1.3 Pump Houses

1.3.1 Present Status

Both the Hurga and Nur El Din pumping stations situate at the concave right bank of the Blue Nile where the water flows along the right bank. These pumping stations are said to be built in approximately 1958, about 30 years back. The maintenance and repair works during those years seem to have not been done satisfactorily due to difficulty in supply of spare parts and appropriate technical support. The superstructures of both pumping stations have been deteriorated severely in comparison with other pumping stations constructed at almost the same time along the Blue Nile such as Wad El Nau and Hag Abdalla pumping stations. The present structural conditions of both pumping stations are outlined hereunder:

(1) Hurga Pumping Station

Three suction pits are built into the river bank with a brick made building for placing three diesel engines. According to the geological analysis conducted by the JICA Study Team, these suction pits are assumed to be on stiff clay of 2 - 8 m or a stratum underlying thereof.

The building is made of steel framed brick masonry walls and corrugated slate roof, while the suction chambers are made of reinforced concrete. The materials of the main structures are enumerated as follows:

Superstructure		
- Roof	:	Corrugated slate
- Wall	:	Brick masonry and slate
- Roof frame	:	Structure Steel
- Column	:	Structure Steel
- Foundation	:	Reinforced concrete
Substructure		
- Suction chamber	:	Reinforced concrete
- Intake structure	:	Reinforced concrete
Discharge chamber	:	Brick masonry

Plain round bars (9 - 19 mm in diameter) were observed on some parts of the walls of the suction pits and retaining walls of the intake structure where reinforcing bars were exposed because spalling of cover concrete has occurred or cover concrete has not been casted adequately. The reinforcing bars exposed have been corroded seriously. The state of those embedded in the concrete is quite good in condition according to observation by tipping cover concrete on the inside wall and the floor of the suction pit during the current study period. The bar arrangement of the said floor is: main bars with 19 mm in diameter at 10 cm intervals and distribution bars with 13 mm in diameter at 20 cm intervals. The same at the said wall is: vertical bars with 10 mm in diameter at 10 cm intervals and horizontal ones with 10 mm in diameters at 20 cm intervals. No cracks have been developed in any of reinforced concrete members. A slight seepage were observed on the walls at lowermost part of a suction chamber during the study period. It is likely to increase when river water goes up. The river bank at both upstream and downstream sides of the pump house is protected by mortar stone masonry, whose condition is fairly good.

(2) Nur El Din Pumping Station

The pump house consists of a pump room with two partition walls built into the river bank and a building for placing three diesel engines. The floor slab of the pump room is concrete made, and most of other structures are of brick masonry. The floor elevation of the pump room is 8.15 m below the diesel engine floor. The walls of the pump room are made of brick masonry and becomes thicker stepwise towards the bottom, forming a sort of gravity type retaining walls. Many traces of seepage were observed on the walls especially on the river side wall durign the study period. Each partition wall of the pump room is made of brick masonry at its upper portion, while reinforced concrete at the lower portion. Round reinforcing bars with 9 mm in diameter are only horizontally arranged at a 30 cm interval in the brick walls of the pump room. The building is made of steel framed brick masonry walls and corrugated slate roof supported by steel frames. The river side wall of the pump room is covered by earth surfaced with dry stone masonry, however, considerable part of the stone masonry at center of the slope has been collapsed.

1.3.2 Dimensions

(1) Hurga Pumping Station

Since no drawings are available, the dimensions of the pump house have been measured during the current study period. Main features of the pump house is illustrated in Fig. 1.6. Deviations from a right dimension were observed at many members of the structure. This is probably attributed to improper form works for placing concrete. The dimensions of members under the ground have not been able to measure during the study period. Such invisible part of the structure are shown in the Fig. 1.6 by dotted lines, referring to the pump installation drawing. Particularly, thickness of the slab and substructure could not be obtained except very limited part.

