MINISTRY OF LANDS AND AGRICULTURE
THE REPUBLIC OF ZIMBABWE

BASIC DESIGN STUDY REPORT

ON

THE NYAKOMBA IRRIGATION DEVELOPMENT PROJECT (PHASE 2)

IN

THE REPUBLIC OF ZIMBABWE

JANUARY 1999

JAPAN INTERNATIONAL COOPERATION AGENCY

TAIYO CONSULTANTS CO., LTD.
SANYU CONSULTANTS INC.

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PREFACE

In response to a request from the Government of the Republic of Zimbabwe the Government of Japan decided to conduct a basic design study on the Nyakomba Irrigation Development Project (Phase 2) and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Zimbabwe a study team from 25 July to 23 August, 1998.

The team held discussions with the officials concerned of the Government of Zimbabwe, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Zimbabwe in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Zimbabwe for their close cooperation extended to the teams.

January 1999

Kimio Fujita
President
Japan International Cooperation Agency

January, 1999

Letter of Transmittal

We are pleased to submit to you the basic design study report on the Nyakomba Irrigation Development Project (Phase 2) in the Republic of Zimbabwe.

This study was conducted by Taiyo Consultants Co., Ltd./ Sanyu Consultants Inc., under a contract to JICA, during the period from July 17 1998 to February 22 1999. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Zimbabwe and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

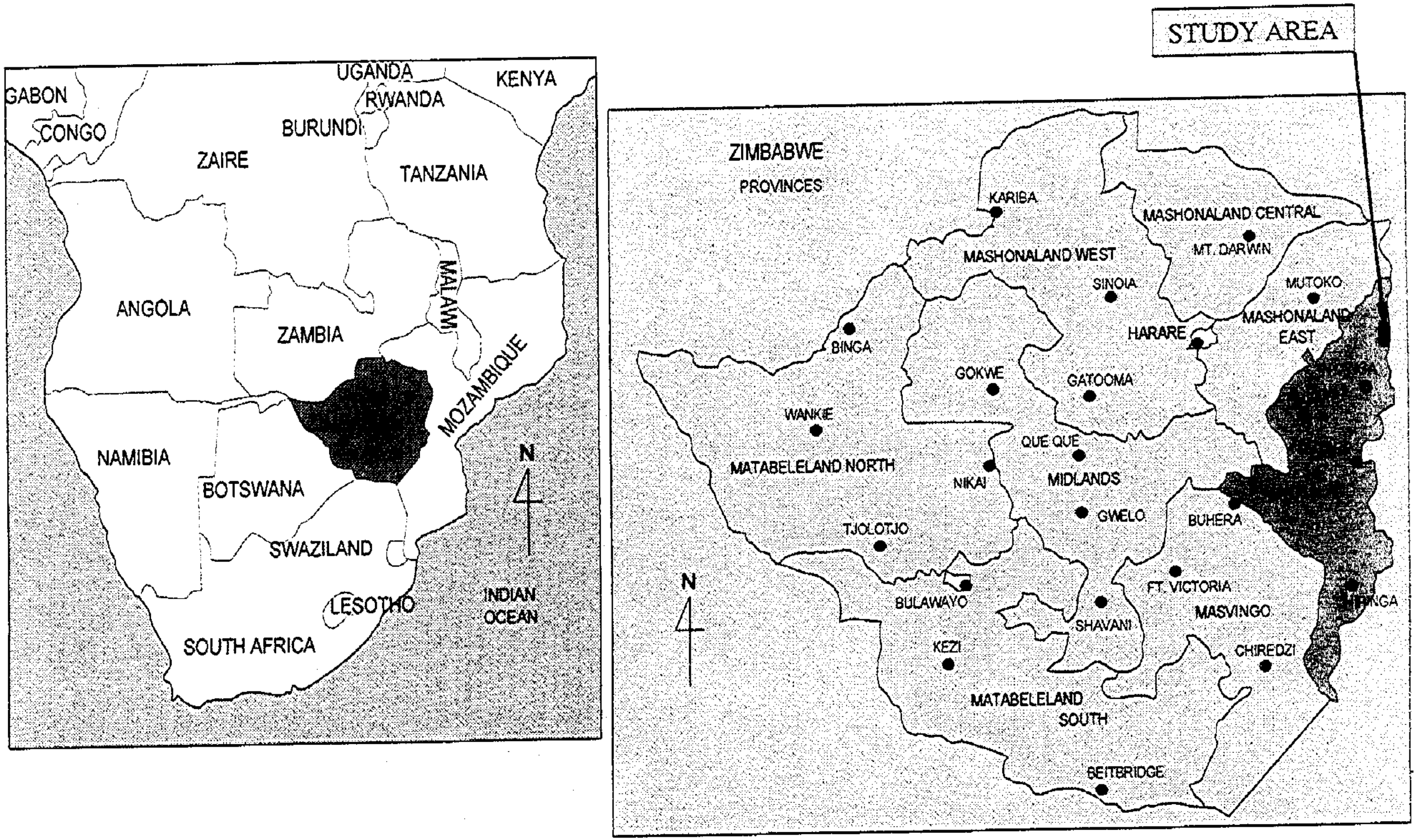
Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

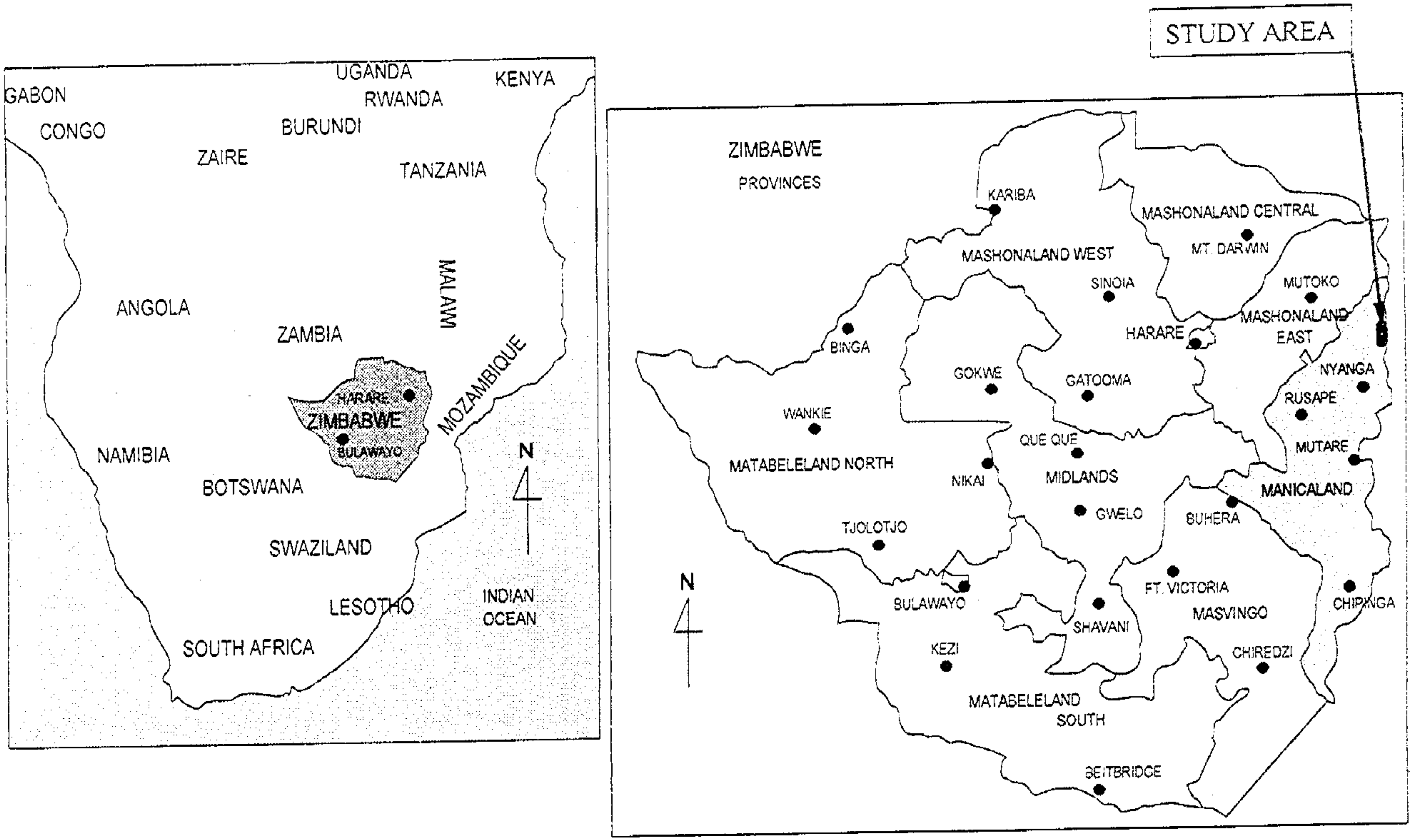
A. Yamada

Asao YAMADA

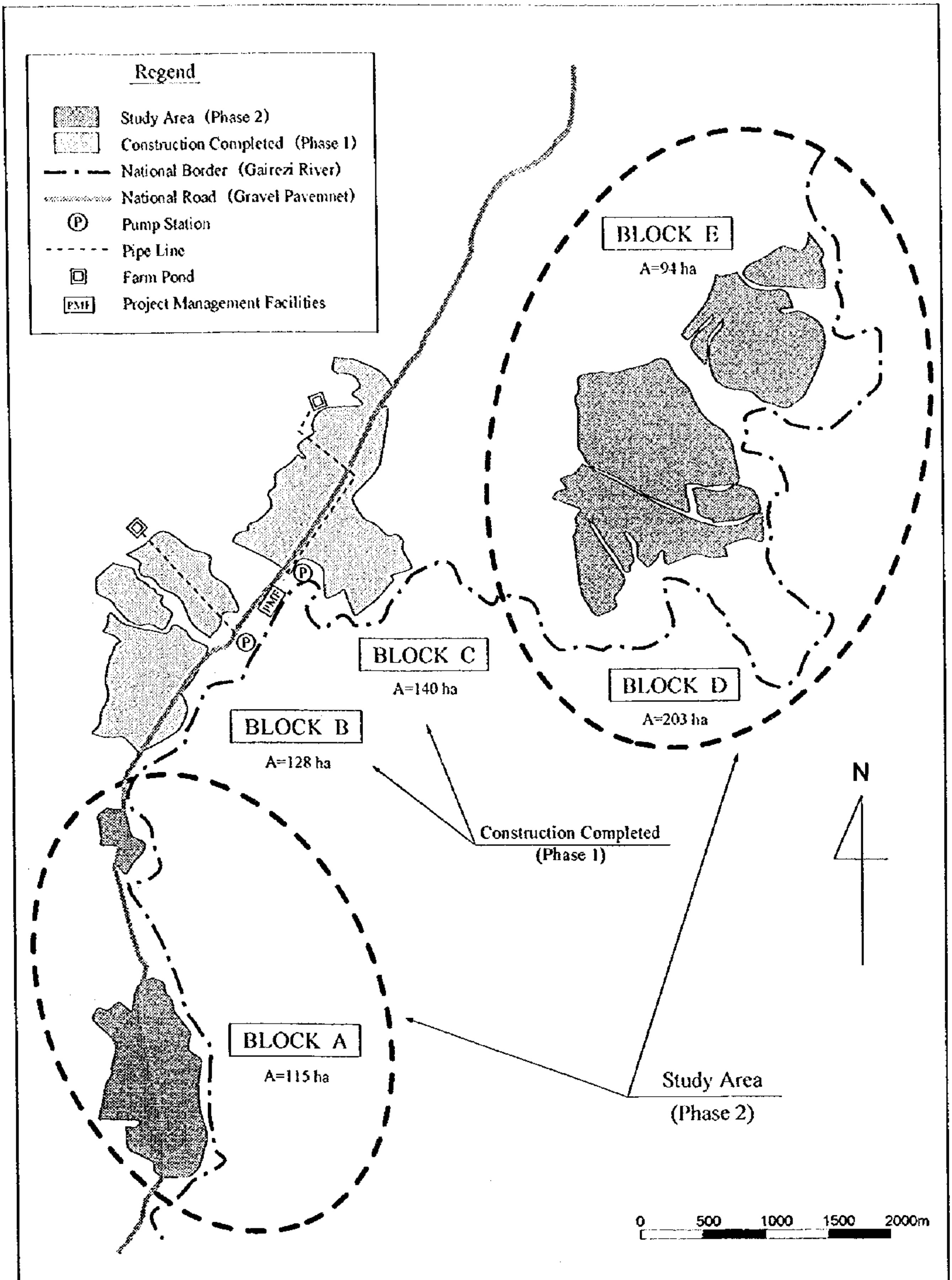
Project manager,
Basic design study team on
The Nyakomba Irrigation
Development Project (Phase 2)
Taiyo Consultants Co., Ltd.



