Basic Design Study Report

on

The Project for The Hurga and Nur El Din Pump Scheme Rehabilitation

in

The Republic of the Sudan

March 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Republic of the Sudan, the Government of Japan decided to conduct a basic design study on the Hurga and Nur El Din Pump Scheme Rehabilitation Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Sudan a study team headed by Mr. Kenichi Shishido, Grant Aid Study and Design Department, JICA from October 13, 1991 to November 6.

The team held discussions with the officials concerned of the Government of Sudan, and conducted a field study at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

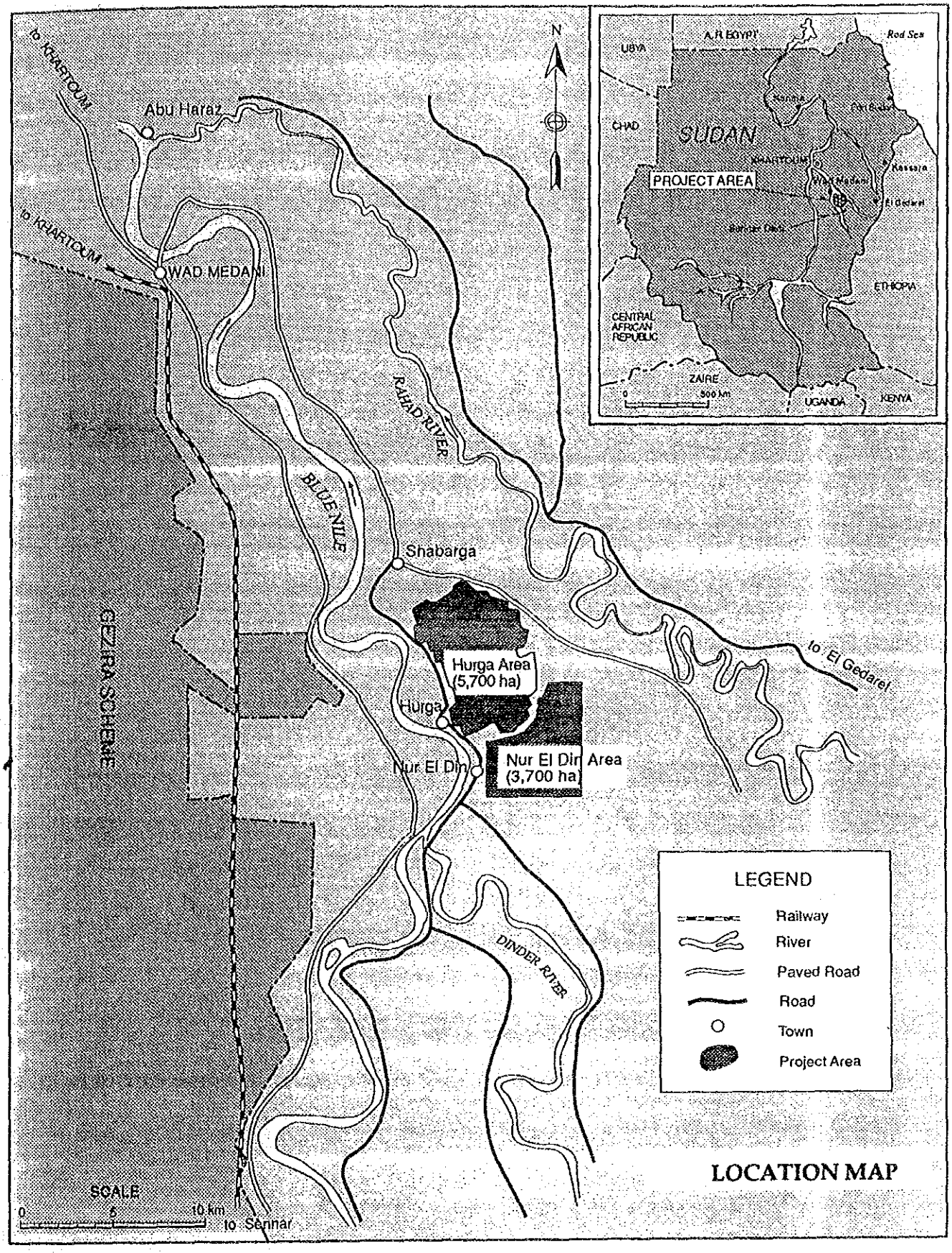
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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

March 1992

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency


to KHARTOUM
Abu Haraz
WAD MEDANI
to KHARTOUM
RAHAD RIVER
BLUE NILE
Shabarga
GEZIRA SCHEME
Hurga Area
(5,700 ha)
Hurga
Nur El Din
Nur El Din Area
(3,700 ha)
to El Gedarel
DINDER RIVER
SCALE
0
5
10 km
to Sennar
N
A.R. EGYPT
Red Sea
LIBYA
CHAD
SUDAN
KHARTOUM
PROJECT AREA
Kassala
El Gedarel
ETHIOPIA
CENTRAL AFRICAN REPUBLIC
ZAIRE
UGANDA
KENYA
0
500 km
LEGEND
Railway
River
Paved Road
Road
Town
Project Area
LOCATION MAP

SUMMARY

SUMMARY

The gross domestic product (GDP) of Sudan was estimated at £S 84.8 billion in 1989/90 corresponding to £S 6,592 million at 1981/82 constant price. This figure was almost the same as that of £S 6,531 million in 1981/82, showing economic stagnation in the last decade. Sudan's foreign trade figures have shown a chronic deficit. In 1989, it recorded a deficit of £S 2,350 million. The economy of Sudan is dominated by agriculture, accounting for 30.6% of GDP, over 90% of the export proceeds, and 63.9% of the labour forces.

Agriculture in Sudan is classified into 4 types by farming practices: i) irrigated agriculture; ii) rainfed mechanized; iii) rainfed traditional, and iv) livestock. The beneficial area of irrigated agriculture has expanded to 4 million feddans. Main crops grown in the irrigated farmland were cotton, wheat, sorghum, groundnuts, and vegetables. Cultivated areas under rainfed agriculture have largely fluctuated annually depending on the climate of the area, and were 16 million feddans in 1989/90. The main crops raised under rainfed area are sorghum, millet, groundnuts, and sesame.

Cotton is the most important cash crop for earning foreign exchange. In 1989/90, cotton was grown on about 702,000 feddans of irrigated farmland. Being substituted for sorghum, wheat has been increasingly consumed in urban areas and the Northern Region as the staple food. In 1989/90, it was planted in 614,000 feddans with a total production of 409,000 tons corresponding to a 66% increase over the previous year, and thereby reaching 45% self-sufficiency. Sorghum is the most important staple food in rural areas and one of the valuable crops for export. Its planting area amounted to 13 million feddans in 1988/89.

The Government of Sudan (GOS) has implemented a series of national development programmes, consistently placing emphasis on development of agriculture as the key industry of the country. The Four-Year Salvation, Recovery, and Development Programme was commenced in 1988, focusing on rehabilitation of existing production units and the removal of transport and energy bottlenecks. Challenging self-sufficiency in wheat is one of the main objectives in the agricultural sector programme.

Aiming at materializing the agricultural sector programme, the Blue Nile Pump Schemes Modernization Study was carried out between July 1988 and March 1990. The Study covered 62 existing pump schemes. The Hurga and Nur El Din schemes were included in the study and given the first priority in its recommended development programme.

GOS had requested the Government of Japan (JOP) to extend a Grant Aid for implementation of the Hurga and Nur El Din Pump Scheme Rehabilitation Project (the Project) in March 1987. GOJ, however, considered it necessary to conduct a feasibility level study beforehand to formulate an optimum development plan and to examine its viability. The Japan International Cooperation Agency (JICA), the governmental organization in charge of international cooperation to developing countries, conducted a feasibility study on the Project between October 1990 and August 1991. Through the feasibility study, a comprehensive improvement plan including construction of an integrated pumping station was formulated, and because of its technical soundness and economic viability urgent implementation of the Project was recommended. Encouraged with this, GOS requested GOJ again to provide a Grant Aid for implementation of part of the Project.

GOJ decided to conduct a Basic Design Study on the Project and JICA sent a study team (the Team) to Sudan from October 16 to November 5, 1991. Based on the results of the field surveys and a series of discussions with GOS's agencies concerned, the significance of the Project, basic design of the work components requested, selection of equipment and facilities, and an operation and maintenance plan were executed by the Team.

The request is summarized below:

Objective of the Project

The objective of the Project is to improve the unfavourable living conditions of the beneficiary tenants through revitalizing the present severely depressed agricultural activities in the Project area. This would help improve the self-sufficiency in the staple food and increase export earnings as well.

Project Works

The proposed works of the Project are: a) a pumping station; b) provision of power supply system; c) construction of a link canal; d) construction of main canals; e) rehabilitation of existing canal system; f) rehabilitation of drainage system; and g) construction of operation and maintenance facilities.

Project Works Requested

Among the project works mentioned above, GOS requested GOJ to implement the work components (a) through (d) under the Japanese Grant Aid, and expressed its intention to construct the remaining components (e) through (g) on its own.

Considering the contents and size of the project works, aims of Japan's Grand Aid, and limit of construction period under the Grant Aid, it was decided that the work components originally requested will be covered under the Grant Aid. In addition, procurement of equipment necessary for the desilting work in the sand settling basin was decided to be covered under the Grant Aid in due consideration of importance of the desilting work after completion of the Project.

The size of the project works requested was considered to be realistic in light of the land use plan, irrigation water requirement, and water management plan. The requested pumping station was considered reasonable with respect to the type of pump and prime mover, and number of pump units. As for the power supply system requested, the selected route for the distribution line was reviewed and considered to be acceptable. The routes of the link canal and new main canals requested were confirmed through a reconnaissance survey. A pump suction dredger was selected to remove deposits in the proposed sand settling basin in the link canal taking into account procurement and running costs.

The work components to be implemented by the Sudan side were duly examined with respect to implementation plan, construction equipment plan, organization for implementation, budget arrangement, etc. As a result, it was considered that those works could be constructed in time with the progress of the construction works to be implemented under the Grant Aid.

Based on the above, a basic design was carried out on the components requested and equipment for the desilting work assuming that those components and equipment will be implemented under the Grant Aid. The main features of those components and equipment are summarized as follows:

i) Pumping Station

- Type of pump suction :	vertical shaft double volume pump
- Rated discharge :	148 m^3/min/unit
- Rated design head:	25 m
- Diameter of pump:	900 mm x 800 mm
- Number of pumps:	4 units (1 spare unit)
- Rated output:	760 kW

ii) Power Supply System

- 33 kV Distribution Line:	9.5 km
- 33 kV Outdoor Switchgears:	Main transformer Circuit breaker Disconnecting switch Metering outfit
- 11 kV Indoor Switchgears:	Control panel 11 kV panel

iii) Link Canal

- Canal	
Length:	345 m
Design Discharge:	8.17 m^3/sec
- Bifurcation	
Type:	Jet flow division works
Discharge:	5.02 m^3/sec for Hurga main canal 3.15 m^3/sec for Nur El Din main canal
- Sand Settling Basin	
Length:	150 m
Width:	water surface 50 m bottom 30 m

iv) New main canals

- Hurga Main Canal

Length:	433 m
Design Discharge:	5.02 m^3/sec

- Nur El Din Main Canal

Length:	1,820 m
Design Discharge:	3.5 m^3/sec

v) Equipment for the desilting work

- Pump Suction Dredger	1 unit

The Ministry of Irrigation (MOI), the Republic of Sudan, will be the executing agency for the Project. The practical agencies for the construction works covered by the Japan's Grant Aid will be the Supervision Directorate of the Under-Secretariat of Projects and the Mechanical & Electrical Under-Secretariat.

The required period for the detailed design will be 3 months and that for the construction works including procurement work for construction materials and equipment will be 12 months.

Implementation of the Project would provide 1,512 households (about 12,100 persons) of beneficiary farmers with a basis for introducing intensive farming under irrigated conditions. As a result, their annual income would increase from a present £S11,300 to £S44,800. Further, various indirect benefits and impacts from implementation of the Project are expected as follows:

i) Increase in Crop Production

As shown in the following table, crop production in the Project area would considerably increase. And it is expected to contribute to: i) improving self-sufficiency in staple food in and around the Project area; ii) increasing export proceeds; and iii) enhancing livestock production in and around the Project, one of the traditional and major industries in the area.

