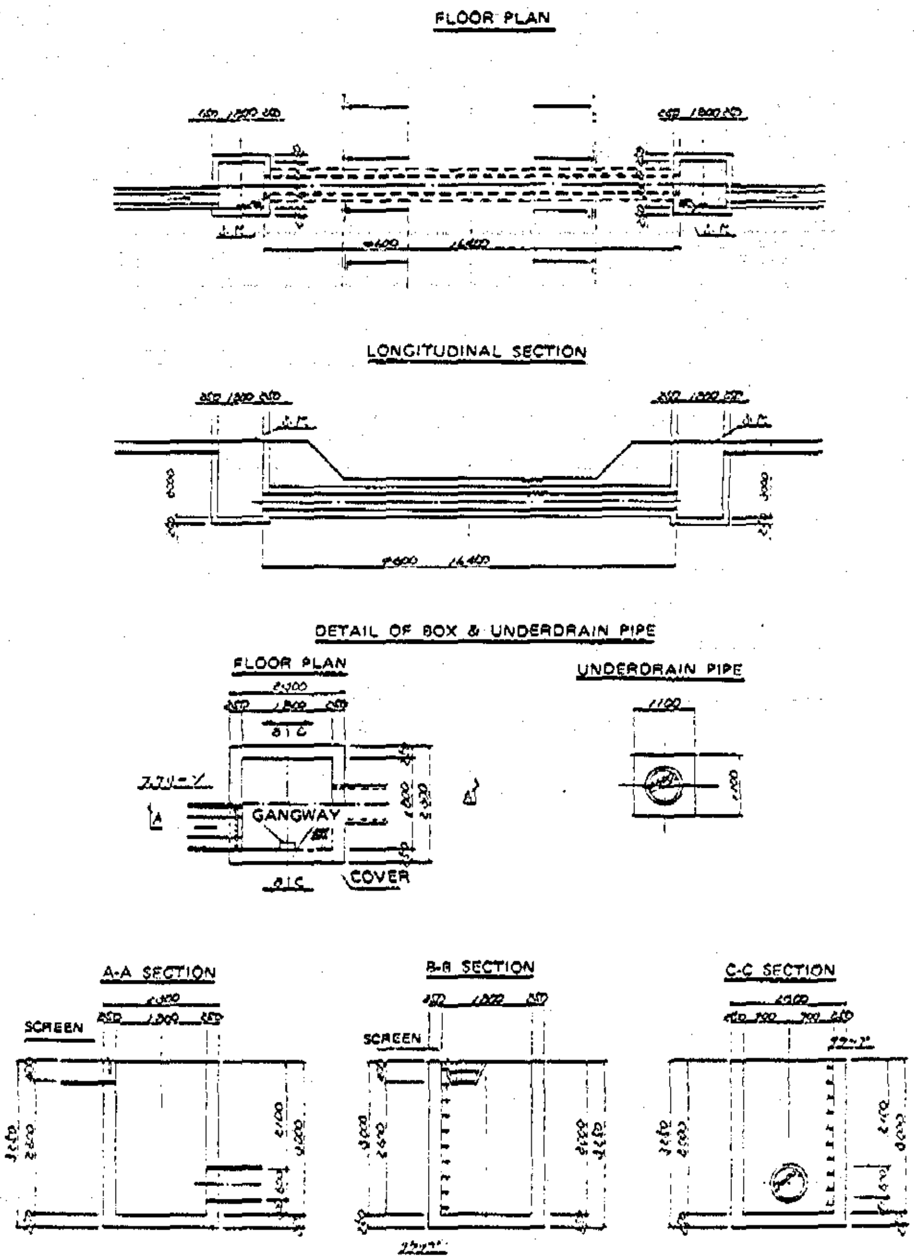


16. Irrigation Cannels

CHECK GATE

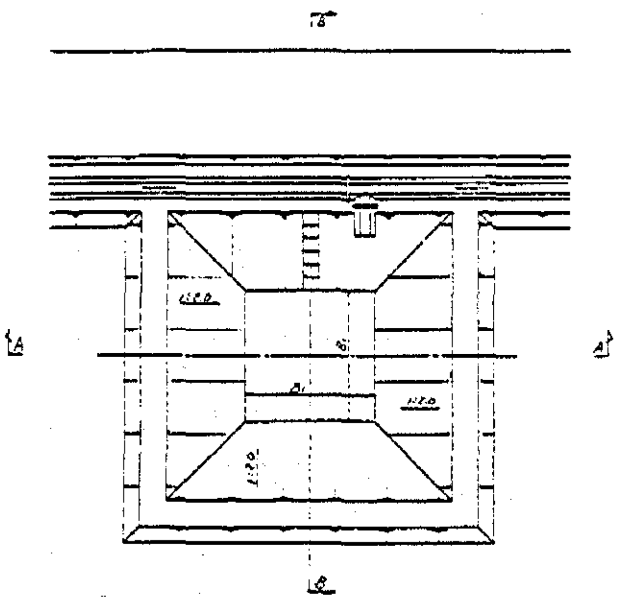


SIPHON I



17. Control Pond

FLOOR PLAN



A-A SECTION

B-B SECTION

DIMENSION OF CONTROL POND

Name of Village	Capacity of Water	Size (Width x Hight)
Sipopa Chikokola	240 m^3	12.5m × 12.5m × 1.5m
Balakasau	60 m^3	5.0m × 5.0m × 1.5m
Mpona	190 m^3	11.0m × 11.0m × 1.5m
Mlanba	50 m^3	4.5m × 4.5m × 1.5m
Mkando	110 m^3	7.5m × 7.5m × 1.5m
Chitowa Kanaventi	100 m^3	7.5m × 7.5m × 1.5m
End of Watercourse	1000 m^3	12.0m × 12.0m × 3.0m × 2

5-4 Basic Plan for Equipment

5-4-1 Equipment Plan

(1) Equipment Necessary for Agricultural Extension Work:

① Agricultural Equipment:

The 3 ha experimentla farm will be subdivided into 20 m x 50 m lots for test cropping. Each lot will be used for one particular research purpose. A small hand operated tractor is preferable for the cultivation of these lots.

It has been planned to provide a tractor with a seat for the purpose of cultivating the entire experimental farm at one time, and for assisting in teh development of neighboring farmlands. As there may be as many as ten farms under cultivation at one time, the total area to be worked will be comparatively large; therefore, the capacity of the tractor with seat shall be 60 HP.

The 60 hp tractors shall be equipped with these necessary accessories: The accessories shall be selected to be compatible with the rotary tiller.

A trailer will be required for transporting fertilizer and agricultural products. Judging from the size of the experimental farm, a two-ton trailer will be sufficient.

A power operated sprayer will be required for the application of agricultural medicines; a 500 liter capacity unit is to be provided.

As the mentioned equipment will be used frequently, two units of each should be provided to prevent work stoppage should be machine breakdown. Necessary spare parts for 20%.

② Equipment for Extension Activities:

Extension activities will be performed in the model field area and in neighboring areas. There will be twelve people stationed at the Project Office; six of them will engage in extension activities. Occasionally office personnel will visit the Department of Agriculture in Lusaka and the District Agricultural Office in Luangwa in order to attend conferences or to go on other business related trips. Therefore, at least three vehicles will be necessary for use at the Project Office. In addition to these two vehicles, one pickup truck will be required to transport equipment required for extension work.

Except for rural road No.216, most roads in teh area are improperly maintained and are not suitable for vehicular traffic. Some roads are too narrow to be used by automobiles and trucks; only motorcycles can get through. For this reason, at least three motorcycles (one per every two extension workers) are required.

During the rainy season, road conditions become worse. However, it is during this season that extension activity work is at its peak. Therefore, the vehicles to be acquired for extension work use must be heavy-duty types (off-road vehicles).

③ Repair Machinery:

In order to carry out efficiently and effectively the implementation of the programme, it will be necessary to conduct periodic inspections of agricultural equipment and to make immediate repairs to said machinery. It will be essential to provide the necessary machinery for this work.