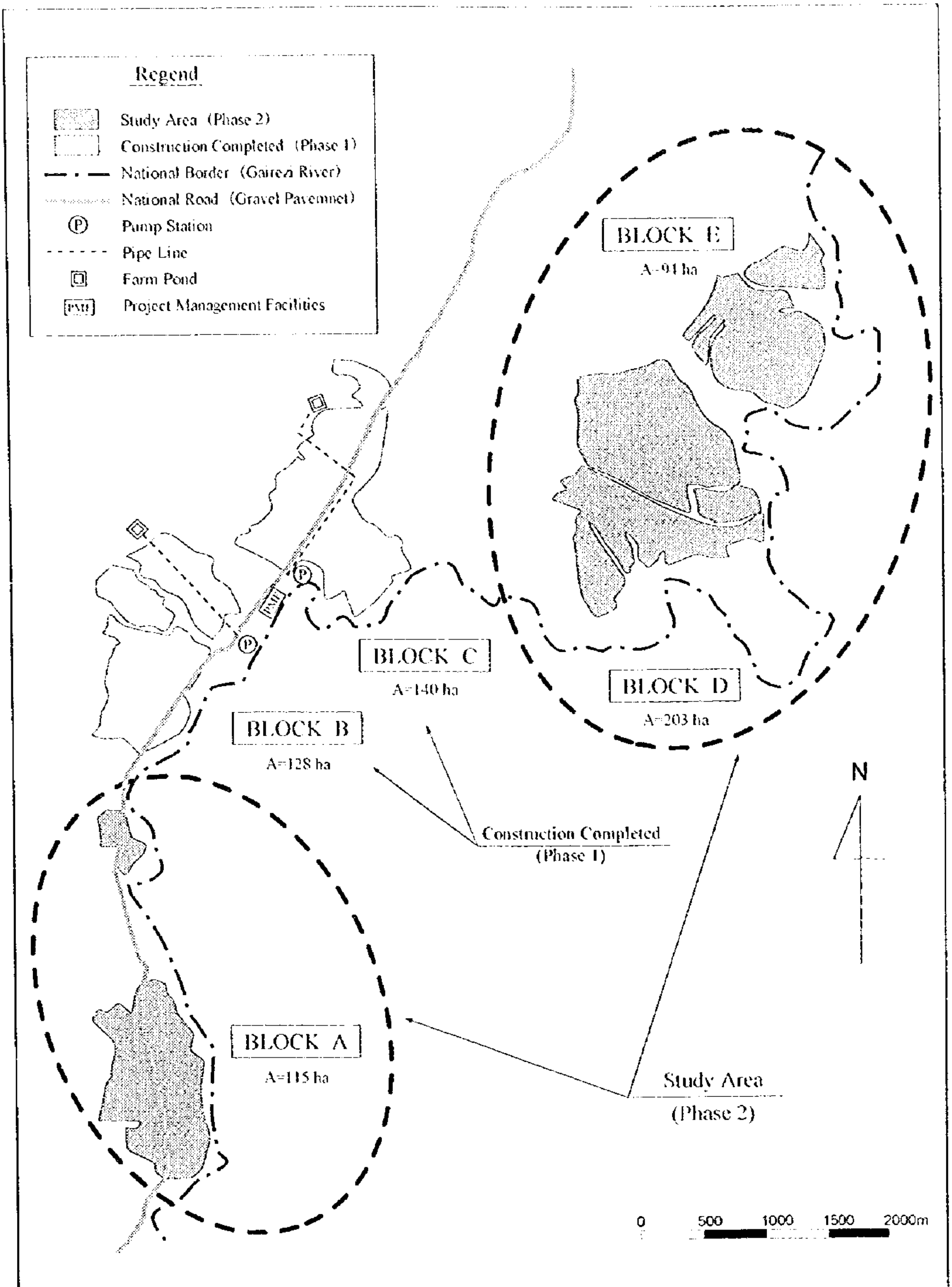
LOCATION MAP



LOCATION MAP



STUDY AREA MAP



STUDY AREA MAP

Panoramic View of the Studied Area (Block A)

Panoramic View of the Studied Area (Block D & E)

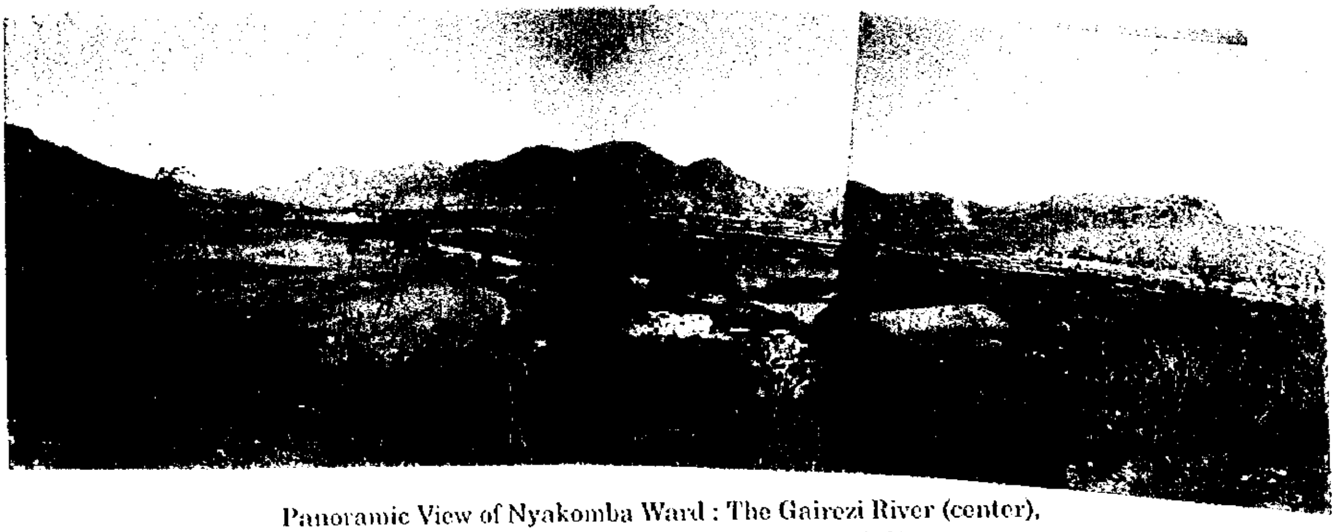
Proposed Construction Site for the Pumping Station
(Block D)

Boring Test at the Pumping Station (Block D)

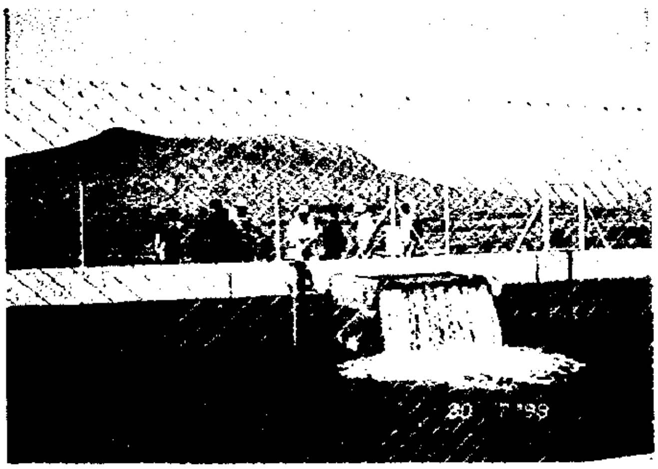
Proposed Construction Site for the Farm Pond
(Block D)

Exchange of Minutes at the Ministry
of Lands and Agriculture

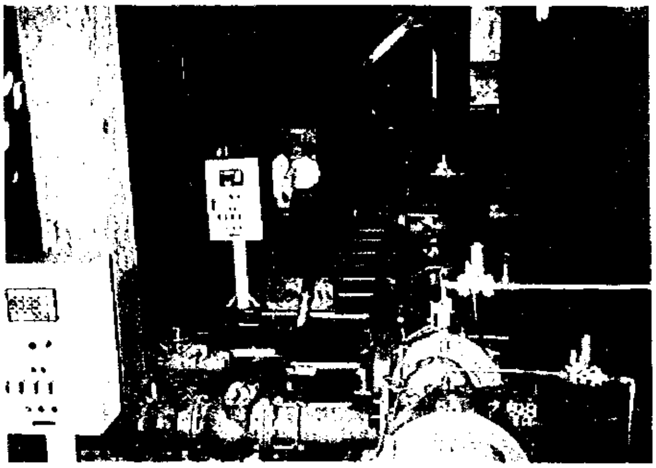
Public Hearing at Block D



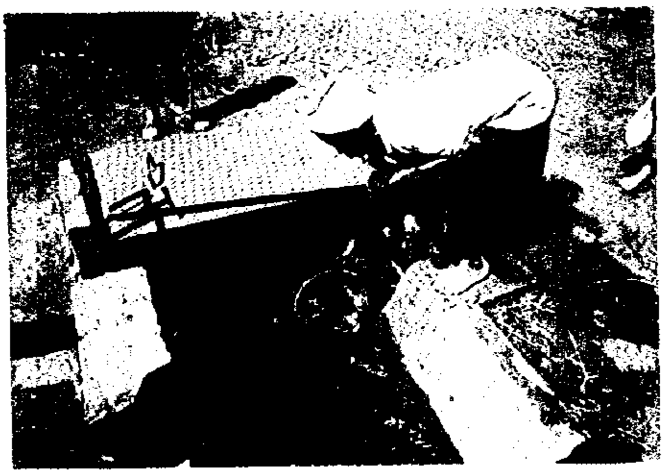
Panoramic View of Nyakomba Ward : The Gairezi River (center),
Already Developed Block C (right), Mozambique (left)



Farm Pond (Block C)



Pumping Station (Block C)



Drawing Water for Domestic Use
from Irrigation Canal

Irrigation by Siphon Pipes (Block C)

ABBREVIATIONS

MOLA	Ministry of Lands and Agriculture
AGRITEX	Department of Agricultural Technical and Extension Services
DWD	Department of Water Development
ZESA	Zimbabwe Electricity Supply Authority
JICA	Japan International Cooperation Agency
JOCV	Japan Overseas Cooperation Volunteers
JIS	Japan Industrial Standard
AFC	Agricultural Finance Cooperation
GMB	Grain Marketing Board
CCZ	Cotton Company of Zimbabwe
LSCF	Large Scale Commercial Farm
ZFU	Zimbabwe Farmers Union
NPMO	Nyakomba Project Management Office
IMC	Irrigation Management Committee
IMF	International Monetary Fund
NVGA	Nyanga Vegetable Grower Association
NDP	Nyanga Development Project
AEO	Agricultural Extension Officer
AES	Agricultural Extension Supervisor
AEW	Agricultural Extension Worker
IDA	International Development Association
AfDB	African Development Bank
ZIMPREST	Zimbabwe Programme for Economic and Social Transformation
S/W	Scope of Works
F/S	Feasibility Study
B/D	Basic Design
E/N	Exchage of Notes
GNP	Gross National Product
GDP	Gross Domestic Product
F/C	Foreign Currency
L/C	Local Currency

MEASURES

mm	millimeter
cm	centimeter
m	meter
km	kilometer
cm^2	square centimeter
m^2	square meter
km^2	square kilometer
ha	hectare
m^3	cubic meter
kg	kilogram
t, ton	metric ton
s, sec	second
min	minute
hr	hour
℃	degree centigrade
%	percentage
kw	kilowatt
mw	megawatt
HP	horse power
PS	0.986HP, 0.7355KW
EL	elevation
MSL	mean sea level
rpm	rotation per minute
bar	1.020 kgf/cm^2, 1.000×10^5 Pa
Z$	Zimbabwean dollar
US$	American dollar
¥	Japanese yen

CONTENTS

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[Appendices]

Chapter 1

Background of the Project

Chapter 1 Background of the Project

1-1 Background of the Project

The republic of Zimbabwe, located in the southern part of Africa, occupies 391,000km^2, with a population of 11,000,000 (as of 1995). It is an inland country surrounded by Zambia, Mozambique, South Africa and Botswana. Its capital city is Harare and situated at about 31° 7′ E Long. and 17° 43′ S Lat.. Agriculture is the key industry of the country and 65 % of its population is in some way with agriculture. The contribution of the agricultural sector to the GDP is about 10 % at present. The First National Development Plan (1986-1990) aimed principally at "land reform and efficient land utilization", and promoted agricultural development in the Communal Lands, where development has progressed considerably more slowly than in urban areas and on the Large Scale Commercial Farms (LSCF). In the Second National Development Plan (1991-1995) and on going Zimbabwe Program for Economic and Social Transformation (ZIMPREST 1996-2000), based on the Structural Adjustment Program, top priority is given to development in the Communal Lands again, and the Ministry of Lands and Agriculture has been playing a key role in promoting resettlement program to provide poor farmers and/or peasant farmers with land.

The large part (about 82% of the country) of Zimbabwe consists of the Communal Lands (42%) and LSCF (40%). As the land ownership system before independence has been inherited, there are following partial characteristics between them.

Namely, LSCF occupies the central part of the country, and is plain and fertile, in which water is relatively abundant. The total area of the Natural Farming Regions 1, 2 and 3, is about 80 thousand km^2, which is 51% of the LSCF. As the area owned by one family is sufficiently large, farmers can leave some parts of their land fallow. Thus, there is no over-cultivation, they can maintain high productivity in their land. The large parts of LSCF are occupied by only about 4,000 white farmers.