Crop	Without-project (ton)	With-project (ton)	Increment (ton)
Cotton	0	4,072	4,072
Wheat	0	4,162	4,162
Sorghum	700	2,262	1,554
Groundnuts	0	2,262	2,262
Fodder	0	6,786	6,786

ii) Improvement of Living Standard

Income of the beneficiary farmers is expected to be improved drastically compared with the present unstable and depressed level. This will accrue motivation for improving living standards, which would vitalize regional economic activities.

iii) Increase in Employment Opportunity

The Project will generate considerable employment opportunities for unskilled labours during the construction period and for seasonal farm labours after implementation of the Project. In addition, introduction of intensive farming will create a demand for farm machinery presently run by the private sector.

iv) Women Activity

As beneficiary tenants are obliged to depend mostly for their living on off-farm incomes, the family labour force left their farms to their wives and children. Such present conditions have forced women to work on the farmland in addition to doing housework. Thus, women of the beneficiary households have had little chance to join social activities. After implementation of the Project, however, the family labour force working outside the Project area would return to their farmland and devote themselves to farming. Furthermore, introduction of mechanized farming would considerably mitigate task loads which will increase due to introduction of intensive farming. Thus, women would have more time to attend social activities.

Both direct and indirect benefits are expected by implementing the Project. It is also expected to impact on the regional economic activities. The Project has been formulated in conformity with the national development programme of Sudan and will become the first comprehensive rehabilitation project among the schemes studied in "the Blue Nile Modernization Study". The implementation of the Project requested by GOS was considered to be quite practical and justifiable. Further, the operation and maintenance plan for the Project seems to be reasonable with respect to organization, staffing, and budget arrangements.

For the smooth implementation, operation, and maintenance of the Project, the following recommendations are made to GOS:

- To complete as scheduled the works to be covered by the GOS;
- To secure budgetary arrangements and staff members necessary for implementation, maintenance, and operation of the Project;
- To execute periodical maintenance and repairs of the Project facilities and equipment;
- To strengthen agricultural supporting services including extension services, training of farmers and supply of agricultural inputs; and
- To introduce a similar programme as BNHP for malaria and schistosomiasis.

BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR THE HURGA AND NUR EL DIN
PUMP SCHEME REHABILITATION
IN
THE REPUBLIC OF THE SUDAN

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UNITS, EXCHANGE RATE AND ABBREVIATIONS

Units

1 feddan	=	0.420 ha
1 ha	=	2.38 feddan
1 kantar	=	143 kg

Exchanger Rate

Official rate

US$1.00 = £S 15.00

Free rate

US$1.00 = £S 30.00

Abbreviations

ABS	Agricultural Bank of Sudan
ARC	Agricultural Research Cooperation
ARS	Agricultural Research Station
BOS	Bank of Sudan
c.i.f.	cost, insurance and freight
CPC	Cotton Public Corporation
CWR	crop water requirement
BNAC	Blue Nile Agricultural Cooperation
ELS	extra long staple cotton
MEC	Earth Moving Corporation
FAO	Food and Agricultural Organization of the United Nations
f.o.b.	free on board
FOP	field outlet pipe
FSL	full supply level
GDP	Gross Domestic Product
GOJ	Government of Japan
GOS	Government of Sudan
HRS	Hydraulic Research Station
ITCZ	Inter-tropical Convergence Zone
JICA	Japan International Cooperation Agency
MOCT	Ministry of Commerce and Trade
MOFEP	Ministry of Finance and Economic Planning
MOANR	Ministry of Agriculture, Natural Resources and Animal
MOI	Ministry of Irrigation
MS	medium-staple cotton
NOC	National Oil Company
NEC	National Electricity Corporation
PPU	Project Preparation Unit
SCPO	Sudan Company for Processing of Oil-seeds
SDR	Special Drawing Rights
SGB	Sudan Gezira Board
SSA	Soil Survey Administration
SOC	Sudan Oil-seed Company

CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

The Government of Sudan (GOS) had requested the Government of Japan (GOJ) to extend a Grant Aid for implementation of the Hurga and Nur El Din Pump Scheme Rehabilitation Project (the Project) in March 1987. GOJ, however, considered it necessary to conduct a feasibility study beforehand. The Japan International Cooperation Agency (JICA), the governmental organization in charge of international cooperation to developing countries, conducted a feasibility study on the Project between October 1990 and August 1991. Through the feasibility study, a comprehensive improvement plan including construction of an integrated pumping station was formulated, and because of its technical soundness and economic viability urgent implementation of the Project was recommended.

Encouraged with this, GOS again requested to GOJ for a Grant Aid for the implementation of part of the Project. The Ministry of Foreign Affairs deemed the Project's objectives appropriate for Japan's Grant Aid and decided to conduct a basic design study to examine the viability of the Project in line with the grant aid programme of Japan. Following this JICA sent a study team (the Team) for the basic design study (the Study), headed by Mr. Kenichi Shishido from Grant Aid Study and Design Department of JICA, from October 16 to November 5, 1991 to: hold discussions with relevant agencies of GOS; conduct field surveys; confirm the contents of the request; and assess the significance, effects, and propriety of the Project as a project to be implemented under Japan's Grant Aid.

The Team conducted surveys in and around the Project area to: i) clarify an implementation plan and organization for implementation of part of the Project to be conducted by GOS, the operation and maintenance plan of the Project, and construction costs; ii) confirm the background of the Project. The Team held a series of discussions with government officials concerned to confirm the contents of the request and other basic issues relating to the implementation of the Project. The agreed minutes of these discussions are presented in Appendix-4. The members and itinerary of the Basic Design Study Team and members of the Working Group are given in Appendices 1, 2, and 3, respectively.

The Team examined the rational and viability of the Project using the results of the field surveys and the discussions, and carried out the Study of the Project works. The Study consists of basic design of a pumping station, a link canal, new main canals and an electric power supply system; implementation plan; estimate of implementation costs; and formulation of a basic plan for operation and maintenance of the Project. This report presents the results of the Study.

CHAPTER 2
BACKGROUND OF THE PROJECT

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2.1 Background of the Project

Sudan, the largest country in Africa, is located in the northern latitudes between 4-22° and the eastern longitudes between 22-38°, and has a land area of 2.5 million km^2. The country shares its international boundary of 7,820 km with eight(8) neighbouring countries. It is bounded on the east by the Red Sea and Ethiopia, on the south by Kenya, Uganda, and Zaire, on the west by the Central African Republic, Chad, and Libya, and on the north by Egypt. Most of the country is made up of a flat plain with altitudes of 200 m in the north and 500 m in the south. Another distinct physical feature is mountainous zones in the east and southern frontiers. The White Nile enters Sudan from Uganda and is fed by a number of tributaries draining the southwest. The Blue Nile, originating from the Ethiopian Highlands, joins the White Nile at Khartoum, the capital of Sudan, and forms the Nile River. General map of Sudan is shown in Figure 2-1.

Sudan has a wide range of tropical continental climates. Much of the northern desert area receives only a few scattered showers each year. Rainfall increases from between 100- 250 mm in the Khartoum region, 350-750 mm in the central area to over 1,100 mm in the south.

The population of Sudan was estimated at 26 million in 1990 based on the last census held in 1983 when the population was 20.5 million. The annual rate of population growth is 3.1% for the country. Sudan is one of the least densely populated countries of the world with an average density of 10.4 persons per km^2.

The gross domestic product (GDP) of Sudan has been sluggish for the last decade. It was estimated at £S 84.8 billion in 1989/90 corresponding to £S 6,592 million at 1981/82 constant price, almost the same as 1981/82's GDP of £S 6,531 million. The per capita GDP in 1889/90 was estimated at £S 2,385 equivalent to US$230.5 at current market prices with an exchange rate of US$1.00 = £S 12.30. The economy of Sudan is dominated by agriculture, accounting for 30.6% of GDP and 63.9% of the labour forces.

Sudan's foreign trade figures showed a chronic deficit. Export proceeds in 1989 were £S 3.02 billion, while import bills reached £S 5.37 billion. Agricultural production shared over 90% of the export proceeds, of which proceeds of cotton accounted for 45%. Manufactured goods and petroleum products constituted about 42% of total imports, followed by machinery & equipment and transport equipment sharing 15% each. Import of wheat and flour occupied 8% of the total and were the most prominent among import of foodstuff.

Agriculture in Sudan is classified into 4 types by farming practices: i) irrigated agriculture; ii) rainfed mechanized; iii) rainfed traditional, and iv) livestock. The beneficial area of irrigated agriculture has expanded to 4 million feddans, but actually planted area was estimated at 2.2 million feddans in 1989/90 cropping season. Main crops grown in the irrigated farmland were cotton, wheat, sorghum, groundnuts, and vegetables. Cultivated areas under rainfed agriculture have largely fluctuated annually depending on climate of the area, and were 6.9 million feddans for mechanized agriculture and 8.8 million feddans for traditional rainfed agriculture in 1989/90. Main crops raised under mechanized rainfed area are sorghum, millet, and sesame, while those under traditional rainfed area are sorghum, groundnuts, millet, and sesame. Production of main crops in 1989/90 are shown below:

Unit: 1,000 tons

Type of Farming	Cotton	Sorghum	Wheat	Groundnuts	Millet	Sesame
Irrigated	408	392	409	110	O	O
Rainfed Mech.	0	853	0	0	18	75
Rainfed Traditional	0	291	0	99	143	65
Total	408	1,536	490	218	161	140

Sources; Agricultural Situation and Outlook

Main food crops produced in Sudan are sorghum, groundnuts, sesame, millet, and wheat. Sorghum is the most important staple food in rural areas and one of the valuable crops for export. Its production reached 4.4 million tons in 1988/89 but dropped to 1.5 million tons in 1989/90 due to unfavourable climatic conditions.

Being substituted for sorghum, wheat has been increasingly consumed in urban areas and the Northern Region as the staple food. Wheat is grown only on irrigated farms, being represented by the Gezira-Managil Scheme producing 235,000 tons in 1989/90. In accordance with the government policy of expansion of wheat production aiming at future self-sufficiency, wheat production has been increased year by year. Its planted area was 393,000 feddans producing 247,000 tons in 1988/89 and increased to 614,000 feddans with a total production of 409,000 tons in 1989/90. Contrasting with this, imported wheat and flour was decreased from 70% of total consumption in 1988/89 to 55% in 1989/90.

Cotton is the most important cash crop for earning foreign exchange. In 1989, cotton accounted for about 45% of total export earnings. It is raised in such large scale irrigation schemes as the Gezira-Managil, New Halfa, Rahad, Es Suki, Blue Nile Pump, and White Nile Pump. Annual production has continuously decreased in recent years. In 1989/90, cotton was planted on about 702,000 feddans of irrigated farmland, producing 408,000 tons. The planting area and production declined by about 11.3% and 0.6% respectively in comparison with those in 1988/89.

With emphasis on the rehabilitation of existing production units and the elimination of transport and energy bottlenecks, GOS implemented the Four Year Salvation Recovery and Development Programme since 1988. The major objectives of the programme are:

1) Inspiration and stimulation of the patriotic spirit and the sanctity of works;
2) A GDP average growth rate not less than 5% per annum;
3) Provision of basic needs in respect of food, water, clothing, shelter, security, health, education, and transport;
4) Food security for rural and urban population;
5) Social justice through reduction of disparities in income and wealth;
6) Progress to be made towards balanced regional development, with emphasis on less developed regions; and
7) Formulation of a post-war development programme for the Southern Region taking into full consideration the extraordinary conditions pertaining to that region.

For agricultural sector, the programme is directed to the rehabilitation and modernization of viable existing irrigated schemes in order to attain self-sufficiency in wheat. To this end, GOS contemplated expanding the irrigated area for wheat and increasing the yield of wheat without adversely affecting other crops.

The National Economic Salvation Programme for 1990/93 was also commenced by GOS in 1990 targeting to arrest the deterioration in the economy and lay the foundation for a sound recovery to put the economy on a path of sustained growth and financial stability. In the programme, it is stated to put more emphasis on agricultural developments as a leading sector. General objectives of this programme are:

1) Revitalization of the Sudanese economy through reallocation of resources toward production;
2) Enhancement of the private sector, whether national or foreign, to play a more active role in achieving the objectives of the programme and to reorient financial, economic and institutional structures to create a more conductive environment for private sector participation; and
3) Maintenance of social balance by protecting the poor during adjustment period.

Aiming at materializing the agricultural programme stated above, the Blue Nile Pump Schemes Modernization Study was conducted between July 1988 and March 1990. The study encompassed 62 existing pump schemes with a total service area of about 284,000 feddans and extension area of 142,000 feddans extending over both banks of the Blue Nile. The Hurga and Nur El Din schemes were included in the study and given first priority for implementation.

2.2 Outline of the Request

Encouraged by the result of the feasibility study on the Hurga and Nur El Din Pump Scheme Rehabilitation Project conducted by JICA, GOS further requested GOJ for grant aid for the rehabilitation of the Hurga and Nur El Din Pump Schemes. The request is summarized below:

Objective of the Project

The objective of the Project is to improve the unfavourable living conditions of the beneficiary tenants through revitalizing the present severely depressed agricultural activities in the Project area. This would contribute to improvement of the self-sufficiency of the staple food and increase in export earnings as well.

Project Works

Proposed works of the Project consist of: a) construction of a pumping station; b) provision of power supply system; c) construction of a link canal; d) construction of main canals; e) rehabilitation of existing canal system; f) rehabilitation of drainage system; g) operation and maintenance facilities. General layout of the proposed works is shown in Figure 2-2.

Project Works Requested

Among the above project works, GOS requested GOJ to implement the work components (a) through (d) under the Japanese Grant Aid, and expressed his intention to construct the remaining components of (e) through (g) on its own side.

2.3 Outline of the Project Area

2.3.1 Socioeconomic Conditions

The Project area is located about 30 km southeast of Wad Medani, capital of Central Region, or 220 km south of Khartoum. Administratively, it falls in El Gezira Province of the Central Region. EL Gezira Province, 35,057 km^2, lies in the centre of Sudan, between latitudes 13°30" and 15°30" and longitudes 32°30" and 34°15". It borders on Khartoum Province on the north, on the Kassala Province on the east, on the Blue Nile Province on the southeast and on the White Nile Province on the west. Wad Medani, the second largest town in Sudan after Khartoum, is located about 190 km south of Khartoum and about 800 km southwest of Port Sudan and is well connected to these cities by rail and highway networks.

Population of EL Gezira Province was reported to be 2.0 million accounting for 9.8% of the national population according to the 1983 census. 16.9% and 81.7% of the population are inhabitants of the urban and rural areas, respectively. The remaining 1.4% is of nomad. Population of the same province in 1990 was estimated at 2.3 million based on the average growth rate of 3.1%. In particular, the population of EL Gezira Province fluctuates seasonally in accordance with movement of agricultural labourers working in the Gezira-Managil Scheme. The number of temporary or seasonal agricultural labourers is estimated at approximately 520,000.

El Gezira Province is economically one of the most active provinces for the agricultural sector as Sudan's major irrigation schemes such as the Gezira-Managil and Rahad Irrigation Schemes are included in the province.

Beneficiary areas of the Project consist of the Hurga area of 13,900 feddans and Nur El Din area of 8,720 feddans, totaling to 22,620 feddans.

There are 18 villages which are involved in the Project; 9 villages each for the Hurga and Nur El Din areas. According to statistics prepared by the Sudan Gezira Board (SGB), population of a villages each for both areas in 1981 were some 18,200 and 7,400 persons, respectively. The number of households of the respective areas was estimated at 2,270 for the Hurga and 920 for the Nur El Din. Of these, the number of beneficiary tenants for the Hurga and Nur El Din areas is estimated at 882 and 630, respectively. A 15-feddan tenancy system is prevailing in both areas at present. The average labour force for agriculture is estimated at 4.8 person per household.

2.3.2 Natural Conditions

The Project area extends over a flat plain on the right bank of the Blue Nile. It gently inclines from south to north at a gradient of 20 to 25 cm/km between altitudes of EL.411.25 m at the southern end of the Project area and EL.407.50 m at the northern most area. The topographic features of the right bank of the Blue Nile are broadly divided into: i) stepped slopes in the upper reaches of both the Nur El Din and Hurga existing pumping stations; and ii) low-lying terrace formation stretching between downstream of the Nur El Din pumping station and the proposed pumping site for the Project.

The climate in and around the Project area is categorized as semiarid with an average annual rainfall of 265 mm, and is characterized by a hot summer lasting from April through June and a cool and dry winter from November to February. About 80% of the annual rainfall concentrates in the rainy season, prevailing during three months from July through September. The mean monthly temperature varies from 33.1℃ in May 23.9℃ in January. The monthly mean maximum relative humidity varies from 83% in August to 29% in April. Daily mean evaporation is estimated to be 7.8 mm by the Penman method. Summary of meteorological data is shown in Table 2-1.

The mean annual discharge of the Blue Nile at the Sennar dam is 30 billion m^3. The monthly mean discharges fluctuate from 386 million m^3/day in August to 9.6 million m^3/day in February. The Ministry of Irrigation forecasts the annual water demand of the Sudan at 19 milliard m^3 for 1995, in which water demand by the Project has been incorporated. The water level of the Blue Nile at the existing Hurga and Nur El Din pumping sites annually fluctuates in a wide range of 8 m as shown in Table 2-2. Annual suspended solids of the Blue Nile at the Sennar dam are estimated at 165 million tons, of which more than 90% are transported during the rainy season from July through September according to the Hydraulic Research Station of MOI.

The soils in the Project area consist of dark brown to brown with a soft mulch and wide deep cracks when dry. They are classified as Vertisol. The land suitability of the Project area is mostly categorized into moderately suitable land with vertisolic, sodicity and fertility limitation.

2.3.3 Social Infrastructure

Out of 18 villages, 13 depend for potable water on community deep wells with elevated water tanks and 2 villages have community deep wells with local water supply systems. There are 2 villages which has neither private nor community wells.

There are 5 elementary schools having a total enrollment of 1,614 students, and 5 intermediate schools with a total students of 590. There is no high school in these villages.

Medical facilities available for those villages are 8 dressing stations, 2 dispensaries, one health centre and one bed clinic.

The public telephone line is not extended to those villages, except for a telecommunication system of the Gezira-Managil Scheme covering the existing Hurga and Nur El Din pumping sites.

Only earth roads connect inter-villages and between the villages and the Project area. The Wad Medani-Gedaref highway runs in the northeast fringe of the Hurga area. The proposed pumping site is connected to the said highway by an earth road of about 12 km, which becomes a muddy road easily during the rainy season.

The public electric power supply system by the National Electric Corporation (NEC) is unavailable in the Project area. At present, the power supply available around the Project area is: i) the terminal of a 33 KV distribution line at Shabarga village approximately 12 km north of the proposed pumping site, which is extended from Meringan Substation located about 8 km south of Wad Medani; and ii) the terminal of a 33 KV distribution line at El Biryab pumping station fed from Hag Abdalla Substation. The El Biryab pumping station is located on the left bank of the Blue Nile and 8 km south of the proposed pumping site. The existing power supply system around the Project area is shown in Figure 2-3.

2.3.4 Agriculture and Agro-economy

A three-course rotation cropping; cotton-sorghum-fallow, was originally established for a 15-feddan tenancy system in the Project area in the 1950s' by the private sector. It has, however, been altered to a sorghum-fallow rotation system in about two third of the Project area since 1981/82 because of severe water shortage and topographic limit. This means one third of the Project area was utilized for sorghum each year. Owing to progressive deterioration of the existing pumping stations, cultivation area has further decreased to 16% (2,260 feddans out of 13,900 feddans) of the Hurga area and 14% (1,260 feddans out of 8,720 feddans) of the Nur El Din area in 1990 cropping season. Present land use of the Project area is shown in Figure 2-4.

Unit yield of sorghum in 1990 cropping season was about 240 kg/feddan in Hurga area and 130 kg/feddans in Nur El Din area. Total production of sorghum in the same year was estimated at 700 tons.

The farm income accrued from sorghum of the beneficiary tenants of the Project area is negligible. They depend for their living mostly on off-farm income and remittances. Off-farm incomes are accrued from livestock products and wages/salaries from temporary or seasonal works outside the Project area. As clearly shown in the following table, the living of the beneficiary tenants is unstable and likely to drop to a subsistence level whenever capricious remittances are ceased.

Unit : £S

Item	Hurga	Nur El Din	Gezira
Income			
Farm income	800	0	31,400
Off-farm income	11,600	10,200	3,100
Expenditure			
Farm input	1,400	800	14,700
Living expense	16,600	15,400	19,700
Net reserve	-5,600	-6,000	100
Remittances	6,400	6,000	-

The Extension Department of the Sudan Gezira Board is responsible for agricultural extension services for the Project area, but such services have been suspended in the recent decade because neither cotton nor wheat have been raised in the same period.

2.3.5 Irrigation and Drainage

There are two independent pumping irrigation systems for the Project area; one each for the Hurga and Nur El Din areas. General layout of the existing irrigation systems is shown in Figure 2-5.

The Hurga pumping station consists of three reinforced concrete suction pits built into the river bank with a building made of steel framed brick masonry walls and corrugated sheet roof. The reinforced concrete structure seems to be generally in good condition, while the building has deteriorated considerably. Three vertical mixed flow type pumps, 800 mm in diameter, are

installed in the suction pits. Each pump unit has a rated discharge capacity of 1.5 m^3/sec at a rated head of 20.5 m. The prime mover of the pump is diesel engines with a rated output of 600 PS. River water is fed to the suction pits through a rectangular concrete inlet channel. Presently two pumps and two engines are operational, but the discharge capacity of these pumps has decreased to 64% of their rated value due to severe deterioration and aging. None of them could be run during the low water stage because of degradation of the Blue Nile, sedimentation in the inlet channel and their poor condition.

The canal network of the Hurga area consists of a main canal, a major canal, 10 minor canals and a large number of field channels. The field channels are composed of watercourses/locally known as Abu Ishreen and Double Abu Ishreen) and secondary watercourses (locally known as Abu Sitta). These canals are well aligned generally in general, but their elevation is not high enough to distribute irrigation water to each commanding area adequately. Many water control structures are provided at strategic points of the canals. Most of these structures have deteriorated or been removed already.

The Nur El Din pumping station consists of a gravity type brick masonry dry pit (pump room) built into the river bank with a building made of steel framed block masonry walls and corrugated sheet roof. Three units of horizontal shaft mixed flow type are installed in the pump rooms. Their rated discharge capacity is 60 m^3/min each at a rated head of 21.03 m. Each pump is driven by a diesel engine having a rated output of 450 PS through a plain belt and pulley. At present, two units each of pumps and diesel engine are operational, but their discharge capacity has fallen to 36% of the rated one.

Similar to the Hurga area, the canal networks of the Nur El Din area consists of a main canal, five minor canals, and a large number of field channels. All the canals are earthen channels with trapezoidal to semicircular cross-sections. The canal network is adequately aligned, but the canal elevation is not high enough to command their respective service areas except for a very limited area. About 60% of the Nur El Din area has never been irrigated due to topographic limit. Conditions of related structures of the canal network are more or less the same with those of the Hurga's one.

The drainage canal system in the Project area has been completely silted up and the original canal routes have disappeared.

The Hurga and Nur El Din schemes have been jointly managed by the Sudan Gezira Board (SGB) and the Ministry of Irrigation(MOI). The Mechanical and Electrical Under-secretary of MOI is responsible for operation and maintenance (O&M) of the pumping stations. The Under-secretariat of Irrigation Gezira-Managil of MOI is responsible for: i) O&M of of the main, major canals and structures on them; ii) maintenance of the minor canals and field outlet pipes on them.

The beneficiary area of the Gezira-Managil Scheme is parcelled into 107 blocks for field management, which are grouped into 14 management groups by SGB. The Hurga and Nur El Din areas are regarded as part of the Gezira-Managil Scheme and falls in Block No.106 and No.107, respectively. Operation of the field outlet pipes and watercourses are under management of SGB.

CHAPTER 3
OUTLINE OF THE PROJECT

CHAPTER 3 OUTLINE OF THE PROJECT

3.1 Objectives

The objectives of the Project are: 1) to increase crop production and to improve unfavourable living conditions of the beneficial farmers in the Project area, and 2) to contribute to improvement of the self-sufficiency of staple food and increase export of cash crops at a national level.

To attain these objectives the Project aims to increase the cropping intensity from the current 16% (mono-culture of sorghum) to 80%, accounting for cotton, wheat and sorghum of 20% each, and groundnut and fodder of 10% each in the Project area of 22,620 feddans by means of construction of an integrated pumping station, rehabilitation of existing canal network, reinforcement of agriculture supporting services, and strengthening of management, operation and maintenance system.