Communal Lands are generally located in marginal areas, and mainly located in the region with little water which is not good for an intensive farming. The total areas of Natural Farming Regions 1, 2 and 3, which are intensive farming areas, only cover about 40 thousand km^2 or 26% of the total Communal Lands. Due to the small area per one family, they are over cultivated and their productivity is becoming extremely low. They were self-sufficient in food before, but at present because of the low productivity and increase of the population, there are a lot of Communal Lands which are not self-sufficient. The total population in the Communal Lands is about 4.3million, and almost of them are suffering from poverty.

Therefore, to improve agricultural productivity and the livelihood of Communal land inhabitants are indispensable for the stability of the nation and the improvement of national economy.

The Nyakomba Ward in the north-eastern part of the Manicaland Province, located along the national border between Zimbabwe and Mozambique, is one of the typical Communal Lands. The Government of the Republic of Zimbabwe requested a formation of the Nyakomba Irrigation Development Project to the Government of Japan (June 1985), and the Japan International Cooperation Agency (JICA) conducted a Feasibility Study on this Project from Aug. 1989 to Oct. 1990. It was decided that the water resources for irrigation would come from the Gairezi River with pumping stations because of availability of sufficient water and its lower cost, after a comparative study with the Nyakomba River Dam plan and a plan for the Weir system in the Gairezi River. Finally the feasibility of the Project with pumping station was confirmed in the study.

Under these conditions, the Government of Zimbabwe requested Grant Aid to the Government of Japan for the construction of the irrigation facilities in five blocks (Block A, B, C, D and E) and their appurtenant facilities in this area (Dec. 1990).

In response to the request, the Government of Japan decided to conduct a Basic Design Study on this Project. As a result of the study made in 1994, it was judged that development of the whole 680ha of this Project was difficult in consideration of insufficient experience of irrigation systems by pumps with such high heads and total project cost as well.
In those conditions, based on the development priority, two blocks (Block B and C) were selected and they were implemented from Dec. 1995 to Mar. 1998 as phase I of the Nyakomba Irrigation Development Project.

At present, farming has been commenced in two blocks (Block B and C). In Block C which was constructed first, they started to harvest crops from the dry season in 1997. The farmers' organization called Irrigation Block Committee has been established in two blocks, and the Project is well operated and maintained by the Committee under the assistance and guidance from AGRITEX.

Then followed the request for Japan's Grant Aid from the Government of Zimbabwe in Dec. 1996, requesting for the construction of the same facilities in the remaining three blocks (Block A, D and E) as phase 2 of the Project.

JICA has dispatched the Basic Design Study Team from 25 Jul. 1998 to 23 Aug. for thirty days to Zimbabwe. The Team conducted the Study including a meeting with farmers in Block C and a public hearing from the expected beneficiaries in Block D. After the assessment of the data and information obtained through the study, JICA sent to Zimbabwe a Study Team for consultation on Draft Report from October 21 to 30, 1998.

1-2 Outline of the request

(1) Objectives of the request

The request is to construct the irrigation facilities for three blocks in the Nyakomba Ward in the Manicaland Province with Japan's Grant Aid as phase 2 of the Nyakomba Irrigation Development Project.

(1)-1 Short term objectives

Increase of farmers' income and the raise of the living standard of the people by the improvement of agricultural production.

(1)-2 Long term objectives

To expedite the Resettlement Scheme of farmers and improve the self-sufficiency of food in Zimbabwe by means of the development in the Communal Land.

(2) Execution Agency

The responsible ministry in Zimbabwe for this Project is the Ministry of Lands and Agriculture. The executing agencies are the Department of Agricultural Technical and Extension Services(AGRITEX) under this Ministry, and the Department of Water Development(DWD) under the Ministry of Rural Resources and Water Development. The works to be executed by each agency have been divided at a particular point in the whole irrigation system: the so called "field edge". The field edge in this Project is an outlet gate of each farm pond.

AGRITEX is in charge of the operation & maintenance of on-farm facilities, such as irrigation canals, drainage canals and farm roads including project management facilities, after the field edge.

DWD is in charge of main irrigation facilities, such as pumping station, head races and farm ponds, before the field edge.

(3) Outline of the request

Following items are requested by the Government of Zimbabwe for development of the Project.

Item	Block		
	Block A	Block D	Block E
Irrigation area (ha)	115	203	94
Pumping station	ϕ 250mm × 3, one station	ϕ 300mm × 3, one station	ϕ 200mm × 2, one station
Pipe line	ϕ 500- ϕ 200mm 3.5km	ϕ 700- ϕ 450mm 2.2km	ϕ 450- ϕ 350mm 1.4km
Irrigation canal Dimension	7.1km 300×400mm	9.8km 300×400mm	4.9km 300×400mm
Farm pond	$110m^3$ × 1 $1,080m^3$ × 1	$830m^3$ × 1 $1,260m^3$ × 1	$450m^3$ × 1 $520m^3$ × 1
Trunk road (km)	5.4	3.3	3.6
Farm road (km)	3.0	7.3	3.9

Chapter 2

Contents of the Project

Chapter 2 Contents of the Project

2-1 Objectives of the Project

The Government of Zimbabwe is aiming at improving the living standard of the indigenous people in the Communal Land, securing food self-sufficiency and creating employment opportunities by means of the expansion of agricultural production. The first target is to raise the existing agriculture from subsistence level to commercial oriented one. This has been clearly stated in the Five Year Development Plan(1996/97～2000/01) of the Manicaland Province, elaborated along the policy guidelines of the National Development Plan. The development of the irrigated farm land has been specified as the key strategy to attain the goal, and the implementation of irrigation development projects has become a high priority issue for the Government.

Although the Government is trying to achieve the goal, the progress of implementation is not necessarily fast and the result is limited, due to the recent tight financial situation of the Government. Under these circumstances, the objectives of the Project are to implement the irrigation development project in the Nyakomba Ward belonging to the Saunyama Communal Land in the north-eastern part of the Nyanga District, the Manicaland Province, with Japan's Grant Aid, and to enable the Government achieve its final goal.

The total area of the Ward is about 5,300ha with a population of 4,700. Irrigation facilities have already been constructed in Block B and C as Phase 1 of this Project and the farming is successfully commenced in Block C already. Encouraged with the success in Block B and C, the implementation of an irrigation scheme is planned in the remaining three blocks (Block A, D and E) as Phase 2 of the Project. Although the present rain fed agriculture is unstable, future farming will be stable and sustainable, realizing double cropping with introduction of the irrigation facilities.

2-2 Basic Concept of the Project

(1) Result of the survey

Following items can be pointed out regarding the Project.

a) As for the priority of the development, Zimbabwean side proposed that three blocks should be developed in order of Block D, Block A and Block E. With this respect, the view of the Study Team is as follows;

Block D is a gently sloped area (gradient: about 1:40) and its cultivated soil (clay with fine sand or clay) is sufficient. Its area is the greatest of the three, therefore, it will produce the intended effect of the development easily. Block A is situated in the middle between the project management facilities constructed in Phase 1 and Nyamaropa business center, therefore, this block is superior in the circulation and marketing of the products. Its topography and soil is better than Block E. Thus, it is thought reasonable to select this block next to Block D. Based upon these views, the Team fully endorses the development priority proposed by Zimbabwean side.

b) With regard to diversion of water from the Gairezi River, the letter of agreement between Zimbabwe and the Government of Mozambique is still effective. Therefore, the reasonable quantity of water can be taken for the Project.

c) AGRITEX bore the expense for the extension of electric power line in Phase 1 of this Project. In Phase 2, as the line is still far shorter, it is expected with certainty that the similar extension work would be borne by AGRITEX.

d) Several projects which are similar to the Nyakomba Irrigation Project both in scale and in system are being implemented in the Province, funded by other foreign donors. The goal aimed at with the requested Project coincides with that of those assisted by other donors, accordingly the composition of the Project can be considered appropriate.

e) Boring survey was done to confirm the bearing capacity of the foundation at the selected site for pumping station and farm pond in three blocks.

The sites of three pumping stations are selected at the left bank of the Gairezi River. The bedrock is exposed in places along the river. The geological structure mainly consists of sand. The dense sand layer is observed from 8m～10m below the surface at block A and D. The bedrock of sand stone is observed from 6m below the surface at block E. The N-value test shows that the layers of all the three sites are firm enough for the direct foundation. As for the sites of farm ponds, the ground consists of clay in block A and D, and the bed rock is exposed in block E. The N-value of the clay layers is more than 10. Refer to the boring test result in the Appendices 6.

(2) Basic Policy of the Project

Through the discussion with the Zimbabwean officials and the result of the public hearing in the Project Site, following basic policy has been drawn up.

Farmers have a strong intention to be relieved from the rain fed agriculture, and they have the definite and strong will to bear the operation & maintenance cost needed for irrigated agriculture. This was expressed as the general opinion of about 60 farmers in the public hearing.

They know the standard and level of the constructed facilities with Phase 1, therefore they expect the next development will have the same standard. Namely, the size of the development area would be such that all the farmers living in the block can participate in and can engage in farming the year round.

Therefore, the standard and size of the Project in Phase 2 should be same as that of Phase 1, though each structure be designed more economically than previous ones.

Taking the above into consideration, the basic policy of the Project is drawn up to construct the irrigation facilities in Nyakomba Ward (Communal Land), Nyanga District, Manicaland Province, aiming at assisting the Government in development of the irrigated farm land along the provincial development strategy. The facilities considered are the pumping station, pipe lines and farm ponds, in every block, and, concrete lining canals, earth lining drain canals and gravel paved farm roads are to be constructed in all the irrigation blocks.

2-3 Basic Design

2-3-1 Design Concept

(1) Pumping Facility

a) Location of Pumping Station

Pumping stations will be at the left bank of the Gairezi River. The bank of the river is covered with grass, and the river's course relatively stabilized. The location of pumping stations will be decided in consideration of selecting places with sufficient depth and relatively fast flow in order to avoid sedimentation and intrusion of contamination into the intake tunnel.

b) Intake Water Level

The width of the Gairezi River is narrow(approximately 20-30m), and the difference between water levels in the dry season and the rainy season is approximately 10m at the maximum. Fluctuation of the water level will be carefully considered in deciding on the selection of pumps, method of installation and height of pump location.

c) Operation and Maintenance of Pumping Facilities

As the difference in water levels between intake and output is considerable, it is necessary to use a high water-head pump with more than 60m as total head. At present, pumps made in Europe and South Africa are normally used for irrigation pumps in similar scale project in Zimbabwe, as the pumps made in Zimbabwe have limited capacity. It is therefore necessary to make a sufficient study regarding selection of pumps from among the pumps made in Zimbabwe, Europe, South Africa and Japan.

Electric motors will be used, as electrification at the site has been completed during phase I of this Project. Pump operation will be conducted by the simple ON-OFF switch system that is usually used in Zimbabwe. In order to make pump operation simple, water will be pumped up to the firm pond that is placed at the highest point of the block, and will be supplied to the main division works by gravity. Water management between the pumps and the firm pond will be carried out by a water level gage installed at the pond and the control board equipped with a buzzer and light.

Operation hours of the pumps is decided as eight hours per day, taking the irrigation method (furrow irrigation), capacity of the farm pond and working hours of the farmers into consideration.

At present, people of the area draw water for domestic use from the Gairezi River. Only women are in charge of this heavy work. The amount of water for their domestic use will be added to the pumping capacity to release them from this burden. However, from the view of preservation of health, it is necessary to lead people that the river water should be used only after boiling. The necessary amount of water per family per day is calculated based on the discussion with AGRITEX as follows;

Water for Domestic Use per Family per Day

Consumed by family members	50 l/person/day × 6 people	300 l/day
Consumed by cattle	50 l/head/day × 5 heads	250 l/day
Others		100 l/day
Total		650 l/day

d) Construction Period

The period of one year is necessary to construct one block, judging from local contractor's capacity of construction, capacity of management and the potential number of skilled laborers to be recruited. This can be judged reasonable through the experience of implementation in Phase I.

Furthermore, the flood in the rainy season must be taken into consideration. The construction of the pumping station must be commenced in the dry season, and be completed by the beginning of December when the rainy season starts usually. (If not, the structure will suffer from a disaster due to the extreme high level of flood water.) The construction schedule should be made considering that at least six months are necessary for the construction of one pumping station.

(2) Irrigation, Drainage and Farm Roads

When facilities are designed, the designs will reflect the proper level of technology and cost complying with local conditions regarding execution skill, materials and financial resources in order to attain easy construction and easy operation and maintenance in future, while satisfying modern technical standards.

a) Design Criteria and Standard of the Project

As for the scales and quality of the structures, the results from investigation in both of Nyamaropa and Nyakomba in Phase I Projects, are referred to, and the

「IRRIGATION MANUAL」 issued by AGRITEX is also referred to.

In Zimbabwe there are standards about concrete and materials for building issued by Standards Association of Zimbabwe, but not enough for design and implementation of civil works. Under such circumstances, the designing has to be made referring to the British Standards (BS) and the Japanese Industrial Standards (JIS).

b) Water Conveyance Facilities

In selecting the route of the pipelines, when they are laid along the district road they will be buried down outside the road area and when they are in the project area proper, they will be buried in the shortest way in principle, provided that there is no special obstacle along the route. The buried depth of pipeline is set as one meter at the minimum to avoid damage due to farming and other activities.