3.2 Study and Examination of the Request

3.2.1 Rational and Justification of the Project

As mentioned in the previous Sub-section 2.2 Outline of the Request, the Project work components requested for Japan's Grant Aid by GOS are: i) construction of a pumping station, ii) construction of a power supply system, iii) construction of a link canal including a sand settling basin and a bifurcation, and iv) construction of two(2) new main canals connecting the link canal and the existing canals. The propriety on implementation of the Project requested was duly examined from the viewpoints of national development programme and effect of the Project as follows:

(1) Significance of Project Implementation

As stated in Chapter 2, GOS has implemented the "Four-Year Salvation, Recovery and Development Programme (1988/89-1991/92)" since 1988, placing the stress on both the rehabilitation of the existing production units and the elimination of the hindrances on transportation and energy. In the Agriculture Sector, one of the emphases is placed on both the self-

sufficiency of wheat and the acquisition of foreign currency by augmenting major crop production through rehabilitation and modernization of existing irrigation facilities

In line with the "Four-Year Programme", GOS executed the master plan study for rehabilitation and modernization of existing 174 pump irrigation schemes along the White Nile between December 1987 to September 1989 and of existing 62 pump irrigation schemes along the Blue Nile between October 1988 and March 1990. In the latter study the Hurga and Nur El Din areas were ranked as the top priority scheme among them.

As was seen clearly in the above, the objectives of the Project well accords with the national development programme and forms a part of the irrigated agriculture development programme in the nation.

(2) Benefits of the Project

By implementing the Project, the cropping intensity in the project area will be increased from the current 16% to 80% and thereby the following crop production is expected.

(Unit : ton)

Crop	Current	Anticipated	Increment
Cotton	0	4,072	4,072
Wheat	0	4,072	4,072
Sorghum	700	2,262	1,562
Groundnut	0	2,262	2,262
Fodder	0	6,786	6,786

The anticipated crop yields were estimated from research data at the Agricultural Research Cooperation of the Ministry of Agriculture, the current unit yields in the Gezira-Managil Scheme, and from proposed farming practices.

The beneficiary farmers of the Project number 1,512 households (12,100 persons) in the relevant 18 villages, and the remaining 1,678 households (13,400 persons) will be more or less benefited indirectly.

At present, the beneficiary farmers of the Project area depend on off-farm incomes and remittances from their relatives for a living. Particularly, they have been forced to stand on the fringe of subsistence because considerable part of their living expenses have been made up by the capricious remittances. After implementation of the Project, however, it is expected that their living conditions will be significantly improved with year round irrigation resulting in an increase in and stable agricultural production. The farm budgets with- and without-Project are shown below.

(Unit:£.S)

Description		With-out Project		With Project
		Hurga	Nur El Din	Whole Area
1)	Gross Income	12,400	10,200	44,800
	Farm income	800	0	41,600
	Off-farm income	11,600	10,200	3,200
2)	Expenditure	18,000	16,200	31,600
	Farm input	1,400	800	11,900
	Living expenses	16,600	15,400	19,700
3)	Net Reserve	-5,600	-6,000	13,200

In addition, the Project would create employment opportunities for unskilled labours during construction, and generate more demand for the farm machinery usually run by private sectors after its implementation since mechanized farming practices will be introduced to cope with a considerable increase in labour requirement.

3.2.2 Implementation and O&M Plan

The executing agency of the Project will be the Ministry of Irrigation (MOI), whose organization structure is shown in Figure 3-1. The Design Directorate of the Projects Under-Secretariat of MOI will carry out the detailed design of the components of the Project works to be implemented by the Sudanese side, and the Supervision Directorate of the Projects Under-Secretariat will render the construction supervision of the said components. The organization structure of the Projects Under-secretariat is shown in Figure 3-2. The counterpart agencies for implementation of the work components expected to be executed by Japanese side, will be the

Supervision Directorate of the Projects Under-secretariat and the Mechanical & Electrical Under-Secretariat of MOI. The former will be in charge of the civil works, and the latter will be in charge of the pumping equipment and the power supply equipment. MOI is reliable as the executing agency of the Project, since it has ample experiences in the implementation of similar projects including the Rahad Irrigation Project.

The operation and maintenance (O&M) of the Project facilities after implementation will be jointly carried out by MOI and the Sudan Gezira Board (SGB). The Mechanical & Electrical Under-Secretariat will be responsible for O&M of the pumping station, and the Under-Secretariat of Irrigation Gezira & Managil will have the responsibility of O&M of main, major, and minor canals as it is. SGB will be responsible for management of watercourses and farming as well. The Mechanical and Electrical Under-Secretariat appears to be reliable for O&M of the pumping station, taking into consideration the performance on management of 19 electrically driven pumping stations along the Blue Nile. The Under-Secretariat of Irrigation Gezira and Managil is appropriate as the responsible body for O&M of the rehabilitated canals networks under the Project, since it has carried out O&M of the Gezira-Managil Scheme commanding a service area of 2.1 million feddans (880,000 ha).

O&M of the pumping equipment will be performed by the Directorate of Pumps, belonging to the Mechanical & Electrical Under-Secretariat, through the Wad Medani Electrical Division. The organization structure of the Mechanical & Electrical Under-Secretariat for the O&M of the Project is shown in Figure 3-3, and O&M staff of the Wad Medani Division in 1989/1990 and after implementation of the Project is shown in the following table:

Position	Current Nos.	Planned Nos.
Senior Engineer	0	1
Electrical Engineer	0	1
Mechanical Engineer	1	1
Electrician	0	1
Mechanic	2	1
Operator	3	2
Greaser	6	0
Fitters	2	1
Helper	8	3
Car Driver	1	2
Store Keeper	1	1
Watchman	3	2

Source : Questionnaire Survey

The differences between the number of current staff and planned are attributed to the change from the existing two(2) pumping stations with diesel engine-pumps to one(1) pumping station with electrical motors , and two (2) operators will be needed since a two(2) shift operation is expected for a 18-hour pump operation a day. The duty of major O&M staff is summarized below:

Position	Duty
Senior Engineer	Responsible person for O&M of new pump station
Electrical Engineer	Assist senior engineer in O&M of electrical equipment in the pump station
Mechanical Engineer	Assist senior engineer in O&M of mechanical equipment in the pump station
Electrician	O&M of electrical equipment
Mechanic	O&M of electrical equipment
Operator	Operation of pumps
Greaser	Supply and storage of fuel and oil
Fitters	Assist mechanic

Source : Questionnaire Survey

O&M of main, major, and minor canals and double Abu Ishureen will be carried out by the Directorate of Gezira of the Under-Secretariat Irrigation Gezira & Managil of MOI through the Wad Medani Division. The organization structure relating to O&M of Project is shown in Figure 3-4, and the number of O&M staff of the Division in 1989/1990 and after implementation of the Project are listed in the following table :

Position	Current Nos	Planned Nos
Assistant Divisional Engineer	1	1
Sectional Engineer	0	2
Clerk	1	2
Book Keeper	1	2
Water Control Staff	16	18
Land Survey Staff	4	10
Canal Maintenance Staff	25	25
Fitters	2	2
Car Driver	2	5
Others	6	12

Source : Questionnaire Survey

The above-listed staffing plan accords with actual staffing of similar irrigation systems in Sudan. The duties of the O&M staff are summarized below:

Position	Duty
Assist.Divisional Engi.	Responsible person for O&M of irrigation system in the Wad Medani area
Sectional Engineer	Preparation and supervision on O&M in the Project area
Clerk	Office administration
Book Keeper	Budgeting, accounting and monitoring
Water Control Staff	Operation of irrigation facilities
Land Survey Staff	Assistance for canal profile survey necessary for investigation of sediment and other damages in canals
Canal Maintenance Staff	Weed clearing in canals and minor repair of canals
Fitters	Maintenance of gates and metal work

Source : Questionnaire Survey

SGB is currently responsible for the agricultural supporting services, the field management and the operation of field channel in the Gezira-Managil Irrigation Scheme with a command area of 2.1 million feddans (882,000 ha). For the purposes of smooth management and operation, the service area of the Gezira-Managil Irrigation Scheme has been divided into 14 Groups and each Group has been sub-divided into 107 Blocks. The Project area is regarded as a part of the service area of Gezira-Managil Scheme, and the Hurga and Nur El Din areas have been labelled Blocks No.106 and No.107, respectively, both of which belong to the Central Group.

This field management system will basically remain unchanged after implementation of the Project.

The Hurga area and the Nur El Din area will be managed by 4 and 3 Block Inspectors, respectively. SGB envisages managing the Project area as a new independent Group after implementation of the Project, since the Project area is located on the east bank of the Blue Nile and far from the the Central Group on the opposite bank which the Project area belong to at present. The organization structure for management and operation of SGB is shown in Figure 3-5, and its staff planned for the Project area are listed below:

Position	Planned Nos.
Block Inspector	2
Second Inspector	2
Third inspector	3
Assistant Entomologist	1
Agricultural Expansionist	1
Agricultural Engineer	1
Horticultural Inspector	1
Agricultural Economist	1
chief Accountant	2
Senior Accountant	2
Assistant Accountant	4
Clerk	2
Assistant Clerk	2
Cashier	2
Head of Canal Ghafeer	2
Canal Ghafeer	19
Office Messenger	2
Block Messenger	2
Store Keeper	2
Assistant Store Keeper	2
Health Labour	2
Guard	8

Source: Questionnaire Survey

3.2.3 Project Components

Components of the Project works consist of:

1) construction of a pumping station;
2) installation of a power supply system;

3) construction of a link canal from the pumping station to two(2) new main canals;
4) construction of the new main canals;
5) rehabilitation of existing irrigation canal networks;
6) construction of drainage canal networks; and
7) construction of operation and maintenance facilities

These works are grouped into three(3) categories : i) irrigation facilities, ii) operation and maintenance facilities, and iii) power supply facilities. Although the rehabilitation/renovation of the irrigation facilities including the pumping station is the decisive issue to revitalize the present severely depressed agricultural condition, the reinforcement and enlargement of the operation and maintenance facilities are equally important to sustain the irrigation facilities at a operational level during the project life after construction, and hence it is essential to construct these facilities simultaneously. In this context, it is desired that the operation and maintenance facilities will be implemented by the Sudanese side. Although the construction of the power supply facilities in Sudan is under management of the National Electricity Corporation (NEC), the power supply facilities for the new pumping station was included in the project works to be undertaken by the Japanese side as planned initially in consideration of the following:

a) The construction of the power transmission line between the proposed pumping site and the El Biryab pumping station should be completed in time with the construction of the pumping station in order to meet the Project schedule;
b) It is desirable for one agency to supervise all of the construction works to facilitate smooth implementation of the Project in the very limited construction period, and
c) The Ministry of Irrigation, which is responsible for the implementation of the Project, has assured the Team to coordinate with NEC for the construction of the power supply facilities.

3.2.4 Components of Project Works

(1) Components of Project Works Requested

As the Ministry of Irrigation put the first priority on the Project, and is expecting its urgent implementation, GOS offered the Study Team to bear the construction of the civil works of the pumping station, the link canal and the new main canals provided that the construction equipment and materials necessary for these works be granted by the Government of Japan.

It is, however, advantageous that the supply and installation of pumps and auxiliary equipment and the construction of pumping station be executed as one package, because: i) the pumping station has to be constructed under a very tight schedule within a limited construction period, resulting from drastic fluctuations of water level of the Blue Nile, and ii) the pumps with long vertical shafts of about 10 m have to be installed with accurate workman-ship. It was considered that the works of the link canal and new main canals should be included in the work components of the Japanese side taking into account the fact that the new pump station will not be able to function unless these facilities are completed

Thus, it was concluded that the work components of (i) pumping station, (ii) power supply facilities, (iii) the link canal, and (iv) the new main canals will be covered under Japanese Grant Aid as originally requested by GOS. As the desilting work in the proposed sand settling basin in the link canal is indispensable to sustain the Project over the project life, it was decided that procurement of equipment for the desilting work will be added to the work components to be covered under the Grant Aid.

In this connection, GOS will have to implement (i) the rehabilitation of the existing irrigation canal networks, (ii) construction of drainage canals network, and (iii) construction of operation and maintenance office and facilities in timing with construction of the works to be covered by the Japanese side.

(2) Pump Station

The pump capacity requested is 148 m^3/min per unit at the rated discharge capacity and 444 m^3/min (7.4 m^3/sec) in total at the peak water requirement, which agrees with the seasonal pumping requirement and fluctuations of water level shown in Table 3-1. This pump capacity was determined under the condition of a 18-hour operation a day at the peak water requirement in due consideration of avoiding the peak power demand hours from 18:00 through 24:00. The requested pump type, a vertical shaft double suction volute pump, was judged to be appropriate since the same type pump had been selected through a thorough comparative study on the pumping station in the feasibility study of the Project.