In order to carry out water management smoothly and efficiently, a stable supply of irrigation water must be realized. To secure stable irrigation, farm ponds combining the role of discharge chamber are to be constructed. The capacity of the ponds are determined in accordance with the allowable shut–down interval of the pumps.

c) Irrigation and drainage canal

Irrigation and drainage canals will be aligned with an interval of 100 meters or less, in consideration of 100-meter oblong length of the fields. As the water will be taken into the fields using siphon pipes, the water level in the canal will be higher than field level by at least 20 cm. Reinforced concrete trapezoidal canals as normally employed by AGRITEX will be adopted as irrigation canals in order to prevent seepage and to make operation and maintenance easy.

Division works, drops, and other appurtenant facilities are to be set up where necessary along the irrigation canals, and the present conditions of local facilities will be taken into consideration in drawing up the design. The ends of the irrigation canals are connected to drainage canals or streams in order to drain off excess and residual water, and chutes will be placed at these connection points.

The drainage canals are, in principle, aligned in lower portion, now being used as natural drainage. The drainage canals will be made of earth. Confluent facilities, drop works and other appurtenant facilities will be set up where necessary along drainage canals. The ends of drainage canals are to join to streams or to the Gairezi River, and chutes are to be placed at these connecting points.

d) Farm Road

Trunk farm roads designed for use by big trucks will link major district roads with the pumping stations, and will be used to deliver machinery. Farms will be provided with secondary farm roads for use in farming activities and canal inspections. The farm roads will be of earthen embankment, the trunk farm roads being 5m wide while the secondary farm roads 3m wide. Embankments is to be either 20 or 30cm higher than farm or ground level. In principle, the secondary farm roads are laid along the drainage canals.

(3) Consideration for the Economical Construction

Pumping stations will be designed economically after the comparison of following items; Type of pumps, The number of pumps, Type of setting.

With regard to the design of farm ponds, the construction cost is changeable according to the planed depth of water. Therefore, optimum depth will be sought through the trial calculation.
Ductile iron pipes were used as a material of pipeline from the pumping station to the farm pond in phase 1 (Block B and C). This time, glass Fibered Reinforced Plastic pipe (FRP) will be adopted, because FRP is cheaper than ductile iron pipe, and FRP is commonly used in public works recently in Zimbabwe.
Irrigation canals will be designed, in particular, considering the gradient of canals and height of drop works referring to the economical and durable types locally adopted.

2-3-2 Basic Design

(1) General Plan

The total area and the general system of the Project are as follows.

- Irrigation facilities in the project areas, which boundaries are fixed on the spot in the presence of AGRITEX staffs, are constructed. The area of each block is as follows.

	Block A	Block D	Block E	Total
Development Area (ha)	115	203	94	412

- Irrigation water is drawn from the Gairezi River by pumps, then pumped through pipelines to a farm pond.

- From the farm pond, water is carried to main division boxes in each sub-block by pipeline, as delivery of water by open canals is impossible because of unfavorable topographic conditions.

- Open irrigation canals are connected to the main division boxes. From the main division boxes, water is distributed to the total area through the open canals. Border irrigation or furrow irrigation is applied as irrigation methods, thus, irrigation water is drawn by siphon pipes from open irrigation canals to the fields.

(2) Facility Plan

(2)-1 Pump Facility

(2)-1-1 Alternative plan

According to the request, every block has the independent pumping station. However, an idea was raised as an alternative plan. That is the plan in which one pumping station may be able to cover to irrigate two blocks, as Block D and E are situated mutually in adjacent. The alternative plan is evaluated as below.

<u>Merit</u>

: In the case of implementation of three blocks, total cost is roughly estimated as 1.8 billion Yen for original plan. However, with the merger of Block D & E, total cost will be reduced to 1.7 billion Yen. This means that about 6% of cut in total cost by the merger.

Demerit

: Although two blocks are located side by side, they belong to the different villages. Accordingly, there might be some in the collection of O & M fee, observance of their bylaw and distribution of irrigation water. This concern is mentioned by some officials of AGRITEX and DA(District Administrator), as well.

: As walking is the only means for daily traffic for common farmers, it is very difficult to communicate between the field and the pump station. Because Block E is away from the pumping station in Block D by about 6 km.

: With the merged plan, the construction cost of Block D is higher than that of original independent plan, if the continuous development of Block E is considered. Namely, without continued implementation in Block E, the commencement of construction in Block D would become of less meaning. It is noted that the implementation of two blocks in one year is too big and deemed almost impossible, judging from the experience in Phase I.

Conclusion

: It is thought more realistic that one pump station be constructed in each block.

(2)-1-2 Conditions of the Design

a) Location and Foundation of Pump Station

Three spots where the river course appeared stable, are selected as proposed locations for the pumping station on the left bank of the Gairezi River. Taking into account implementability, station sites are selected where cofferdam and excavation works are found less difficult, where the bedrock is not exposed on the surface to avoid difficult excavation work.
Foundation piles are thought not needed for pumping stations, as bearing capacity is confirmed sufficient by boring test.(Refer to Appendix 6.)

b) Intake Water Level

The width of the Gairezi River is narrow (approximately 20-30 m), and the difference between water levels in the dry season and the rainy season is approximately 10m at the maximum. The fluctuation of water level in the river was carefully examined in selection and decision of the pumps, its installation method and the elevation of pumping units to be installed.

As there are no records of water level, high water level of the Gairezi River which is essential for the design of the pumping station, is to be collected through the interview at site. Low water level of the river is measured at site during the Basic Design Study, because the level is considered constant every year. Thus, the design levels of the river are determined as follows.

Design Level of the River

Item	Block A	Block D	Block E
Flood water level (m)	816.0	808.0	801.5
Low water level (m)	806.6	799.9	793.4

c) Operation and Maintenance of Pump Facilities

It is found necessary to use a high water-head pump with total head of about 60 m. Taking into account the importance of the facilities, time of delivery, reliability and after-sales service, pumps manufactured in Japan have been selected in Phase 1. Consequently, pumps made in Japan are also selected taking interchangeability of repair parts into account, in this Project.

Electric motors are selected, as the electrification at the site has been completed. As wiring material and control devices are widely been used in Zimbabwe and easily available, Zimbabwean products are considered to be used as much as possible. The operation of pumps is planned to be made by the simple ON-OFF switch system as usually practiced in Zimbabwe.

Water is pumped up straight to the firm ponds which are located at the highest points of each block, and the pumps will be shut-off by water level gauges installed at the ponds.

Operating hours per day will be eight (8) hours as same as the local farmers' working hours. This arrangement has been made taking furrow irrigation method adopted and rather small storage capacity of the farm ponds (maximum pumping capacity for 30 minutes) provided into account.

d) Conditions for Scale of Pump

• Unit Water Requirements: Q

The peak water requirements are used for calculating the design capacity of pumps. In calculating the water peak requirements, the cropping pattern, unit water requirements, area to be irrigated and irrigation efficiency are taken into consideration. The result of the calculation is shown below. (Refer to the Chapter 2, Section 2-3-2, (2)-2, b).)

Q=2.11 l/sec/ha

• Design Discharge of Each Block

Multiplying the unit water requirement with the areas to be served and adding the needs for domestic use, design discharge of each block is calculated as follows.

Block	Area	Irrigation Water Requirements	Domestic Water	Design Discharge
A	115 ha	2.11 x 115 = 242.7 (l/sec)	2.6 l/sec*	245.3 l/sec
D	203 ha	2.11 x 203 = 248.3 (l/sec)	4.5 l/sec	432.8 l/sec
E	94 ha	2.11 x 94 = 198.3 (l/sec)	2.1 l/sec	200.4 l/sec

* Suppose a farm land of one hectare is given every family. Water of 650 l/day is needed for one family.

650 l/day/family÷(8hours/day×3,600sec)×115families=2.6 l/sec

650 l/day/family÷(8hours/day×3,600sec)×203families=4.5 l/sec

650 l/day/family÷(8hours/day×3,600sec)× 94families=2.1 l/sec

• Design Discharge per Pump

Taking into account the seasonal variation of water requirements and dependability of water supply, each pumping station has been planned to have three pumping units. The design discharge of each pump is calculated as follows.

Block	Design Discharge (Q)	Discharge per one Pump	Pump Diameter
A	245.3 l/sec = 14.7 m^3/min	Q ÷ 3 = 4.90 m^3/min	ø 200 mm
D	432.8 l/ sec = 25.9 m^3/min	Q ÷ 3 = 8.63 m^3/min	ø 300 mm
E	200.4 l/ sec = 12.0 m^3/min	Q ÷ 3 = 4.00 m^3/min	ø 200 mm

• Design Suction Level and Actual Pump Head

Water level of the Gairezi River in dry season is almost the same every year, according to the interview survey and the observation conducted during the construction term in Phase 1. Therefore, the design suction levels of each pumping station are determined, based on the lowest water levels measured during this study and taking screen losses into account. The design discharge water level is the sum of the highest water level of the farm pond and the overflow depth from a discharge pit in each farm pond. The following table shows the design suction level, design discharge water level and actual pump head for each.

Block	Design Suction Level	Design Discharge Water Level	Actual Pump Head
A	806.5 m	852.2 m	45.7 m
D	799.8 m	852.2 m	52.4 m
E	793.3 m	837.2 m	43.9 m

(2)-1-3 Design of the Pump

a) Total Head

The total heads of the pumps are calculated based on the local conditions, adding actual head and pipe loss, and the following formula is used.

$$H = Ha + Hl = Ha + hl + V^2/2g$$

$$hl = f \times L/D \times V^2/2g$$

$$f = 134/C^{1.85} \times 1/(D^{1/6} \times V^{0.15})$$

Hazen & Williams formula

H: Total head (m)
Ha: Actual head (m)
Hl: Total head loss (m)
hl: Pipe loss (m)
L: Pipe length (m)
D: Pipe bore (m)
V: Velocity (m/s)
g: Acceleration of gravity (m/s^2)
f: Coefficient
C: Coefficient depending on the pipe (C=130)

According to the aforementioned selection, the design total head with some margin head is determined as follows.

Item	Block A	Block D	Block E
Actual Head	45.70 m	52.4 m	43.90 m
Screen Loss	(0.30 m)	(0.30 m)	(0.30 m)
Pump Loss	2.45 m	0.79 m	1.77 m
Suction	(0.32 m)	(0.17 m)	(0.22 m)
Discharge	(2.13 m)	(0.62 m)	(1.55 m)
Velocity Loss	0.12 m	0.12 m	0.13 m
Pipe Loss	3.78 m	4.70 m	7.54 m
Total Head	52.00 m	58.00 m	53.34 m
Design Total Head	52.0 m	58.0 m	53.5 m

b) Number and Bore of Pump

The number and bore of pumps to be installed are decided in consideration of the following.

- Multiple pumps are installed to deal with emergency breakdowns.
- The number and bore of pumps are decided to facilitate efficient operation complying with fluctuations of water requirements. A combination of different pump bores is considered. In consideration of simple operation and maintenance, however, all the pumps have the same bore.
- The capacity of a single pump is not less than minimum monthly water requirements.
- It is a prime consideration that installation, construction and operation & maintenance are economical. Large bore pumps are not chosen, since that size of pump is not wide-spread in Zimbabwe.

Monthly Discharge

Monthly discharge is calculated from the monthly water requirements, taking into consideration operation days, operation hours and irrigation efficiency with water for daily living , and the results are shown below.

Unit: 1,000m³

Block	Jan.	Feb.	Mar.	Apr.	May	Jun.
A	147.9	51.2	112.0	118.2	85.7	121.9
D	261.1	90.4	197.7	208.8	151.3	215.2
E	120.9	41.8	91.6	96.8	70.0	99.6
Block	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
A	219.0	181.7	93.6	79.6	175.4	165.0
D	386.4	320.8	165.3	140.5	309.6	291.1
E	178.9	148.5	76.5	65.0	143.4	134.8

Type of Combination

Taking into consideration the monthly water requirements and design total discharge mentioned above, the following types of combination are considered. However, types of combination with more than four pumps are not considered due to augmentation of pump station space and equipment cost.

Pump bore is chosen from the followings, based on the "Design Standard for Pumps" issued in Japan. Volute pumps may have the characteristic where a higher head pump has less bore.

Standard Bore (mm)	Hertzian Wave (Hz)	Discharge (m^3/min)	Average Discharge (m^3/min)
150	50	1.80 ~ 3.00	2.40
200	50	3.00 ~ 5.00	4.00
250	50	5.00 ~ 8.00	6.50
300	50	8.00 ~ 12.00	10.00
350	50	12.00 ~ 18.00	16.00
400	50	18.00 ~ 23.00	20.50

Block A

Type	φ300mm 1 unit φ200mm 1 unit	φ250mm 2 units	φ250mm 1 unit φ200mm 2 units	φ200mm 3 units
Scale of civil works & buildings	Relatively smaller, about 130m².	Relatively smaller, about 130m².	Relatively larger, about 150m².	Relatively larger, about 150m².
Adaptability to water requirements	Forced to operate at limited capacity.	Difficult to adapt to the monthly minimum water requirements.	Sufficiently adaptable to the water requirements.	Sufficiently adaptable to the water requirements.
Operation and Maintenance	Various spare parts are needed due to different bores.	Few spare parts are needed due to same bore.	Various spare parts are needed due to different bores.	Few spare parts are needed due to same bore.
Evaluation	△	△	○	◎

Block D

Type	φ400mm 1 unit φ300mm 1 unit	φ350mm 2 units	φ350mm 1 unit φ250mm 2 units	φ300mm 3 units
Scale of civil works & buildings	Relatively smaller, about 130m².	Relatively smaller, about 130m².	Relatively larger, about 150m².	Relatively larger, about 150m².
Adaptability to water requirements	Forced to operate at limited capacity.	Difficult to adapt to the monthly minimum water requirements.	Sufficiently adaptable to the water requirements.	Sufficiently adaptable to the water requirements.
Operation and Maintenance	Various spare parts are needed due to different bores.	Few spare parts are needed due same bore.	Various spare parts are needed due to different bores.	Few spare parts are needed due to same bore.
Evaluation	△	△	○	◎

Block E

Type	φ300mm 1 unit φ200mm 1 unit	φ250mm 2 units	φ250mm 1 unit φ150mm 2 units	φ200mm 3 units
Scale of civil works & buildings	Relatively smaller, about 130m².	Relatively smaller, about 130m².	Relatively larger, about 150m².	Relatively larger, about 150m².
Adaptability to water requirements	Forced to operate at limited capacity.	Difficult to adapt to the monthly minimum water requirements.	Sufficiently adaptable to the water requirements.	Sufficiently adaptable to the water requirements.
Operation and Maintenance	Various spare parts are needed due to different bores.	Few spare parts are needed due to same bore.	Various spare parts are needed due to different bores.	Few spare parts are needed due to same bore.
Evaluation	△	△	○	◎

As shown in the above comparison, it is considered that the "φ200mm 3 units" type of combination (marked with ◎ for Block A and E) and "φ300mm 3 units" type of combination (marked with ◎ for Block D) are the most suitable one.

Consequently, a summary of bore. discharge and total head comes as follows.

Block	Pump Bore (mm)	Total Head (m)	Discharge (m^3/min/unit)
A	200	52.00	4.89
D	300	58.00	8.63
E	200	53.50	4.00

c) Type of Pump

Type of Pump

The following pumps are proposed for the selection of pump type based on the aforementioned bore, discharge and total head:

(a) Horizontal Double Suction Volute Pump
(b) Vertical Suction Volute Pump

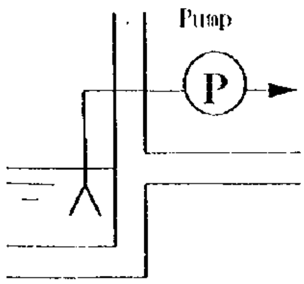
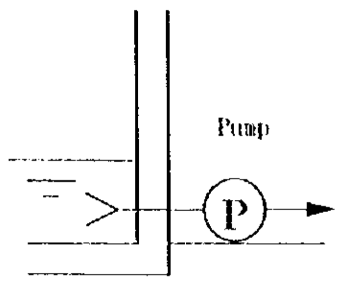
Comparison of Pump Types

Item	(a) Horizontal Double Suction	(b) Vertical Suction
Suction Performance	Durable because of less thrust force. Good suction performance. Characteristic curve is round.	Less than (a). Characteristic curve is round.
Maintenance	Easy as pumps and motors are installed horizontally.	Very difficult as motors are installed above pumps, so need to move motors.
Installation	Easy as pumps and motors are installed horizontally and as one body.	Very difficult as motors are installed above pumps.
Civil & Building	Need wider space than (b), unit load is smaller than (b).	Less space than (a), unit load is bigger than (a).
Evaluation	◎	○

As shown in the above comparison, it is considered that horizontal double suction volute pumps are the most suitable ones, and they are adopted for this Project.

Type of Setting

Generally, there are two types of pump setting, namely the suction type and the forcing type. The forcing type is adopted in this Project since this type does not require vacuum pump and a procedure of operation comes easy in accordance with a comparison study. The result of the comparison study is shown as follows.

Item	Suction Type	Forcing Type
Method of Operation	Unfavorable for automatic operation as filling up (priming) is needed.	Favorable for automatic operation as filling up (priming) is not needed.
Operation & Maintenance	O & M items come a lot as some appurtenances are needed.	O & M items come a few as no appurtenance is needed.
Level of Pump Setting	Shallow	Deep
Allocation		

Since seasonal variation of water level of the Gairezi River is big, even the suction type is adopted, the pump setting location is lower than the high water level due to its suction performance. In short, the suction type still requires water-tight structure and there is no advantage in this case. Therefore, the forcing type is adopted taking into consideration operability and operation and maintenance.

Cavitation

There is no possibility of occurrence of cavitation. Because of forcing type is adopted, dimension and layout of suction pipes are based on the Design Standard for Pumps issued by the Ministry of Agriculture, Forestry and fisheries.

Pump Revolution

Since the pump discharge is 4.00 m^3/min/unit ~ 8.63 m^3/min/unit, the suitable pump revolution is calculated in accordance with the "Design Standard for Pumps" and is 4P-1450 rpm for horizontal double suction pumps.

d) Required Power

All pump stations are supplied with sufficient electricity. Electric motors are selected as prime movers. Required power is calculated by the following formula:

$$L = \frac{K \times Q \times H \times r}{n/100}$$

$$P = L \times (1 + A) \times nt$$

L:	Shaft power (kw)
K:	Constant figure (K = 0.163 at kw unit)
r:	Specific weight of liquid (r =1.0 at water)
n:	Pump efficiency (%)
Q:	Discharge (m^3/min)
H:	Total head (m)
P:	Required power (kw)
A:	Margin (A = 0.1 at motor)
nt:	Transmitting efficiency (nt = 1.0 at coupling)

Calculation of Design Required Power

Item	Block A	Block D	Block E
Q	4.89 m^3/min	8.63 m^3/min	4.00 m^3/min
H	52.0 m	58.0 m	53.5 m
n	65.0 %	71.0 %	65.0 %
L	63.8 kw	114.9 kw	53.7 kw
P	70.2 kw	126.4 kw	59.0 kw
Design Required Power	75 kw	132 kw	75 kw

The following pump efficiency is used based on the "Design Standard for Pumps".

Bore (mm)	Volute	High Head Pump Vertical, Mixed Flow
200	65%	-
250	68%	-
300	71%	69%
350	74%	71%

c) Pump Arrangement and Plane Plan

There are a straight type, a two-line type, a face-to-face type and an inclined type for pump arrangement. The straight type is selected in this Project, although the straight type requires a wider installation space than the others, since this type of pump arrangement is usually applied in Zimbabwe, and it is easy to operate and maintain with great safety. Pump installation spans to walls require more than 1.0 m (o 200 mm) and 1.1 m (o 300 mm) for the suction portion, 2.0 m (o 200 mm) and 2.55 m (o 300 mm) for the discharge portion, and space between pumps is more than 1.0 m, according to the "Design Standard for Pumps".

f) Valves

Suction Side

Since a valve in suction portion is used for the repair and maintenance of pump, a reliable and high-performance valve is required. Therefore, a manual sluice valve is applied taking into account the economical operation and reliability.

Discharge Side

The discharge valve and check valve in discharge portion are operated automatically, therefore reliable valves with high performance are necessary. An electrical butterfly valve and a check valve are applied so as to be operated easily and to obtain relatively lower cost of materials.

g) Supplementary Facilities

Sealing Water Facility

A quantity of sealing water is required with a minimum of 30 litres for the operation of three pumps. Clean water is necessary for the sealing water, so river water is not adequate. Water from a deep well, that is used for cleaning the machine and building as well as for daily use, is supplied for the sealing water. The required pressure for sealing is approximately 10 m. Water pressure is obtained by installing a water tank with a height of about 10 m on the top of the building. The water level of the river is high in the rainy season, therefore the building should be constructed high enough in order to avoid the intrusion of river water.

Counter-measure for Water Hammer

Flywheels are applied in order to prevent the condition known as water hammer that may possibly occur at the time of power stoppages due to high pump heads. After the installation of flywheels, the maximum negative pressure is 3.6m. This pressure is within the allowable range which is shown below.

Allowable negative pressure in pipes

Less than	φ 500mm	-7m
Less than	φ 1,000mm	-6m
Above	φ 1,000mm	-5m

h) Electric Facility

For these proposed pump stations, the power source to be used is by the public 33 or 11 kV electric line . As the design capacity of the motors is low in these pump stations, 380 V is used for the power which is supplied by the Zimbabwean side.

i) Pump Facility and Equipment Plan

Block A

Description	Specification	Quantity
-1. Main Pump	Horizontal Double Suction Volute Pump 4.89 m^3/min x 52 m x 75 kW φ 200mm x φ 100mm motor and coupling water-proof, squirrel cage 50 Hz, 380 V, 3-phase, 1,450 rpm	3 sets
-2. Valves	Sluice valve, φ 200mm Electrical butterfly valve, φ 200mm Check valve, φ 200mm	3 units 3 units 3 units
-3. Pipes Around Pumps	Suction and Discharge	1 l.s.
-4. Water Supply System	Submersible pump φ 50mm Reservoir Pipeline for sealing water system Pipeline for cleaning	2 sets 1 set 1 set 1 set
-5. Electric Facility	Power receiving panel Control panel Auxiliary panel Local panel	1 unit 3 units 1 unit 5 units
-6. Overhead Crane	Manual, 1 ton capacity with manual chain block (1 ton)	2 units
-7. Bar Screen	2,000 mm x 2,000 mm	1 unit

Block D

Description	Specification	Quantity
-1. Main Pump	Horizontal Double Suction Volute Pump 8.63 m^3/min x 58 m x 132 kW φ 300mm x φ 200mm motor and coupling water-proof, squirrel cage 50 Hz, 380 V, 3-phase, 1,450 rpm	3 sets
-2. Valves	Sluice valve, φ 300mm Electrical butterfly valve, φ 300mm Check valve, φ 300mm	3 units 3 units 3 units
-3. Pipes Around Pumps	Suction and Discharge	1 l.s.
-4. Water Supply System	Submersible pump φ 50mm Reservoir Pipeline for sealing water system Pipeline for cleaning	2 sets 1 set 1 set 1 set
-5. Electric Facility	Power receiving panel Control panel Auxiliary panel Local panel	1 unit 3 units 1 unit 5 units
-6. Overhead Crane	Manual, 1 ton capacity with manual chain block (1 ton)	2 units
-7. Bar Screen	2,000 mm x 2,000 mm	1 unit

Block E

Description	Specification	Quantity
-1. Main Pump	Horizontal Double Suction Volute Pump 4.00 m^3/min x 53.5 m x 75 kW ϕ 200mm x ϕ 100mm motor and coupling water-proof, squirrel cage 50 Hz, 380 V, 3-phase, 1,450 rpm	3 sets
-2. Valves	Sluice valve, ϕ 200mm Electrical butterfly valve, ϕ 200mm Check valve, ϕ 200mm	3 units 3 units 3 units
-3. Pipes Around Pumps	Suction and Discharge	1 l.s.
-4. Water Supply System	Submersible pump ϕ 50mm Reservoir Pipeline for sealing water system Pipeline for cleaning	2 sets 1 set 1 set 1 set
-5. Electric Facility	Power receiving panel Control panel Auxiliary panel Local panel	1 unit 3 units 1 unit 5 units
-6. Overhead Crane	Manual, 1 ton capacity with manual chain block (1 ton)	2 units
-7. Bar Screen	2,000 mm x 2,000 mm	1 unit

(2)-2 Irrigation, Drainage and Farm Roads

a) Irrigation System

Irrigation water is drawn from the Gairezi River by pumps, then conveyed through pipelines to farm ponds constructed at elevated sites within the project area. Open concrete irrigation canals carry the water from these farm ponds to the farms.
To simplify the operation of the overall system, each farm pond serves one block only, and main division works are constructed for each small block within the block. The water flows by gravity through pipelines from the farm ponds to the main division works. After the main division works, the water is delivered through open canals. From the open canals, water is taken into fields by means of siphon system, thus, irrigation method is planed as furrow or border irrigation.

b) Design Conditions

The conditions for the basic design of irrigation and drainage facilities, i.e., the water allowance and the rate of runoff, are as follows.

[Water Requirement]

The water requirement is calculated by the irrigation interval determined based on the available soil moisture and effective soil layer, taking into account the effective rainfall and crop evapotranspiration.
The crop evapotranspiration is figured out using the Modified Penman's Method being uniformly used in Zimbabwe,

$$ETc = ETo \times Kc$$

Where:

ETc: Crop evapotranspiration (mm)
ETo: Standard evapotranspiration (mm)
Kc: Crop coefficient

The monthly average of ETo is calculated by use of the ETo map widely used for irrigation planning in Zimbabwe.
The individual Kc is adopted from the Irrigation Drainage Technical Manual No.