An electric motor had been selected as the prime mover of the pump through an alternative study between an electric motor and a diesel engine in the same feasibility study. At the selection, it had been confirmed in the feasibility study that NEC put the priority on and secured the electric power supply to the pumping stations for the irrigation purpose despite the fact that electric power supply fulfils only 80 % of the potential demand and that the running cost of the motor is about 40% cheaper than that of the diesel engine. In this basic design study, it was re-confirmed that the motor was superior to the diesel engine because electricity charge increased by only 25% from that at the the time of the feasibility study against a 330% hike in fuel price in the same period

The requested number of pump units include one (1) standby unit for the following reasons:

i) The pumps should be limited to run to 18 hours a day even if any of the installed pumps is in need of maintenance or repair to avoid operation during peak power demand hours from 18:00 through 24:00;

ii) It is presumed to take considerable time for procurement of spare parts; and

iii) A standby pump unit has been customarily installed in Sudan at pumping stations for irrigation.

(3) Power Supply System

In Sudan, the electric power supply system is constructed and managed by NEC under administration of the Ministry of Energy and Mining. The present power supply system of NEC consists of the Blue Nile Grid System commanding the Central Region and the Eastern Grid System covering a part of the Eastern Region. The Project area and its surroundings are included in the Blue Nile Grid System. However, the distribution network of the Blue Nile Grid system has not extended to the proposed pumping site, and available power supply system around the Project area is:

i) the terminal of 33 kV distribution line at Shabarga village approximately 12 km north of the proposed pumping site, which is fed from the Meringan sub-station 8 km south of Wad Medani; and

ii) the terminal of 33 kV distribution line at the El Biryab pump station extending from the Hag Abdulla sub-station about 40 km south of Wad Medani. The El Biryab pumping station is located on the west bank of the Nile 8 km south of the proposed pumping site.

The requested power supply system consists of:

i) a 33 kV distribution line connecting the El Biryab pumping station to the proposed pumping site; and

ii) a outdoor switch yard at the proposed pumping station.

Although two routes for the distribution line were conceived for the Project in the feasibility study; one from the El Biryab pumping station and the other from the Shabarga village, the route from the El Biryab pumping station had been chosen, since the existing capacity of the Meringan sub-station has been fully utilized and there is no room for feeding the new pumping station.

The 33 kV distribution line was planned to cross the Blue Nile just downstream of the confluence with the Dinder river as shown in Figure 3-6. A pair of steel tower were considered for the river crossing, and no particular problems are expected in implementation of this work.

(4) Link Canal

The link canal requested is an earthen open channel connecting an outlet pond of the pumping station with the main canals commanding the Hurga and Nur El Din areas. The design capacity of the canal is 8.17 m^3/sec so as to meet a 18-hour operation of the pumps. The channel is 450 m long and has a desilting basin on the way and a bifurcation structure at the end to bifurcate the water into the Hurga main canal and the Nur El Din main canal in proportion to respective service areas.

MOI, the responsible agency for operation and maintenance (O&M) of existing irrigation systems, contemplates introducing sand settling basins in canal systems so as to mitigate enormous time and costs spent for the desilting work in the existing canals. The sand settling basin proposed in the link canal is, therefore, meet MOI's intention, and desilting in the sand settling basin is more advantageous than that in the canal system according to cost comparison.

Although the plan of these facilities was reasonable as a rule, further study was made in their basic design taking the result of field survey conducted in the current study period and the basic design of the proposed pumping station into account as discussed in the succeeding Chapter 4.

(5) New Main Canals

The requested new main canals are earthen open channels connecting the above-mentioned link canal to the existing Hurga main canal and the Nur El Din main canal through the bifurcation. The new Hurga main canal is about 0.5 km long with a design discharge of 5.02 m^3/sec. While, the new Nur El Din main canal is about 1.9 km long having a design discharge of 3.15 m^3/sec. These design discharges are reasonable since they were computed as the maximum flow requirement estimated based on a 18-hour pump operation a day, besides these canal

routes are also adequate as the result of the field survey carried out during current study period.

(6) Equipment for the Desilting Work

Desilting work in the sand settling basin is essential to maintain function of the canal system. Generally two desilting methods are conceivable, i.e. : i) flushing deposits by gravity flow; and ii) removing deposits mechanically. In the case of the Project, although it is topographically applicable, the former method was discarded because: i) irrigation has to be suspended during flushing; and ii) it seems to be rather difficult to flush deposited soils which are contained in the water tapped from the Blue Nile. It was, therefore, considered that desilting by means of draglines or pump suction dredgers is suitable for the Project and that including procurement of either equipment in the work components to be covered under the Grant Aid is reasonable.

(7) Work Components to Be Implemented by GOS

The works that GOS considered to be implemented by its own side consist of: i) rehabilitation of the existing irrigation canal networks; ii) construction of drainage canal network; and iii) construction of O&M office and facilities. The major works of the irrigation canals are heightening of the existing canals and replacement of existing related structures entailed by the heightening. The main work for the drainage canals is excavation. Sudan has no technical difficulty in construction because of ample experience on similar works.

Therefore, the study on the works to be covered by Sudan's side was concentrated to implementation plan, availability of construction equipment, construction equipment needed and budget for implementation of these works. The conditions employed for the study were: i) work volume consisting of embankment provisionally estimated at 1,696 x 10^3 m^3 and preliminarily estimated excavation of 232 x 10^3 m^3; and ii) provisionally prepared construction schedule for the works under the Japanese Grant aid requested during current field survey period.

Implementation Plan

The executing agency for the works will be the Ministry of Irrigation (MOI), and these works will be contracted to the Public Corporation for Irrigation Works and Earth Moving (PCIWEM) as sizable projects, which had been implemented by MOI, were exclusively contracted with PCIWEM. In Sudan there was virtually no case that the irrigation works of MOI were contracted with the private sectors.

PCIWEM is organizationally under the management of MOI, though it is financially independent from MOI. PCIWEM comprises two (2) corporations: Irrigation Work Corporation (IWC); and Earth Moving Corporation (EMC). IWC mainly constructs head works (diversion weir), pumping stations, irrigation canals structures, etc, while EMC mainly engages in such works as desilting and removing of sediment in the existing irrigation canals, rehabilitation and construction of canals and drains, etc. The earth moving by EMC, amounted to 10.2×10^6 m^3 in 1987/88, 9.9×10^6 m^3 in 1988/89, 18.0×10^6 m^3 in 1989/90, and 18.6×10^6 m^3 in 1990/91.

Construction Equipment

Major construction equipment owned by EMC as of June 1991 were as follows:

(Units: nos.)

Equipment	Operational	Out of Order
Dragline	64	14
Hydraulic Excavator	73	0
Scraper	12	3
Bulldozer	53	24
Motor Grader	30	17
Fuel Tanker	15	-

In addition to the equipment listed above, 8 draglines and 32 hydraulic excavators, were under procurement, and are scheduled to be delivered by the end of January 1992 according to EMC. Among this equipment, almost all of the draglines and hydraulic excavators and a few bulldozers were being used for the earth moving in existing canals and drains. All scrapers had been occupied with the Ramash Project and other three projects, all of which were expected to be completed by February 1992.

An operation plan of this equipment after that time was not available during the current field survey. According to the Director General of EMC, the use of construction equipment depends on the equipment requirement of the works contracted by MOI. Considering that EMC is under management of MOI, and MOI places top priority on implementation of the Project, it could fully be expected that the construction equipment owned by EMC would be allocated to the Project with top priority.

According to the implementation plan on rehabilitation of canals network provisionally prepared by MOI during the current field survey period, the construction equipment required for this project is as follows:

Equipment	Required Nos.
Hydraulic Excavator	3
Scraper	6
Bulldozer	12
Motor Grader	2

Since the equipment requirements listed above were based on the net running hours of 8.5 hours/day, which is a little bit longer and unrealistic, the number of the equipment requirement may increase when a detailed construction plan is prepared. However, taking into consideration the construction equipment owned by EMC and the policy of MOI on this Project, it seems to be highly possible to mobilize the numbers of equipment necessary for rehabilitation of existing canals and drains involved in the Project

Budget of the Ministry of Irrigation

MOI has estimated for the construction cost on the rehabilitation of irrigation canal networks and construction of the drainage canal network at £S 155×10^6. The estimated cost seems to be appropriate because it is only 10% more than £S 139.1×10^6 of the construction cost estimated in the feasibility study. Furthermore, the annual disbursement scheduled by MOI seems to be practical in comparison with the annual budget scale of MOI as shown below.

Disbursement Schedule of the Project

(Unit : £.Sx10^6)

Fiscal Year	1992/93	1993/94	1994/95	Total
Construction Cost	31.0	79.3	44.7	155.0

Annual Budget and Expenditure of MOI

(Unit : £.Sx10^6)

Item	88/89	89/90	90/91	91/92
Personnel cost	(?)	(?)	(?)	
Budget				
Performance	33.6	59.3	56.0	-
O&M cost				
Budget	60.0	245.8	325.0	842.0
Performance	38.1	151.0	324.9	-
Develop. cost *				
Budget	47.2	38.4	264.6	176.5
Performance	50.1	39.9	(?)	-

Source: Questionnaire Survey
* : Excluding foreign aid fund.

Operation and Maintenance Facilities

In addition to the rehabilitation of the irrigation and drainage canal networks, MOI and Sudan Gezira Board(SGB) expressed their intention of providing O&M facilities and equipment necessary for pursuing effective operation and sustaining the Project over the project life. The major facilities and equipment considered were:

O&M Facility Borne by the Ministry of Irrigation

Facility	Size	Q'ty
Administration office	390 m^2	1
Store	40 m^2	1
Fuel storage	10 m^2	1
Garage	85 m^2	1
Staff quarter	300 m^2	1
Staff quarter	270 m^2	1
Staff quarter	130 m^2	3
Staff quarter	90 m^2	14
Staff quarter	65 m^2	5
Water supply facility		1 system
Power supply system in the complex		1 system
Others		

O&M Facility Borne by the Sudan Gezira Board

Facilities	Size	Q'ty
Staff quarter	large	6
Staff quarter	medium	3
Staff quarter	small	3
Labour dormitory	*	46
Large store	*	2
Fuel storage	*	2
Fuel tank	*	2
Generator	*	2
Vehicle for O&M works		12

* : Based on the standard of Sudan Gezira Board.

The above-listed facilities seems to be appropriate for O&M of the Project facilities after implementation of the Project, in consideration of both the existing O&M facilities and the O&M staff planned.

3.3 Project Description

3.3.1 Executing Agency and Operational Structure

The Executing agency of the Project will be the Ministry of Irrigation (MOI) of GOS. The Supervision Directorate of the Projects Under-

Secretariat of MOI will be in charge of supervising construction works of the Project. He will be assisted by the Mechanical & Electrical Under-Secretariat of MOI on installation of pumps and electrical equipment.

Prior to the construction, the detailed design of the work component to be covered by the Japanese side will be performed by the Design Department of the Projects Under-Secretariat, and both the preparation of the tender documents and the evaluation of pre-qualification and tender for the works will be carried out by both the Supervision Directorate and the Mechanical & Electrical Under-Secretariat under the assistance of the Consultant.

On the other hand, the planning and detailed design of the works to be covered by GOS will be carried out by the Design Department of the Projects Under-Secretariat, and the succeeding construction work will be executed by the Supervision Directorate of the Project Under-secretariat.

3.3.2 Plan of Operation

The development plan of the Project, which has been formulated through the current study, comprises agricultural development plan, facility plan, operation and maintenance plan, and agriculture supporting services plan.

Based on the proposed cropping pattern of a 5-course rotation and proposed farming practices, the land use plan and anticipated crop yield were set as follows:

Crop (feddans)	Cropping Area	Unit Yield (kg/feddans)
Cotton	4,524	900
Wheat	4,524	920
Sorghum	2,262	1,000
Groundnut	2,262	1,000
Fodder	4,524	1,000
Fallow	4,524	-

The irrigation and drainage plan aims at materializing year-round irrigation for the Project area of 22,620 feddans (9,500 ha) by means of rehabilitation of existing irrigation and drainage systems and facilities including construction of a new pumping station

The operation and maintenance plan comprises both the plan on strengthening staff under existing O&M system and the plan on providing O&M facility and equipment.

In order to attain the target yield of the proposed crops, the agriculture supporting services being rendered by SGB in the existing Gezira-Managil Scheme will be applied to the Project area.