24, issued by FAO.

Irrigation requirement calculated with the crop evapotranspiration includes 80 % of rainfall probability. The probable rainfall is calculated using the monthly rainfall records observed at the Nyamaropa Irrigation Office.

The peak irrigation requirement thus calculated will occur in July. The calculation is shown as follows;

Calculation of the Unit Water Requirement

Crops	Beans	Wheat(1)	Wheat(2)	Onion	Wheat(2)	Total
Cropping Area (ha)	0.30	0.30	0.30	0.05	0.05	1.00
Kc	1.05	1.17	0.88	1.07	0.88	
Corrected Kc	1.12	1.06	1.00	1.12	1.00	
ETc/month (mm)	117.7	124.1	88.1	120.0	88.1	
Converted Water Requirement per ha	35.3	37.2	26.4	6.0	4.4	109.3
Application Efficiency	0.65					
Water Requirement	109.3/0.65=168.2 (mm/month)					

ETo/day=3.23mm, by the ETo map of Zimbabwe in July ETo/month=3.23x31=100.1mm

- Unit Water Requirement

  168.2mm/month÷31days/month = 5.5mm/day

  ∴55m³/ha/day

- Pumping capacity per ha (Q(l/sec/ha)) is calculated as follows;

  55×10^3(l/ha/day)÷8(hours)÷3600(sec)÷Ec

  Ec = Conveyance efficiency : 0.90

  ∴ Q=2.11 l/sec/ha

[Rate of Runoff]

The rate of runoff is calculated so that two hours of rainfall in a hilly catchment area can be drained from the irrigated area in four hours. The calculation method is as follows.

$$Rt = R_{24} (t/24)^k$$

Where:

Rt:	Rainfall in the time of concentration of t hour (mm)	
R_{24}:	Rainfall per day at ten-year probability (mm)	
k:	Constant	k = 1/3 ~ 2/3 -----» 1/2

Rainfall per day is calculated at 123.2 mm, and Rt is 35.6 mm in two hours of time of concentration. Using Rt the rate of runoff (q) is calculated as follows.

$$q = 10 \times Rt \times f \div (3,600 \times t)$$

Where:

q: Rate of runoff ($m^3/s/ha$)

f: Runoff coefficient

- Farm: 0.52 (0.45~0.62)
- Hilly area: 0.82 (0.72~0.92)

The runoff coefficients (f) of 0.52 and 0.82 were chosen for farm and hilly area respectively.

Thus, qt was calculated as follows.

q_2 = 0.0405 $m^3/s/ha$ (Hilly area)

q_4 = 0.0182 $m^3/s/ha$ (Farm)

c) Pipeline

Table 3.2 shows the length and the discharge of the pipelines. Pipe diameters are selected to provide an economical velocity during pump operation, as shown in the following table.

Table 3.1 Pipe Diameter and Velocity

Pipe Diameter (mm)	Velocity (m/s)
ø 75 ~ ø150	0.7 ~ 1.0 m/sec
ø 200 ~ ø400	0.9 ~ 1.6 m/sec
ø 450 ~	1.2 ~ 1.8 m/sec

Table 3.2 Dimension of Pipeline

Block	Pipeline No.	Discharge	Length	Diameter	Remarks
A	A-P-1	0.245 m^3/sec	800 m	ø 450 mm	FRP
A	A-P-2-1	0.051 m^3/sec	70 m	ø 200 mm	PVC
A	A-P-2-2	0.024 m^3/sec	2,040 m	ø 200 mm	PVC
A	A-P-3-1	0.191 m^3/sec	340 m	ø 450 mm	FRP
A	A-P-3-2	0.180 m^3/sec	170 m	ø 450 mm	FRP
A	A-P-3-3	0.108 m^3/sec	120 m	ø 400 mm	FRP
A	A-P-3-4	0.037 m^3/sec	160 m	ø 300 mm	PVC
D	D-P-1	0.432 m^3/sec	1,400m	ø 600mm	FRP
D	D-P-2-1	0.381 m^3/sec	50m	ø 500mm	FRP
D	D-P-2-2	0.256 m^3/sec	260m	ø 500mm	FRP
D	D-P-2-3	0.064 m^3/sec	410m	ø 400mm	FRP
D	D-P-3-1	0.047 m^3/sec	200m	ø 200mm	PVC
E	E-P-1	0.200 m^3/sec	1,300m	ø 400mm	FRP
E	E-P-2-1	0.057 m^3/sec	50m	ø 200mm	PVC
E	E-P-3-1	0.141 m^3/sec	250m	ø 300mm	PVC
E	E-P-3-2	0.101 m^3/sec	400m	ø 300mm	PVC

Types of pipe are determined taking the internal pressure and external pressure (e.g., earth pressure, dynamic load, etc.) into consideration.

For this Project, the planned internal water pressure between the pumping station and farm ponds is relatively high, ranging from 5.8 to 5.2 kg/cm^2. Therefore, based on the calculated result, fiber reinforced plastic pipe of superior durability is adopted because of its easy installation for the head races between the pumping stations and farm ponds.

As the planned interior pressure between the farm ponds and main division works, is not very high, PVC pipe (available in Zimbabwe) is adopted for those pipeline sections.

The loss of head, for the pipes chosen above, is calculated using the following Hazen & Williams formula.

$$hf = 10.67 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85} \times L$$

Where;

hf:	Friction loss
C:	Coefficient depending on the pipe (FRP, PVC: C = 150)
D:	Pipe diameter (m)
Q:	Discharge (m^3/sec)
L:	Pipe length (m)

Individual pipe loss is shown in the following table.

Table 3.3 Water-head Loss of Pipeline

Pipeline	Diameter	Length	Pipe Loss
A-P-1	ø 450 mm	800 m	6.3 m
D-P-1	ø 600 mm	1,400 m	5.6 m
E-P-1	ø 400 mm	1,300 m	9.6 m

Air valves are installed at intervals of 500 m on the line and at longitudinal protrusions. Blow-off valves will be provided at depressions for operation and maintenance.

Water hammer du to the sudden stop of pumps is analyzed. The result shows that a negative pressure of 33m arises in the pipeline. As this pressure causes the water column separation, flywheels are to be installed between a pump and a motor. After the installation negative pressure is decreased to 3.6m and maximum pressure is 87m. Therefore, FRP pipe which has the allowable pressure of 10bar (98m) is chosen as the material of the head race.

d) Farm Ponds

Trouble-free and efficient water management is only possible when a stable volume of irrigation water is supplied. To guarantee such a stable supply, farm ponds which will serve the additional role of discharge chambers are constructed.

Locations of farm ponds are so selected that the irrigation water can flow by gravity through pipelines from the farm ponds to the main division works in each small irrigation block. The proposed sites for farm ponds are adjacent to villages on the boundary between farms and hilly land. These locations will also facilitate the residents of the villages to use this water for their domestic use.

The capacity of each farm pond is determined in accordance with the allowed pump's shut-down interval. An allowed interruption interval is set because when a pump is started up shortly after being shut off, excessive load may act to the motor. As the pump's allowed shut-down interval is 20 minutes at the shortest, so the volume of water pumped in 30 minutes is considered appropriate as the capacity of farm ponds. The following table shows the proposed capacity of the farm ponds in each block.

Table 3.4 Capacity of Farm Pond

Block	Farm Pond	Irrigation Area	Capacity
A	A-F.P.	115 ha	450 m3
D	D-F.P.	203 ha	780 m3
E	E-F.P.	94 ha	360 m3

T-type reinforced concrete retaining walls are applied for the structure of the farm ponds, taking into account durability and water-tightness. The shape of the ponds is rectangular with an effective water depth of 2.0 m and free board of 0.5 m. The construction costs of three effective water depths (i.e. 1m, 2m, 3m) are compared. The result shows the depth of 2m is the most economical. The spillway of a pond directly discharges excess water into existing small streams. The capacity of the spillway is same as the maximum pumping capacity.

e) Main Division Works

Each small irrigation block is equipped with a main division structure to receive irrigation water from farm ponds and distribute it to farms through open canals. The main division works are made of reinforced concrete. The water level is adjusted by a sluice valve installed at its inlet, as the inlet pipe pressure is not high. The outlet from the division is so constructed that attached sluice valves can adjust the discharge into the open canals.

f) Irrigation Canals

Irrigation canals are laid out to distribute the water from the main division works to each farm in the project area.

The irrigation canals are of reinforced concrete trapezoidal sections with side-wall gradients of 60 degrees, in order to reduce the seepage and to facilitate both maintenance and irrigation operations. The irrigation canal sections are designed with the conditions that a longitudinal gradient of I = 1/250 is set, the design velocity is assumed to be less than critical velocity and the design water depth is less than half of side-wall height in order to secure room as water is taken into the field by siphon pipes. The following formula by Manning is used for the velocity study.

$$V=(1/n) \times R^{2/3} \times I^{1/2}$$

V: Mean velocity (m/sec)

I: Hydraulic gradient (canal bed slope)

R: Hydraulic mean depth (m)

n: Coefficient of roughness

Based upon the calculation, three types of irrigation canals are designed. Types A, B and C are shown in the table below.

Table 3.8 Irrigation Canal Types

Type	Discharge (m^3/s)	Bottom Width (m)	Height (m)
A	0.118 ~ 0.068	0.30	0.40
B	0.068 ~ 0.021	0.25	0.35
C	0.021 ~ 0.000	0.20	0.30

The length of irrigation canal for each block is as follows.

- Block A: 11,210 m
- Block D: 16,240 m
- Block E: 8,420 m

g) Appurtenant structures for Irrigation Canals

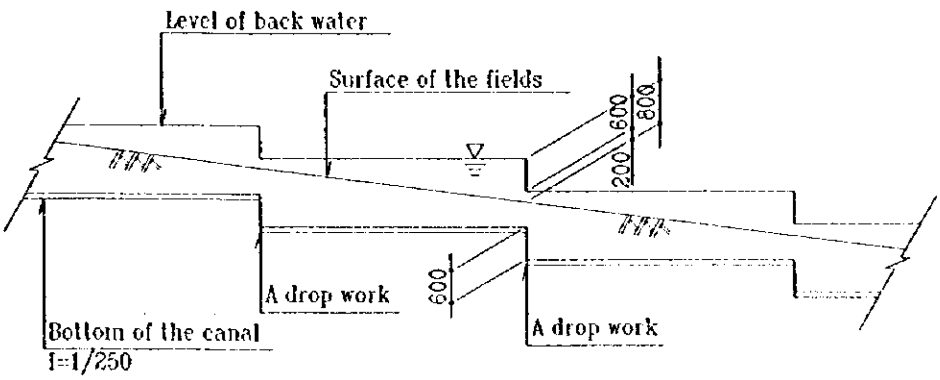
Along the irrigation canals, a varied types of structures are provided at various points as necessary. They are: division works, drops, road cross siphons, canal cross siphons, canal cross culverts, cut throat flumes and chutes.

[Division Works]

Division works are constructed at junctions of the irrigation canals. Their structure is made of reinforced concrete and is fitted with square steel sluice gates manufactured in Zimbabwe. The dimensions of gates is matched with the sections of each irrigation canal. (Refer to the drawing No. 30.)

[Drops]

As already stated, the longitudinal gradient of the irrigation canals is set at I = 1/250. The topographical gradient of farms is steeper than that of the canals. Drops are, therefore, installed. A fall is made uniformly 60 cm, and locations for the drops are determined according to topographical conditions. The level of back water is planed to be higher at least 20cm than the field's level even just after the drop works to secure sufficient water to the fields by siphon pipes. To avoid excessive erosion in the fields, the maximum deference of the levels is planed as 80cm. These relations are illustrated below.



[Road Cross Siphons]

Road cross siphons are constructed at the points where roads intersect the irrigation canals. Reinforced concrete pipes are laid under roads with a reinforced concrete box placed at the both ends of the pipe.

All the road crossing pipes will have a diameter of 600 mm to simplify their maintenance. Where a canal crosses a major district road, burial depth is set at 1.0 m, and where it crosses a farm road, the depth is 0.8 m. (Refer to the drawing No.29.)

[Canal Cross Siphons]

Canal cross siphons are built at intersections of irrigation canals with small rivers or drainage canals in the project area. Their structure is identical to that of the road crossing siphons, but their depth is set at 0.6 m.

[Entrance Works]

One entrance work is provided at each canal so that tractors and other equipment can cross the canals. Reinforced concrete slab structure is adopted. (Refer to the drawing No.29.)

[Cut Throat Flumes]

Cut throat flumes are installed downstream of division works (beginning of each canal) to so monitor the discharge of irrigation canals, that proper water management can be performed. These flumes are widely used by AGRITEX.

[Chutes]

For drainage of excess water into drainage canals and rivers at the ends of irrigation canals, chutes are built in order to withstand the water force and prevent soil erosion. Made of reinforced concrete, these chutes have a stepped configuration. Gabions are installed around the chutes to prevent erosion caused by change of the flow direction.

h) Drainage Canals

Drainage canals will be constructed to drain rain water in the project area. The drainage canals will generally be laid down along low-lying areas which are presently used as natural drainage. The downstream ends of canals will be connected to streams and to the Gairezi River. The drainage canals will be trapezoidal shaped earth canals, with a side gradient of 1:1.0. To simplify maintenance, the smallest sections will be of 0.6 m wide in bottom width and average canal depth of 0.65 m. Manning's formula is used to determine this canal section.

The following three types of canals are designed, by the size of drainage area.

Type	Size of the Area (ha)	Maximum Discharge (m^3/s)	Bottom Width (m)	Water Depth (m)	Minimum Depth (m)	Maximum Depth (m)
1	0 ~10	0.180	0.60	0.250	0.35	0.95
2	10~15	0.270	0.70	0.291	0.40	1.00
3	15~25	0.432	0.70	0.378	0.50	1.10

The drainage canal length for each block is determined as follows.

- Block A: 9,450 meters
- Block D: 16,300 meters
- Block E: 9,440 meters

i) Appurtenant Structures for Drainage Canals

Along the drainage canals, structures such as confluence facilities, drops, road crossing culverts, revetment works, canal crossing culverts (entrance works) and chutes are provided at various points as necessary to secure the canals from erosion and collapse.

[Confluence Facilities]

Confluence facilities made of gabions are placed at confluence points of the drainage canals in order to disperse the energy of flow and prevent soil erosion. (Refer to the drawing No.32.)

[Drops]

Because the surface slop of the farms is steep, the earthen drainage canals are less resistant against erosion. Falls uniformly 60 cm in height are made along the drainage, and the locations are determined according to topographical conditions. The structure is of concrete wall with gabion protections downstream. (Refer to the drawing No.32.)

[Road Crossing Culverts]

Road crossing culverts are constructed at points where roads intersect the drainage canals. The culverts are formed with reinforced concrete pipes and buried beneath the roads. Gabions are provided at downstream of the culverts to prevent erosion caused by flow. (Refer to the drawing No.33.)

[Revetment Works]

Revetment works made of gabions are placed at points where the drainage canals bend, in order to subdue water force and prevent erosion and scouring. (Refer to the drawing No.32.)

[Canal Crossing Culverts (Entrance Works)]

To allow machinery to enter farms from farm roads, entrance works are provided at 100 m intervals. Their structure will be identical to that of the canal crossing culverts, but the width will be made 3.0 m so that machinery can enter from the roads, obstacles free. (Refer to the drawing No.33.)

[Chutes]

For drainage of water into small rivers and the Gairezi River at the downstream ends of drainage canals, chutes are provided to disperse flow energy and to prevent soil erosion. Made of reinforced concrete, these chutes have a stepped configuration. Gabions are installed around the chutes to prevent erosion caused by rapid flow. (Refer to the drawing No.33.)

j) Farm Roads

Trunk farm roads designed for the use of heavy trucks link the arterial district roads with the pumping stations, and are used to deliver machinery. Farms are provided with secondary farm roads for use in farming activities and canal inspections. In principle, the secondary farm roads are aligned along all the drainage canals.
The farm roads are of embankment, and the trunk farm roads are of 5 m wide, while the secondary roads 3 m wide. Embankments are 30 cm high for the trunk farm roads while 20 cm high for the secondary farm roads. Their longitudinal gradients are set not greater than 10 %. The cross-sectional gradient of 2 % and 10 centimeters thick of the gravel pavement are specified. The effective width of the

trunk farm roads is 4.0 m while that of the secondary farm roads 2.5 m.
The lengths of farm road to be built for each block are as follows.

	Trunk Farm Roads	Secondary Farm Roads
- Block A	410 m	7,380 m
- Block D	1,100 m	16,790 m
- Block E	1,150 m	8,930 m

k) Scope of Work

Basic design is carried along with the above-mentioned design concept, and the scope of works is summarized as follows.

Item	Block A	Block D	Block E
Area (ha)	115	203	94
Pump Station	ø200 x 3 One station	ø300 x 3 One station	ø200 x 3 One station
Pipeline(km)	3.7 ø450~ø200	2.3 ø600~ø200	2.0 ø400~ø200
Farm Ponds (m^3)	430 x1	780 x1	360 x1
Irrigation Canal (km)	11.21	16.24	8.42
Drainage Canal(km)	9.45	16.30	9.44
Trunk Farm Road (km)	0.4	1.1	1.2
Secondary Farm Road (km)	7.4	16.8	8.9

(2)-3 Equipment

Animal tillage is prevailing in Zimbabwe, but introduction of agricultural machine is needed to achieve year round farming. One tractor is thought needed for one block.
As AGRITEX owns many tractors and skilled operators at present, there will not be any troubles and difficulties in maintenance and management of those tractors. British made tractors which are prevailing in Zimbabwe and AGRITEX hopes to procure those of similar made, as their spare parts and consumables are easy to purchase.
Because of importance of irrigation pumps and their appurtenant for this project, Japanese made equipment is planned to procure as mentioned in paragraph 3-1-5 "Procurement Plan".
Followings are the summary list of equipment.

Equipment	Specifications
Horizontal Double Suction Volute Pump	ø200 mm x 75 Kw x 3 units (Block A) ø300 mm x 150 Kw x 3 units (Block D) ø200 mm x 75 Kw x 3 units (Block E)
Tractor	4WD 75HP x 1 unit (One for each block)
Attachments: Rotary Harrow, Disk Plow Ridger, Trailer	Each 1 unit
Bulldozer	14ton x 1 unit (Block D only)
Bicycle	Normal type with a bicycle pump x 12(Four per each block)

(2)-4 Basic Design Drawings

Refer to attached basic design drawings.

Chapter 3

Implementation Plan

Chapter 3 Implementation Plan

3-1 Implementation Plan

3-1-1 Implementation Concept

(1) Project Concept

AGRITEX and DWD are the two executing agencies of this Grant Aid Project and both will hold specific responsibilities as parts of two different ministries. AGRITEX is under the Ministry of Lands and Agriculture, and DWD under the Ministry of Rural Resources and Water Development. The responsibilities entrusted to each of these agencies will involve two distinct areas that are clearly differentiated by a particular bench mark in the field. This bench mark commonly referred to here as the "field edge" coincides with the outlet gate of each farm pond. DWD, responsible for the development and supply of all surface water in Zimbabwe, will consequently be in charge of all facilities located between the water source and the field edge. These include the pump house, head races and the farm ponds. AGRITEX, on the other hand, will be in charge of the facilities located from the field edge to the field boundaries. These include the irrigation canals, drainage canals and farm roads. AGRITEX will also handle the operation of the project management office.

Both government bodies have considerable experiences in irrigation development projects. They have provincial offices in Mutare, Manicaland. AGRITEX has also a district office in Nyanga, the site of the project area. The two provincial offices will actually manage and implement the Project and they will be assisted in that task by the Consultant.

(2) Use of Local Contractors

Local contractors usually have ordinary construction equipment, and special ones are available by rent in the city. Therefore, it is not necessary to bring them in from Japan. One of the conditions for selection requires the subcontractor to have experience in the type of work ordered by AGRITEX or DWD.

(3) Dispatch of Technical Experts

Pump and electric equipment installation requires the dispatch of technical experts. The pump equipment is the most important item of this Project, which requires expertise and special knowledge for its handling. Zimbabwe does not count many specialists who can easily install high head pumps like the ones adopted in this Project. Therefore, the supervision and inspection by Japanese experts are deemed essential to ensure the credibility of the work. Hence, two Japanese experts, one in pump and the other in electric equipment, will be dispatched for the installation.

3-1-2 Implementation Conditions

(1) Labor Laws

Labor conditions, wages, etc., in Zimbabwe require one to abide by the law of the National Employment Council for Construction Industry when hiring construction laborers. Wages are stipulated on hourly basis for each type of labor. Excepting special cases, every hired laborer should be paid the exact amount provided by the law. In addition, particular attention should be attached to the articles of the law dealing with the shut down period at the end and beginning of the year. Every construction site is shut down forcedly for about twenty days. It is necessary to take this into consideration when establishing the construction schedule.

(2) Execution Period

From December to February, when the rainfall is particularly heavy, the water level of the Gairezi River is about 10m higher compared with the one in dry season. The high water level will prevent any work at the lower parts of the pump station. The flood can not only suspend the work but may possibly inflict damages resulting from the floating of the structure or submersion of the equipment, if the work remains uncompleted by this time. The work schedule of this Project should be established taking into consideration this constraint.

(3) Suspension of Traffic

As the Nyamaropa-Elim Road, which runs through the Project Area, is the principal district road, the suspension of traffic will not be allowed even under construction of crossing structure of the road. Hence, one way traffic must at least be secured during the construction.

(4) Temporary coffering of the river

The temporary coffering of the Girezi River is necessary for the construction of the pump station. As this river is shallow and its flow velocity low, the sandbagging method is to be adopted. After the construction of the main structure the sandbagging material should be taken away paying special attention not to throw any thing back into the river. The detailed construction method of the coffering should be planned with the contractor, and careful supervision of the work is required so as to carry out the construction as planned.

3-1-3 Scope of Works

As for the share of the Project cost between Zimbabwe and Japan, an arrangement is to be made similarly to the case in Phase 1. The cost of the main work which includes the construction of the pump station, installation of pipe lines, etc., is to be borne by Japan, while that of the works mentioned below including land leveling should be borne by Zimbabwe.

- Extension of the power line to the Blocks A, D and E (about 6km in length) and installation of transformers.
- Construction of fence to enclose three Blocks.
- Land leveling in three Blocks.

However, the site investigation in Block B and C after the completion of the construction in Phase 1 revealed that the Japan's share was completed but that of Zimbabwe such as land leveling and fencing in Block B was not finished yet due to insufficient budget. As a result, farming is not commenced in Block B. Considering this situation, some remedial measures should be taken.

One of these measures can be as follows;
The Zimbabwean Government has prepared a Counterpart Fund in accordance with conditions tied to Japan's Non-Project Aid and KR Aid. As this Fund can be made

available for this Project if the proper procedures are engaged, this will constitute an effective measure when the budget allocation is scarce.

3-1-4 Consultant Supervision

(1) The Basic Concept

The detailed design and supervisory work will be conducted by a Japanese consulting firm in accordance with an operation contract to be signed with the Ministry of Lands and Agriculture following the signature of the Exchange of Notes (E/N). This operation contract will be prepared in accordance with the E/N, and will come into effect after its approval by the Government of Japan.
The terms of the contract include two work items as explained below;

a) Detailed Design Work

It includes;

- Detailed Design Study,
- Rules concerning the bidding procedures and the establishment of the construction contract between a Japanese corporation and the Ministry of Lands and Agriculture.

b) Construction Control Work

It consists of:

- Grasping the real situation of the work site throughout the construction period; works such as quality control, operation control and safety control are to be executed.

(2) Items considered in the Construction Control Work

a) Quality Control

When building concrete structures or embankment, the quality of the material used may widely vary. Such dispersion should be checked using tools such as statistical methods, for example, so as to find proper counter measures to improve the quality whenever necessary. The material should be tested periodically to ascertain that it meets standards. Establishing a reasonably accurate quality control method would guarantee good quality and economical execution of the work.

b) Operation Control

Comparing the actual progress of the work and the work schedule submitted by the contractor, proper adjustments should be made. In particular, labor force, equipment and material should be put to practical use, and a proper management of the process is necessary in order for the work to be completed within the scheduled construction period.

c) Control of Finished Work Quality

When executing the work, information such as dimension, irregularity, datum level and gradient etc., as related to the completed portion of the work should be gradually recorded. Photographic records should also be kept as a support material. Judging from the results, the accuracy of the execution and the degree of the execution technique should be checked considering they constitute useful management data.

d) Safety Control

The work should be managed putting safety as the primary concern. Temporary works are often not paid the necessary attention, but on the contrary they should be executed as strictly as possible following a fixed plan. Thus, the safety of laborers will be maintained.

(3) Organization of the Construction Control Work

Because the work is widespread and complicated, the supervisor in charge of the management should be permanently stationed. An agricultural civil engineer having experience in the implementation of agricultural projects should be appointed considering that the work consists mainly of irrigation facilities construction and land consolidation.

3-1-5 Procurement Plan

The procurement plan of the equipment and material should be made following the concept mentioned below.

(1) Equipment procured

a) Irrigation pumps (pump, motor and appurtenant facilities)

It has been decided that irrigation pump facilities are to be procured from Japan, since the pumps applied in this Project will operate at high heads, and careful systematic study is needed to prevent water hammer.

b) Electric Facilities

Similarly, the operation and relay panels needed to operate the said pumps must be procured from Japan for a matter of conformity.

c) Agricultural Machinery

The medium sized tractor to be introduced in this Project can be procured through the local sales agents. The tractors put into circulation in the market are mainly from the West and Japan. One tractor of English make was procured in Phase 1; tractors of the same type, which parts can be easily obtained from the sales agents, are to be procured in this Phase. Several attachments of the tractor are also put into circulation locally; they are to be procured together with the tractor.

d) Land Leveling Equipment

The middle sized bulldozer with spare parts which is introduced for Block D, can be procured locally through the sales agents.

e) Other equipment

Bicycles are to be provided for the inspection of the farm pond and pump station. They are procured in Zimbabwe.

f) Spare parts

For the efficient use of the equipment, necessary spare parts are to be provided in a sufficient number to allow for about two years operation.

g) Procurement Route

As Zimbabwe is a country without a seaport, all the equipment from Japan is to be transported by ship to Beira Port, Mozambique. The distance between Beira and Mutare, the capital of Manicaland Province, is 350 km, and railways as well as roads are in good condition. Beira Port is well equipped; for instance, imported crude oil to Zimbabwe is unloaded there and transported directly to Mutare through pipe line, suggesting that the unloading of equipment will not be a problem.

h) Hand over of the Equipment and Material

All the equipment and material will be transported to the construction site or supply point and handed over to the person or organization in charge. Spare parts will be handed over after the installation or necessary test operation along with the operation and inspection manuals in English.