3.3.3 Location and Condition of the Project Site

The proposed pumping station is located on the east bank of the Blue Nile and 1.5 km downstream of the existing Nur El Din pumping station or 0.7 km upstream of the existing Hurga pumping station. The site is at the end of a gradual concave of the river, and the flow is quite stable and close to the east bank. The river bank at low water level is very stable because of its stiff clay.

The project area is a flat land extending up-and down-stream from the proposed pumping site. A paved trunk road connecting Wad Medani and Gedaref runs on the north-east end of the project area. A 12 km long earthen road branches off from the trunk road at 30 km point from Wad Medani and reaches to the pumping site. This earthen road is likely to becomes muddy and less trafficable during the rainy season.

3.3.4 Outline of the Facility and Equipment

The outline of the facilities and equipment which would be covered by the Japanese side is as follows:

(1) Pump Station

Pump type	Vertical shaft double suction volute pump	
Rating discharge	148	m^3/min/unit
Rating head	25	m
Inlet pipe	1,100, 900	m m
Pump diameter	900x800	m m
Discharge pipe	900, 1,100, 1,800	m m
Nos. of units	4	units
Rating output of motor	760	kw

(2) Head Race

Design discharge	8.17	m^3/sec
Canal length	345	m
Desilting basin		
Length	150	m
Surface width	50	m
Bottom width	30	m

Bifurcation

Design discharge

5.02 m^3/sec for Hurga canal

3.15 m^3/sec for Nur El Din canal

(3) New Main Canal

Hurga Canal		
Design discharge	5.02	m^3/sec
Length	433	m
Nur El Din Canal		
Design Discharge	3.15	m^3/sec
Length	1,820	m

(4) Power Supply System

33 kV Distribution Line	9.5 km
Outdoor Switchgears	33 kV Switchboard 3,000 kVA Transformer
Indoor Switchgear	11 kVA Switchboard Motor Starter 6 sets of Control panel

(5) Equipment for the Desilting Work

3.3.5 Operation and Maintenance Plan

(1) Operation and Maintenance

Indent for irrigation water will be submitted every 10 days to the Senior Engineer, despatched to the pumping station by the Mechanical and Electrical Under-secretariat, by the Assistant Divisional Engineer for the

Hurga and Nur El Din of the Wad Medani Division of the Under-Secretariat of Irrigation Gezira & Managil.

The irrigation water demand will be computed based on both the crop water requirement and the actually cropped area. The number of pump units to be run and their running hours will be decided by the Senior Engineer based on the indent submitted by the Assistant Divisional Engineer. The pumps would then be run by the pump operator in line with the instruction of the Senior Engineer accordingly.

The gates of various turnouts on the main canal will be adjusted in conformity with pump operation by the Section Engineer of the Assistant Divisional Engineer, one would be stationed each for the Hurga area and the Nur El Din area . In principal, the opening height of those gates will be adjusted at a 10-day interval, however, minor adjustments will be made in practice from time to time. Gates of the turnouts installed on the minor canals will be opened for 12 hours from 6:00 AM to 6:00 PM every day by Ghafeers in accordance with the instruction of the Block Inspector dispatched from SGB.

Apart from the gates operation mentioned above, maintenance works will be continuously carried out to sustain the function of the constructed facilities as designed. The Mechanical & Electrical Under-Secretariat will execute the regular maintenance of the pumping station (daily, weekly, monthly and yearly), procure necessary spare parts, and make necessary repairs, if required. In addition, the following maintenance works will have to be carried out to sustain the constructed canals and related structures:

1) clearing of silt and sand deposits from desilting basin;
2) operation and maintenance of canal service roads;
3) clearing of weeds from canals;
4) maintenance and minor repair of canals and related structures;
5) large repairs of canals and related structures; and
6) greasing,painting,etc. of gates and metal works;

Among the works itemized above, works 1) and 2) would be executed by EMC contracted with the Under-Secretariat of Projects, and other works

would be carried out by the Under-Secretariat of Irrigation Gezira and Managil.

(2) Management and Operation System

The management and operation system necessary for smooth operation and maintenance stated above is as discussed in the preceding clause "3.2.2 Implementation and Operation System".

(3) Operation and Maintenance Cost

The annual budget of the Ministry of Irrigation necessary for the operation and maintenance of the project facilities is estimated as follows:

Cost Item	Q'ty	Unit Price	Amount(£.S)
1. Personnel cost*			900
2. Running cost			
Electricity charge		***	3,500
Fuel and oil cost			50
3. O &M cost			
Earth moving	150,000m^3	14**	2,100
Others			300
4. Office expenditure			200
5. Material and others			100
Total			7,150

* : By Questionnaire Survey.
** : Based on 1990/91 performance of EMC on earth moving; earth moving of 18.6x 10^6 m^3 at a contract amount of £S 256x10^6 .
***: Tariff of electricity is as shown below.

(1)	Base Charge	
	i) Max.Demand Charge	£S 3.0/KVA
	ii) Service Capacity Charge	£S 1.0/KVA
(2)	Consumption Charge	
	i) For Critical Months	
	Off-peak rate	£S 0.42/KWH
	Peak rate	£S 1.22/KWH
	ii) For Other Months	
	Off-peak rate	£S 0.10/KWH
	Peak rate	£S 0.70/KWH

CHAPTER 4
BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4.1 Design Policy

The Project aims to pump irrigation water from the Blue Nile and supply it to the existing Hurga and Nur El Din main canals. The project works consist of the supply and installation of pumping equipment, the construction of a pumping station, a link canal and two (2) new main canals, and the construction of a power supply system to the pumping station. These facilities were in principle planned so as to have appropriate scales for their respective purposes from both technical and economic viewpoints. They were also planned so as to effectively revitalize social and economic activities of inhabitants in the area. In preparing basic design of these facilities, due consideration was given to simplification of design and maximum use of locally available materials so that they could be easily and effectively operated, maintained, and repaired by local technicians themselves. The basic design policies for the respective facilities are as explained below:

Pumping Equipment

1) To maintain water supply at the lowest low water level condition:

   The water level of the Blue Nile at the proposed pumping site fluctuates as much as 8 meters through a year. The pumping equipment was designed to meet the irrigation water requirement at the monthly mean low water level between 1974 and 1990, and also to secure irrigation water supply without interruption at the lowest low water level condition.

2) To limit operation of the pumps to 18 hours a day maximum:

   At present, the electric power supply condition in Sudan is unstable due to a shortage of power generation as well as fuel supply conditions, especially during March to August. The pumping equipment was therefore designed to limit the pump operation to 18 hours a day to avoid operation during the peak demand of electricity between 6:00 pm and 12:00 pm.

3) To secure the reliable pumping operation:

In Sudan, the spare parts of pumping equipment are not available in market and thus it would take a long time to procure parts to repair pumping equipment. To secure reliable pump operation, it was proposed to provide a spare pump unit in addition to supply of spare parts and maintenance equipment and tools.

4) To minimize maintenance works:

The discharge control in response to the seasonal variation of irrigation water requirement and water level of the Blue Nile was planned to be made by controlling the number of running pumps and operation hours of each pump unit. The complicate discharge control system such as speed control system of pump motor was not applied to minimize maintenance works as much as possible. The voltage of main pump motors was set at 11,000 V in accordance with the voltage system of NEC, and 6,600 V or 3,300 V was not applied in order to facilitate inspection and maintenance works.

Pumping Station

1) The size of the pumping station was determined so as to fit the kinds and numbers of proposed pumps and motors. Structural design was made taking into consideration the loads acting on the structure, site condition, bearing capacity, and economic view points for construction.

2) The foundation of the pumping station was designed to support safely the structure and not to undergo harmful settlement. The pumping station was designed to be founded on steady soil. A sole type of foundation was employed for the pumping station so as to avoid differential settlement of the structure.

3) The floor plan of the pumping station was designed to have enough space for easy operation and maintenance of the equipment.

4) Since the construction period will be limited to about 12 months, excluding the rainy season, the pumping station was designed so that the pumping equipment such as pumps, motors, etc. can be installed after substantial completion of the pumping station.

5) The maximum use of locally available materials will be given first consideration. However, imported materials will be employed in case the materials are not locally available, are poor in quality, or are limited in quantity.

6) The type of building employed for the pumping station was that normally adopted in the country.

Link Canal and New Main Canals

1) The required water levels for the link canal and the main canals were examined taking into consideration the canal profiles at farm level.

2) The canals and related structures were planned so that their construction, operation and maintenance could be made easily.

3) A sand settling basin was proposed in the link canal in order to settle the suspended soils pumped up with the irrigation water from the Blue Nile. And, excavated soils for construction of the basin were planned to be used as much as possible as the embankment materials of the canals .

4) A structure to bifurcate the irrigation water in the link canal to the existing Hurga and Nur El Din canals was designed so that the water could be divided automatically in proportion to the respective service areas.

Power Supply System

1) The electric power required for the proposed pumping station was planned to be supplied from the Hag Abdalla substation, located approximately 28 km south of the proposed pumping site, through a

33 kV distribution line. Though one of the main transformers at the Hag Abdalla substation has been transferred to any other substation at present, a new transformer of 10,000 kVA capacity has been planned to be installed by the middle of 1992.

2) A 33 kV distribution line exists between the Hag Abdalla substation and the El Biryab pumping station which is located approximately 9 km south of the proposed pumping site. A new 33 kV distribution line was planned to be constructed between the El Biryab pumping station and the proposed pumping site and connected to the existing distribution line at the terminal support of the El Biryab pumping station.

3) 33 kV outdoor switchgears including a 33/11 kV step-down transformer were designed to be installed at the proposed pumping site. Through this transformer the electric power was planned to be supplied to 11 kV high tension metal-enclosed cubicles installed in the cubicle room of the proposed pumping station.

4) The electric power was planned to be supplied to pump-motors from high voltage motor starter panels and also supplied to the other facilities from a low tension distribution panel after stepping down to 380-220 V voltage level by a station service transformer.

Equipment for the Desilting Work

1) This equipment will be used to remove sediments in the sand settling basin without hampering irrigation .

2) Capacity and number of the equipment were determined in due consideration of the volume of suspended solids contained in the tapped water through the pumps, sediment capacity of the sand settling basin, and operation hours of the equipment.

3) Easy operation, maintenance, and repair were considered in selection of the equipment.

4) Minimizing O&M cost was also taken into account in selection of the equipment.

4.2 Study and Examination on Design Criteria

In the basic design, the following design conditions were taken into account.

(1) Bench Mark

Bench marks used for the design are BM (H-1): El. 411.373 and BM (N-3): El. 410.418, both of which were established by MOI. These elevations are based on an arbitrary elevation, while reduced elevations used for water level record are derived from the Sudanese Standard Datum, so called Irrigation Datum of El. 360,000 at Khartoum. Thus, as a result the actual elevations of the above BMs are 80 cm higher than the arbitrary ones. Therefore, careful attention should be paid in case the elevations derived from the above BMs are compared with those of water records. Locations of bench marks mentioned above are shown in Figure 4-1.

(2) Design Water Level

The design water levels of pumping equipment are as follows:

- Flood water level	:	El. 402.110 m
- High water level	:	El. 398.640 m
- Low water level	:	El. 391.020 m
- Lowest low water level	:	El. 389.020 m
- Discharge water level	:	El. 413.600 m

It is to be noted that these water levels are based on the BM system established by MOI mentioned above. The flood water level employed corresponds to a 100-year probable one, and the lowest low water level is the lowest water level recorded in June 1990. The pumping equipment was designed to meet the required irrigation water based on the high water and low water levels derived from the monthly mean water level between 1974 and

1990, and also to keep irrigation water supply without interruption even at the lowest low water level condition.

(3) Water Requirement

The pumping water requirement based on the proposed cropping pattern in terms of m^3/sec is as follows:

(m^3/sec)

10-day	Jan	Feb	Mar	Apr	May	Jun	Jun	Aug	Sep	Oct	Nov	Dec
1st	4.83	3.61	1.09	0.00	2.65	4.66	6.34	6.45	8.17	7.05	5.32	4.50
2nd	4.54	3.18	0.00	0.00	3.26	5.69	7.86	6.50	7.44	5.98	5.26	4.73
3rd	4.14	2.12	0.00	2.23	3.84	6.49	6.60	6.87	6.75	5.89	4.18	4.90

The above water requirement includes 10% delivery and 10% drainage losses in addition to the net water requirement.

(4) Water Quality

The pH value of the Blue Nile water ranges from 7.5 to 9.0, and hence neither acid-resistant nor alkali-resistant materials were proposed in the design of pumping equipment. However, abrasion-resistant materials were proposed for impellers of pumps because of high sediment load of the Blue Nile especially in flood season.

(5) Temperature

The average minimum and maximum monthly temperatures considered in the design are 14.7°C and 41.5°C respectively, and the maximum temperature expected is 50°C. Therefore, due attention was paid on the temperature rise in the design of pump motors, transformers, etc.

(6) Site of the Pumping Station

The pumping station was proposed to be located on the right bank of the Blue Nile, about 700 m upstream of the existing Hurga pumping station.

(7) Earthquake

There are little possibility of occurrence of earth-quakes in the country.

(8) Bearing Capacity

The following bearing capacity at the site of the pumping station was adopted in the design:

N-value	:	N = 23
Internal friction angle	:	f = 33°
Bearing capacity	:	qa = 23 ton/m^2

The results of geological survey at the proposed pumping site are shown in Figures 4-2 to 4-5.

(9) Ground Water Level

The ground water level at the proposed pumping site was assumed to be El. 399.0, though it might go up and down according to the water level of the Blue Nile.

(10) Design Standards for the Pumping Station

Design of the pumping station was made based on Japanese standards, since no particular standards were available in the country.

(11) Floor Plan for the Pumping Station

To determine the floor plan for the pumping station, spaces between respective pumps were set so that they could be used as maintenance passages to inspect the pumps. And also, spaces for installation of the pumping equipment and spaces for maintenance and repair of the equipment were considered. The required height of the pumping station was determined taking into consideration the required lifting height of the overhead crane.

(12) Canal Design Discharge

The design discharge of 8.17 m^3/sec, which meets the maximum pumping requirement, was adopted for the link canal. The design discharges of the Hurga and Nur El Din main canals were determined at 5.02 m^3/sec and 3.15 m^3/sec, respectively.

(13) Design Standards for Canals

Design of the canals and their related structures was based on the standards of MOI of Sudan, aiming at maximum use of existing facilities and easy maintenance and operation of the facilities to be constructed in the future.

(14) Meteorological Condition

The following conditions were considered in the design of the 33 kV overhead distribution line:

Maximum ambient temperature	50℃
Mean ambient temperature	30℃
Minimum ambient temperature	25℃
Maximum wind velocity	25 m/sec

Though detailed data of thunder storm days were not available, according to the standard practice in Sudan, no overhead grounding wire was proposed for the 33 kV distribution line except for the river crossing section.

(15) Support

The type of proposed support for the overhead distribution line is precast square concrete pole to be manufactured at the site, as this type has been used in many distribution lines in Sudan and has proved good performances over a long period of use.

(16) River Crossing Tower

The distribution line was planned to cross over the Blue Nile between El Biryab pumping station and the proposed pumping site. Since the width of

Blue Nile River at the crossing point is approximately 300 m and it is close to the ferry ports on the Blue Nile, a pair of steel towers having enough height were proposed to secure sufficient clearance above the ferry boats.

The height of the steel tower was decided taking account of the following conditions:

Highest water level	El. 402.45 m
Height of ferry boat	6.0 m
Allowable clearance of conductor	6.0 m
Maximum sag of conductors	11.2 m

(17) Conductors

All aluminium stranded conductor is normally used for 33 kV distribution lines in Sudan. However, at the river crossing point, the conductor will have to be strung with high tension to minimize the conductor sags, and therefore the conventional aluminium conductor was considered not applicable for such high tension stringing. On this reason, the aluminium conductor steel reinforced (ACSR), which has high tensile strength than all aluminium conductor, was selected for the river crossing section.

Moreover, considering that the new 33 kV distribution of line overland sections is in only 9.5 km long and the use of two different types of conductors for such a short distribution line is economically favourable, the ACSR conductor was also proposed to be used for overland section.

(18) Equipment for the Desilting Work

The desilting work is to remove mechanically deposits in the sand settling basin and dispose them to the Blue Nile downstream of the proposed pumping site. Equipment necessary for the desilting work in the canals was not considered.

4.3 Basic Plan

4.3.1 Pumping Equipment

(1) Main Pump

The main pumps proposed are of vertical shaft double suction volute type, and the number of pump units proposed is four(4) in total including one spare pump unit. The main features of main pumps are shown in Table 4-1 and summarized as follows:

- Type of pump suction : vertical shaft double volume pump
- Rated discharge : 148 m^3/min/unit
- Rated design head : 25 m
- Diameter of pump : 900 mm x 800 mm
- Number of pump : 4 units (1 unit spare)

The rated discharge of the pumps was determined based on Figure 4-6, Expected Characteristic Curve of Pump, and Figure 4-7, System Curve. The rated design head was obtained from the static head of 22.58 m plus a head loss of 2.168 m as shown in Table 4-2.

(2) Main Motor

The main features of the main motors are as follows:

- Type : vertical shaft squirrel cage induction motor
- Rated output : 760 kW
- Voltage : 11,000 V
- Number of poles : 10P
- Speed : 600 rpm.

(3) Setting Elevation of Pumps and Motors

In case the pump units are installed below the lowest low water level, no priming of pump is needed at starting operation of pumps and the control system of the pump becomes simple. But, the overall construction cost of the pumping station becomes considerably high since deep foundation of the pump house including construction works of suction pipes in wet condition is required. The setting level of the pump was set at EL.391.500 m so as to avoid breaking out of cavitation phenomena even at the lowest low water level. A vacuum pump unit was proposed for priming, because the suction water level possibly drops below the setting elevation of the pump at the low water stage. The elevation of motors was set at El. 402.50 m so as to have sufficient freeboard against a 100-year probable flood.

(4) Piping Works

The piping works for the pumps are composed of:

- horizontal suction pipes: 4 lanes
- discharge pipes within pump house: 4 lanes
- manifold type confluence pipe and discharge pipe outside pump house: 1 lane

Flexible pipes were proposed for the suction pipes and the main discharge pipe to accommodate the expected pressure settlement of the pump house. One integrated discharge pipeline with a manifold type confluence pipe was applied to reduce the construction cost of piping works. The discharge pipeline was designed to be backfilled after installation works to eliminate an expansion joint for thermal shrinkage/ elongation of the pipeline.

A discharge flow meter and an integrating flow meter were proposed to monitor the operating condition of pumping equipment.

(5) Valves

For the operation and maintenance of pumping equipment, the following valves were proposed for each pump unit:

- sluice valve in suction pipe,
- check valve in discharge pipe, and
- butterfly valve in discharge pipe.

The manually operated sluice valve was considered for the maintenance of pumping unit even in high water level conditions of the Blue Nile. The swing type check valve was planned to be installed at the discharge outlet of each pump unit to prevent reverse flow during stopping of operation. Electrically operated butterfly valves were proposed to be provided at the discharge outlet of each pump unit to prevent over-discharge of pumps at a high water level condition of the Blue Nile.

(6) Overhead Crane

For the installation and maintenance works of pumping equipment, an electrically operated overhead crane was proposed. The hoisting capacity was determined based on the heaviest component of pumping equipment, namely, the main motor.

(7) Priming Equipment

Priming of the pumping equipment by a vacuum pump is needed prior to starting operation when the suction water level drops below El.392.0 m. Two sets of vacuum pumps, one for stand-by duty were proposed for priming.

(8) Drainage Pump

Though the pump house was designed to be a waterproof structure, water leakage from the pumping equipment through grand packings of pump shafts and valve shafts is unavoidable. Two sets of drainage pump, one for stand-by duty were proposed for draining such casual water within the pump house.

(9) Inspection Deck

To increase accessibility to the pump equipment and improve workability of maintenance and inspection works of the pump equipment, inspection decks were designed around the pump unit.

4.3.2 Pumping Station

(1) Site of the Pumping Station

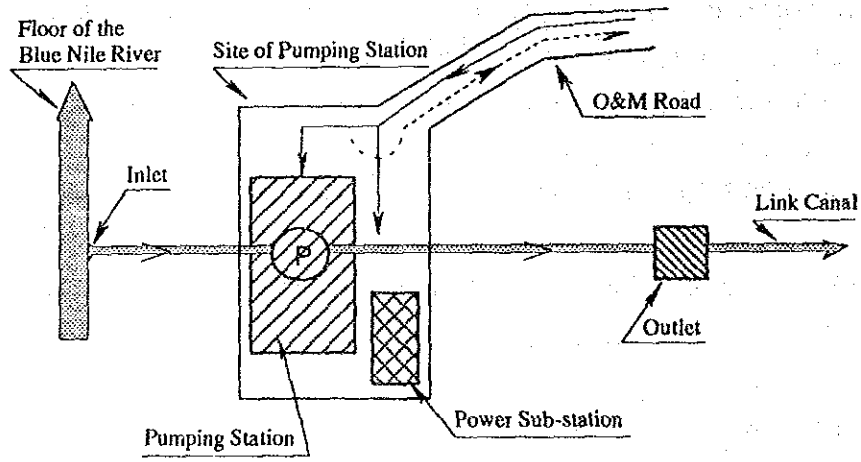
The proposed pumping station will be located on the right bank of the Blue Nile about 700 m upstream of the existing Hurga pumping station. This site is an advantageous point for irrigation water supply to the existing Hurga and Nur El Din schemes, and a stable point as for the river flow and topographic conditions. This site is also suitable for construction of the pumping station from the viewpoint of site topography and geology. The river bank at the site forms stepped steep slopes consisting of low-lying terrace of 10 m depth at El.391.02 m and gently sloped bank top of about 20 m depth ranging from El.397 to El.400 m. After this, the ground surface elevation further increases gently with a ground depth of about 30 m and reaches El.406 m, which is higher than the 100-year probable flood water level of the Blue Nile.

(2) Layout Plan

Construction works of the pumping station mainly consist of an inlet, a pumping station and an outlet. From economic reason and easiness of construction works, the pumping station was planned to be situated on the low-lying terrace and gently sloped bank top at about 18 m from the bank of the river at low water level. A power substation for the pumping equipment was planned to be placed at the back yard of the pumping station. The ground level of the pumping station was set at El.402.25 m so that the level becomes higher than the 100-year probable flood level since the motors and power substation were designed to be set on the ground. The outlet, connected with the link canal, was designed to be placed at about 55 m inside from the pumping station taking into consideration the topographic conditions and

easiness of setting works of the discharge pipe. As for the inlet, suction pipes were planned to be extended to the river directly at the low water level of the Blue Nile so as to avoid silting in the suction pit or the inlet channel. Since the mouth of the suction pipe is extended to the river, where there is continuous flow of the Blue Nile even at the low water stage, it is likely that a harmful influence against a suction of pumps due to silting in the suction pit is avoidable.

The layout of the pumping station was planned so as to have enough space for access by vehicles to the site for operation and maintenance and for installing the power sub-station. The layout of other facilities in the pumping station is the one normally adopted in the existing pumping stations in Sudan. The layout plan of the pumping station, flow of access and water are illustrated as follows:



The basic designs of the inlet, pumping station and outlet are discussed in the following paragraphs and the basic drawings of these facilities are shown in the attached drawings.

(3) Basic Design of the Inlet

As mentioned previously, suction pipes were designed to be extended to the river at the low water level of the Blue Nile, in order to avoid silting at the suction pit or the inlet channel. Elevation of the inlet base was set at El.366.02 m so that the irrigation water could be tapped even at the lowest low

water level of El.389.02 m. The base was planned to be covered by gabion mattress. Sheet piles were proposed as retaining walls of the inlet and these piles were expected to function as coffering works during the construction of the pump house. The construction period required for piling works was considered shorter than other construction methods to protect this portion. Erosion of river bank has not been developing distinctively at the existing Hurga and Nur El Din pumping stations. It was considered, therefore, that the bank erosion will not likely occur in the future at the proposed site since the topographic and geological conditions are rather the same as those at the sites of the above existing pumping stations. It was designed, however, that the slope between the inlet and the pumping station be protected by wet stone masonry so as to fit the natural bank slope, since this portion is very important for protecting the pumping station against a flood of the Blue Nile. Main features of the inlet are as follows:

- Inlet	Width	:	20 m
	Height	:	5.68 m
	Base	:	Protection by gabion mattress
	Wall	:	Protection by sheet pile (L = 10 m, with tie-rod)
- Slope protection	Works	:	Wet stone masonry
	Slope	:	1:1.0
	Height	:	9.75 m

(4) Basic Plan for Pumping Station

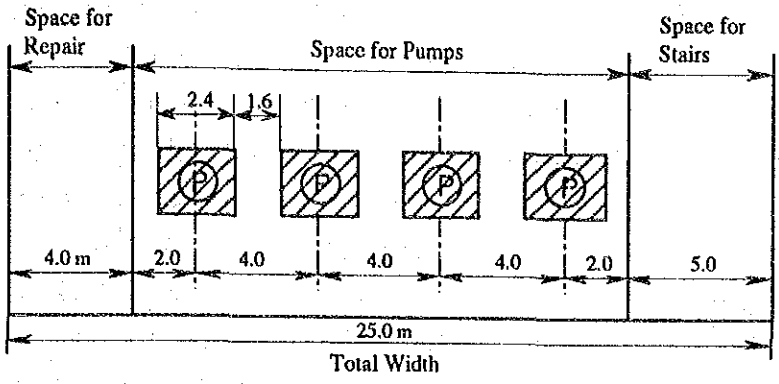
Floor Plan

The following dimensions of the pumping equipment were adopted in order to determine the floor plan of the pumping station.