The following table shows all the descriptions, quantities and places of procurement.

Places of Procurement

Equipment	Quantities	Places
[Irrigation pump facilities]		
: Pump, Motor, Appurtenant	L.S.	Japan
[Electric facilities]		
: Power receiving panel, Starting panel, Distribution panel	L.S.	Japan
[Agricultural machinery]		
: Tractor(4 WD, diesel type, 75 HP)	1	Zimbabwe
: Attachment(Rotary harrow, Disk plow, Ridger, Trailer)	L.S	Zimbabwe
[Land leveling equipment]		
: Bulldozer(14ton class)	1	Zimbabwe
: Attachment	L.S	Zimbabwe
[Others]		
: Bicycle	4	Zimbabwe

Bulldozer and its attachment are procured only for Block D, all the other items are adopted to the three blocks.

(2) Construction machinery and material

a) Material for construction

Material will be as much as possible procured locally. FRP pipes, the conveyance pipes connecting the pump station to the farm pond, and their fittings can be purchased in Zimbabwe without any difficulties.

b) Construction machinery

This type of work does not require the use of special machinery. Therefore, all the machinery can be leased from the local leasing company and would not require to bring anything from Japan.

3-1-6 Implementation Schedule

(1) Implementation schedule

After the basic design study, it is necessary to complete the detailed design study, documentation of the bidding, bidding and evaluation, and it takes about 4.5 months until the contract signing of the construction work.
The necessary construction period is estimated as about eleven months in Block D, and about ten months in both Block A and E.

The construction period of this Project will require about one year to complete each Block, taking into consideration natural conditions, site and working conditions, construction method, low costs and so on. Hence, the three Blocks will be constructed separately in three terms.

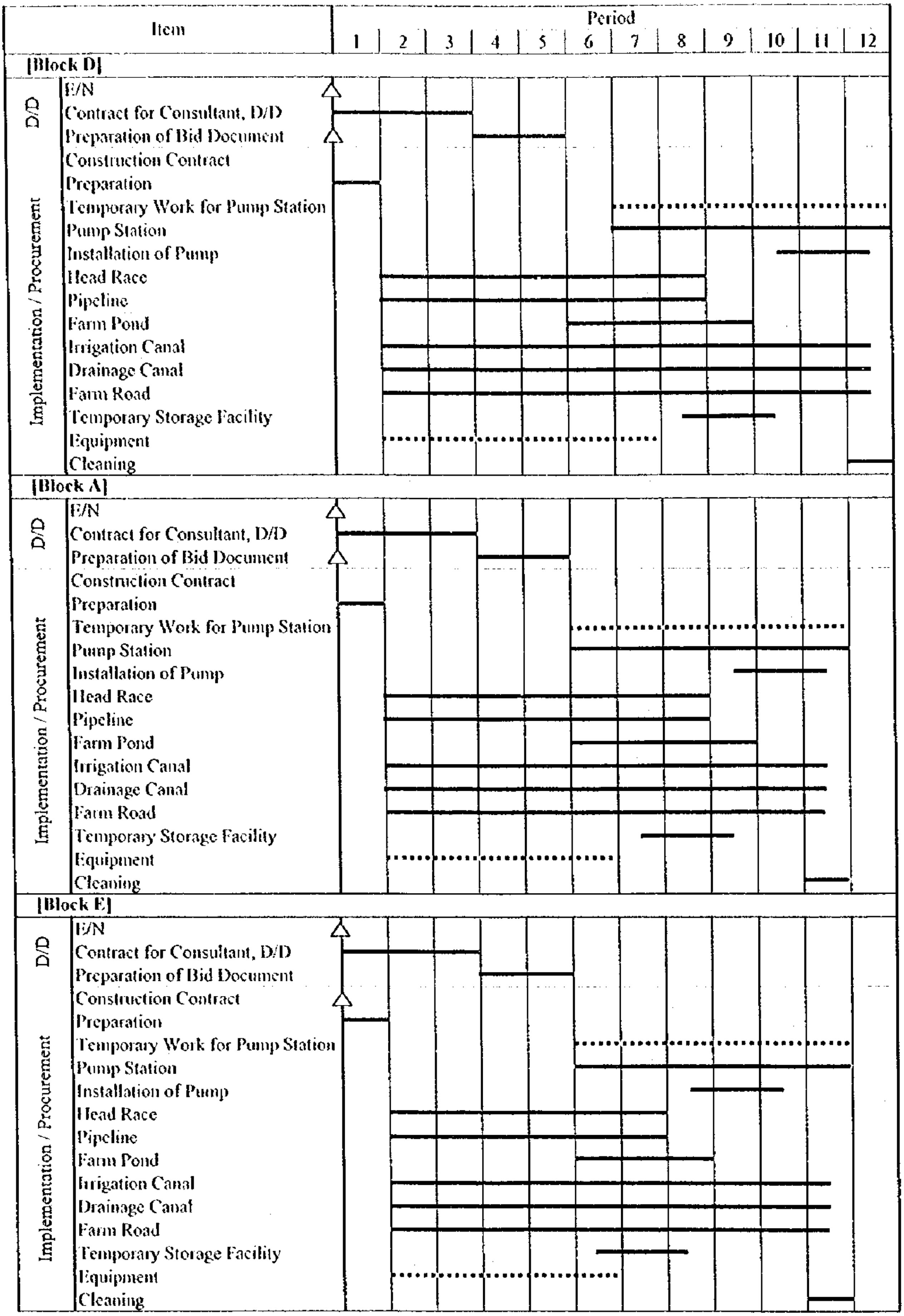
Considering the priority, the construction order is considered to be Block D, A and E. The work items and quantities by term are as follows.

Block	Work Item	Quantities
Construction Work in Block D (A=203ha)		
Construction Works to be borne by Japan		
	The Pump Station	1
	Conveyance pipe and farm pond	L.S.
	Irrigation and drainage canal	L.S.
	Farm road	L.S.
	Procurement of farming and land leveling equipment	L.S.
	Temporary storage facility	1
Construction Works to be borne by Zimbabwe		
	Ext. of power line & installation of transformer	L.S.
	Leveling & fencing work	L.S.

Construction Work in Block A (A=115ha)		
Construction Works to be borne by Japan		
	The Pump Station	1
	Conveyance pipe and farm pond	L.S.
	Irrigation and drainage canal	L.S.
	Farm road	L.S.
	Procurement of farming equipment	L.S.
	Temporary storage facility	1
Construction Works to be borne by Zimbabwe		
	Ext. of power line & installation of transformer	L.S.
	Leveling & fencing work	L.S.

Construction Work in Block E (A=94ha)		
Construction Works to be borne by Japan		
	The Pump Station	1
	Conveyance pipe and farm pond	L.S.
	Irrigation and drainage canal	L.S.
	Farm road	L.S.
	Procurement of farming equipment	L.S.
	Temporary storage facility	1
Construction Works to be borne by Zimbabwe		
	Ext. of power line & installation of transformer	L.S.
	Leveling & fencing work	L.S.

The construction schedule of the Project is shown in the next figure.



Implementation Schedule (Item to be borne by the Government of Japan)

3-1-7 Obligations of recipient country

Except the above mentioned construction work to be borne by Zimbabwe, other items to be undertaken by the Government of Zimbabwe confirmed in the Minutes are as follows;

1) To secure land necessary for the sites of the project and to clear and level the land prior to commencement of the construction work,
2) To provide facilities for distribution of electricity, water supply and drainage and other incidental facilities in and around the sites,
3) To secure all expenses and prompt execution for unloading, customs clearance at the port disembarkation and internal transportation of the products purchased under the Grant Aid,
4) To exempt Japanese nationals from customs duties, internal taxes and other fiscal levies which will be imposed in the recipient country with respect to the supply of the products and services under the Verified Contracts,
5) To accord Japanese nationals whose services may be required in connection with the supply of the products and services under Verified Contracts, such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work.

3-2 Project Cost Estimation

The Project cost to be borne by the Government of Zimbabwe is estimated as follows;

(1) Construction in Block D, Area=203 ha

Land leveling work	203 ha	Z$ 1,000,000
Fencing work	8.0 km	Z$ 640,000
Extension of power line	3.7 km	Z$ 1,000,000
Installation of transformer	1,000 KVA	Z$ 500,000
Sub-total		Z$ 3,140,000

(2) Construction in Block A, Area=115 ha

Land leveling work	115 ha	Z$ 600,000
Fencing work	11.0 km	Z$ 880,000
Extension of power line	0.5 km	Z$ 150,000
Installation of transformer	750 KVA	Z$ 300,000
Sub-total		Z$ 1,930,000

(3) Construction in Block E, Area= 94 ha

Land leveling work	94 ha	Z$ 450,000
Fencing work	5.2 km	Z$ 420,000
Extension of power line	4.2 km	Z$ 1,150,000
Installation of transformer	750 KVA	Z$ 300,000
Sub-total		Z$ 2,320,000
Total		Z$ 7,390,000

3-3 Operation and Maintenance Cost

After the completion of the construction work, the operation and maintenance is to be carried out according to the following policies.

(1) Organization and method of operation and maintenance of the Project

a) Management allotment of the facilities

Management allotment of the completed facilities is divided at the field edge, which is defined previously as the bench mark coinciding with the outlet gate of each farm pond or the boundary between the facilities pertinent to the water source and the so called on-farm facilities. The share is shown below.

DWD	Facilities pertinent to water source (Pump station, Head race, Farm pond)
AGRITEX	On farm facilities (Distribution pipe, Irrigation and drainage canal, Road, Management office and etc.)

b) Organization of the operation and maintenance

DWD which is in charge of the water source, assigns pump operators to the pump station and manages the operation and maintenance of the pumps. Daily operation will be carried out by operators following the pump manual. When serious troubles occur, mechanics from the Provincial Office in Mutare will cope with the matter.

On the other hand, an AEW will manage the on-firm facilities, who is assigned to this Project from the Nyanga District Office of AGRITEX. Troubles will be also dealt with in the Provincial Office in Mutare.

The farmers' association established in each block will conduct the actual operation under the management of the AEW. The organization of the farmers' association is shown in the figure below.

Block Committee	8 members

↓ Subordinate organization

Water Controllers	10 members
Maintenance Committee	3 members
Marketing Committee	3 members
Health Committee	3 members
Disciplinary Committee	3 members
Finance Committee	3 members

In Block C where farming has been commenced, a Block Committee consisting of eight members, a sub committee composed of Water Controllers (ten members) and a Marketing Committee (three members) have already been set. The operation and maintenance work is being carried out based on the regulation called Nyakomba Irrigation Bylaws. After the completion of the construction in the total five blocks, an Irrigation Management Committee (IMC) is due to be established, which will be in charge of carrying out the O & M.

(2) Securing necessary staffs and budget

The pumping operators from DWD and AEW from AGRITEX are sent to the Project. Necessary budget is prepared by the provincial offices of both organizations in Mutare, thus the Project is well maintained so far.

On the other hand, farmers' organizations have been established in Block B and C (Phase 1), all the committee members are selected already. The similar organizations are expected to be established in Phase 2 as well. These organizations must bear the following expenses for the operation and maintenance of the Project.

1. Electricity charge for pumping water
2. Maintenance fee for main irrigation and on-farm facilities
3. Some percentage of the replacement cost of facilities
4. Operation cost for their organization
5. Some percentage of the contingency portion of the O&M cost borne by AGRITEX and DWD.

AGRITEX will bear the O&M related costs till March 1999 as a grace period, and farmers have already agreed to bear these costs starting April. They have started to deposit money (Z$840/family). The amount is equivalent to the one supplied by AGRITEX to every farmer as the cost of inputs for the first cropping. AGRITEX agrees this deposit can be used for the payment of O&M cost from April.

According to the investigation in Block C (Phase 1), farmers' income in irrigated farming doubles that in rain fed farming (about Z$ 18,000 against Z$ 9,400). This income excludes the cash value of the crop self consumed by the family and O&M cost borne by the farmers (This cost is estimated as about Z$350/family/month, hence, Z$4,200/family/year), which is higher than the average income computed for the industrial sector in Zimbabwe (Z$ 15,194 1995).

In Phase 2, there is a mutual agreement between AGRITEX and farmers which agrees AGRITEX bears the expense for electricity during the grace period, after this period, farmers take over every obligation. The grace period is one year, after completion of the construction work and distribution of farm land to the farmers.

Chapter 4

Project Evaluation and Recommendation