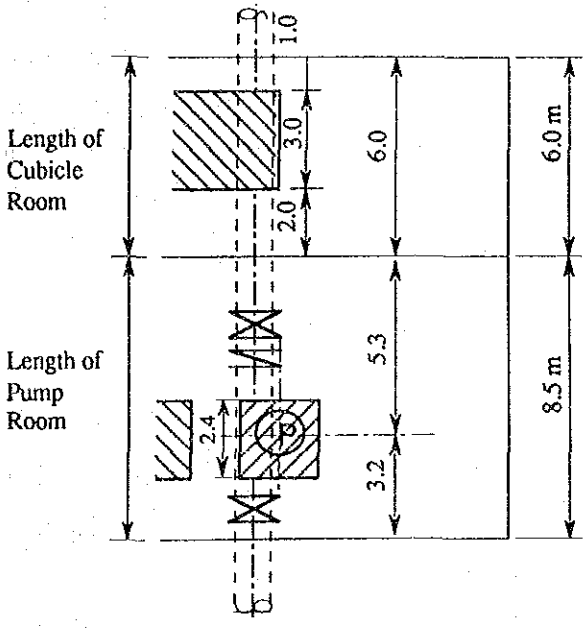
- Suction and discharge pipe
  Diameter : D = 1,100 mm, 4 lanes
- Pump Type : Vertical shaft double suction volute pump,
  Dia. 900 mm x 800 mm, 4 nos.

	Width	:	2.4 m	
	Length	:	2.4 m	
	Height	:	3.0 m	
- Motor	Type	:	Vertical shaft squirrel cage induction motor, Rated output 760 kW, 4 nos.	
	Width	:	2.0 m	
	Length	:	2.3 m	
	Height	:	4.0 m	
- Valve	Sluice valve	:	Dia.	900 mm
			Lin. length	1.35 m.
	Check valve	:	Dia.	900 mm
			Lin. length	0.50 m
	Butterfly valve	:	Dia.	900mm
			Lin. length	1.35 m

The required width of the pumping station was determined to meet the width of the pump, the widest piece of equipment. It was determined that a space between each pump would be 1.6 m and that a distance between the centre to centre of each pump would be 4.0 m in order to keep enough space for inspection and maintenance of the pumps. In addition, a space with a width of 4.0 m is to be provided in order to carry in, install, maintain and repair the equipment, where one pump could be overhauled and repaired. Though the motors were designed to be set on a nearly same level as the ground level of the pumping station, the pumps were designed to be placed underground considering the suction head of pumps. Therefore, a space for stairs for getting down to the pump room was proposed for inspection, maintenance and repair. The dimension of the space for the stairs was determined to be 5.0 m including allowance. The required dimension of the pumping station thus determined is illustrated below:



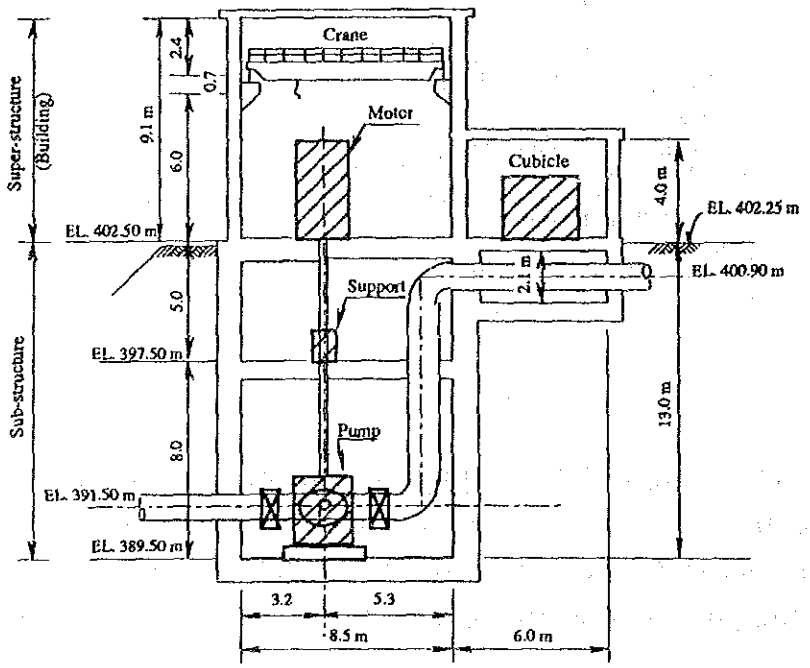
The required length of the pumping station was determined to be 8.5 m which is the total of the pump length (2.4 m), length of valves (3.2 m), length of bend pipe (1.1 m), required space (1.1 m) between the centre of discharge pipe and the wall, length of flanges, etc. (0.7 m). The length of the cubicle room was decided to be 6.0 m taking into account the width of the cubicle (3.0 m), required space (1.0 m) between the cubicle and the wall, and operation width (2.0 m). The required length of the pumping station is illustrated below:



Section Plan

The section plan of the pumping station was decided taking into consideration the setting places for pumps and motors, construction method, construction cost, and required height of overhead crane. Since the setting elevation of the pumps is El.391.50 m at the centre line of the pumps and the

suction pipes, the floor level of the pump room was decided to be El.389.50 m taking into account the height of the pumps and their bases. The setting elevation of the motors is El.402.50 m, which was decided to corresponding with the 100-year probable flood level of El.402.11 m. Taking into consideration the necessity for supports of transmission shafts between the motors and the pumps and from the structural viewpoint, an intermediate floor for the supports of transmission shafts was planned at a level of El.397.50 m. Two floors, therefore, were planned for the substructure of the pumping station. The required building (superstructure) height of the pumping station was determined according to the required height of overhead crane for installation, maintenance and repair of the equipment. The height from the floor to the ceiling of the superstructure was determined to be 9.1 m breaking down to the required lifting height of the transmission shaft (6.0 m), mechanical height (0.7 m) between a moving rail and a lifting hook, and the required height (2.4 m) from the rail to the ceiling. The required height of the cubicle room is 4.0 m summing up the height of the cubicle (2.5 m) and an allowance (1.5 m). Under the cubicle room, an empty room was planned so that the discharge pipes could be set under the cubicle room after substantial completion of the building construction works. Electric cables from the cubicles to the motors will pass through this room. The height of this room was designed to be 2.1 m in order to install the discharge pipes and inspect the electric cables. The section plan of the pumping station is illustrated below:



Structural Design

Taking into consideration the local customs and conditions, structural strength, durability of structures, procurement of construction materials and construction cost, the superstructure (building) was planned to be a dust proof structure made of brick walls with reinforced concrete frames, and the substructure was designed to be a water- proof structure made of reinforced concrete walls with box type. Study of the foundation of the pumping station, study of the uplift pressure and structural design are summarized below:

a) Study of the Foundation

Mat foundation type was chosen for the pumping station because the site has a good foundation ground consisting of a sandy layer and its bearing capacity was estimated to be rather high (23 ton/m^2). The pumping station is quite safe against the bearing stress of the foundation ground at the site since the load acting on the foundation ground (19 ton/m^2) was estimated to be smaller than the bearing capacity (23 ton/m^2) on the foundation ground.

b) Study of the Uplift Pressure

Uplift pressure acting on the pumping station by the ground water was estimated at 10.5 ton/m^2 based on the ground water level of El.399.0 m. This uplift pressure is smaller than the weight of the pumping station (about 19 ton/m^2).

c) Structural Design

Loads acting on the pumping station are dead weights, earth pressure, water pressure, weights of the pumping equipment, and crowd load. The weights, loads and allowable stresses used in the basic design are summarized below:

- Unit weights of materials

Water	1.00 ton/m^3
Steel	7.85 ton/m^2
Plain concrete	2.20 ton/m^3
Reinforced concrete	2.40 ton/m^3

Mortar	2.00 ton/m^3
Earth	1.80 ton/m^3
Earth in water	1.00 ton/m^3
- Crowd load	W = 500 kg/m^2
- Coefficient of earth pressure	Ka = 0.5 (coefficient of earth pressure at rest)
- Allowable stresses	
Reinforced concrete	
Design stress	sk = 210 kg/cm^3
Bending compressive stress	sa = 7.0 kg/cm^3
Shearing stress (Beam)	ta = 6.5 kg/cm^3
Shearing stress (Slabs)	ta = 8.5 kg/cm^3
Bonding stress	toa = 15 kg/cm^3
Reinforcement bar (Deformed bar SD30)	
Tensile stress (Ordinary cases)	ssa = 1,800 kg/cm^3
Tensile stress (In case requiring high water tightness)	ssa = 1,600 kg/cm^3
- Weights of the pumping equipment	
Pump	11 ton/no.
Motor (with table)	15 ton/no.
Steel pipe	1.1 ton/m
Sluice valve (manually operated)	0.5 ton/no.
Check valve	0.3 ton/no.
Butterfly valve	1.0 ton/no.
Overhead crane (Nominal weight 15 ton) max. wheel load at rail	11.5 ton

Structural calculations for the superstructure (building) were carried out by a method based on rigid frame of reinforced concrete beams. On the other hand, structural calculations for the substructure were made by the following respective methods based on the slab and the wall because rather wide openings in the slab of the ground floor and the

first basement were designed to install the pumps and transmission shafts.

Side wall and base floor	:	Rigid frame of reinforced concrete slab
Ground and first basement floors	:	Slab with beams

Lighting fixtures in the pumping station were proposed taking into account the following required illumination for each room:

Room for the cubicles	:	250 luxes
Room for the motors	:	150 luxes
Room for the pumps and the supports for transmission shafts	:	50 luxes

Main features of the pumping station are summarized below:

- Superstructure (Installation of the Motors and Overhead Crane)

Width	:	25.0 m
Length	:	8.5 m
Height	:	9.1 m
Beam	:	Reinforced concrete
Wall	:	Brick masonry with mortar finishing (T = 20 cm)

- Sub-structure (Installation of the Pumps and Supports for Transmission Shafts)

Width	:	21.0 m
Length	:	8.5 m
Height (Two floors)	:	13.0 m
Upper and middle floors	:	Beam and slab structure of reinforced concrete
Side wall and base floor	:	Slab structure of reinforced concrete

- Cubicle Room (Installation of the Cubicles)

Width	:	21.0 m
Length	:	6.0 m
Height	:	4.0 m
Beam	:	Reinforced concrete
Wall	:	Brick masonry with mortar finishing (T = 20 cm)
Empty room under the cubicle room	:	Reinforced concrete box structure

(5) Basic Design of the Outlet

Irrigation water tapped from the Blue Nile will be discharged to the outlet pond passing through the inlet and the pumping station, and will be supplied to the link canal. Four (4) discharge pipes of 1,100 mm diameter were designed to pass through the pumping station and under the cubicle room at El.400.90 m at the centre of pipes under the cubicle room. Those were planned to be gathered to a manifold type confluence pipe. One confluence discharge pipe with a diameter of 1,800 mm will be aligned to be level on a ground over a length of 8.0 m and extended to the outlet pond on sloped ground with an inclination of 1:3.0. Elevation of the centre of the pipe at the outlet pond is El.410.10 m and the horizontal distance between the pumping station and the outlet pond is about 44.0 m. The outlet pond was designed to be of reinforced concrete flume type, and its main features are as follows:

Width	:	8.0 m
Length	:	10.0 m
Height	:	6.0 m
Structural type	:	Reinforced concrete flume type
Designed water level	:	El. 413.60 m
Base elevation	:	El. 408.60 m
Elevation of the centre of discharge pipe	:	El. 410.10 m