The major dimensions of the pump house is summarized as follows:

Building	:	12.3 m x 20.3 m x 10.4 m (height)
Suction chambers	:	4.3 m to 4.0 m (width) x 4.5 m (length) x 15.5 m (height)
Entrance		
- Upstream side	:	4.0 m (width) x 4.0 m (height)
- Downstream side	:	3.6 m (width) x 4.0 m (height)
Intake structure	:	13.0 to 13.4 m (width) x 13.6 m (length)

(2) Nur El Din Pumping Station

Since no drawings are available for the Nur El Din pumping sation as well, dimension survey was carried out during the current study period. The outside dimensions of the substructure mostly could not be measured. Salient features of the pump house is shown in Fig. 1.7. Such outline was assumed based on secondhand information and shown by the broken line in the Fig. 1.7.

The major dimensions are as follows:

Building	:	10.9 m x 26.5 m x 7.9 m (height)
Pump room	:	7.0 m (width) x 5.1 m (length) x 8.5 m (height)
Entrance		
- Upstream side	:	1.0 m (width) x 2.0 m (height)
- Downstream side	:	2.9 m (width) x 3.0 m (height)

1.3.3 Non-destructive Test on Hardness of Concrete

Because of significant advantages of speed, cost and lack of damage in testing concrete, non-destructive testing methods are widely applied to both new and existing structures in many countries. For the new structures, it is principally used for quality control. As for the existing structures, it is usually employed for assessing structural adequacy.

In order to assess soundness and potential durability of the concrete members of the Hurga pump house, a non-destructive concrete test by means of Schmidt Hammer was carried out by the JICA Study Team in collaboration with an engineer of MOI. Details of the tests and results are given in APPENDIX-I.

Since most of the substructure situates under the ground, the tests on the substructure were limited to the part exposed to the open air such as the retaining wall of the intake structure, inside of walls of the suction pits front wall of the suction pits.

Avoiding spots of concrete surface with coarser particles of the aggregate, the tested spots of the concrete were selected to those with somewhat smoother surface than the others in general. The result of the tests, i.e., obtained as a scale of rebound number, therefore showed similar hardness in terms of compressive strength as shown in the following table.

Estimated Compressive Strength of Concrete (kg.f/cm^2)

Location	Strength			Direction
	Mean	Max.	Min.	
Footing of superstructure	215	302	158	Horizontal
Foot of column	261	307	212	Horizontal
Gear floor	141	151	125	Vertical
Suction chamber	160	192	82	Horizontal
Intake wall	176	222	153	Horizontal

The estimated mean compressive strength of the floor for the reduction gear was estimated at as low as 141 kg.f/cm^2, where the rebounding tests were applied in the vertical direction. Although this value is remarkably lower than those obtained at vertical surfaces, it is difficult to clarify the reason lying behind the difference between the gear floor and other surfaces without calibrating the test results by destructive tests using cores taken from the same spots. This probably resulted from either descipation of the impact energy at testing on the horizontal surface or some other reason such as misleading by calibration using correction factors for the direction. Accordingly, it would be appropriate to estimate the mean compressive strength of this structure at 191 kg.f/cm^2 eliminating the said peculiarly low value at the gear floor. This value appears to indicate sufficient hardness of the reinforced concrete members.

Due to the limitation of this test method that the tests provides a measure of the surface hardness of the concrete and that especially in case no calibration by destructive tests is conducted, the result of the tests should not be utilized for more than reference only. In case the Hurga pump house is determined to be utilized further through an alternative study of pumping station, which will be discussed in the subsequent Chapter II of this report, obtaining more reliable information on potential durability or structural integrity is prerequisite. Therefore, this test results should be complemented by destructive tests and another comparative non-destructive method of test in design stage of the Project.

1.3.4 Siltation on the Inlet Channel

The sediment load of the Blue Nile has deposited heavily from the intake to the suction chambers of the Hurga pumping station. The maximum height of the siltation reaches 2 m above the top of the inlet opening of the suction chamber. The inlet channel is totally deposited 3 to 4 m depth resulting in stagnating water in the suction chambers.

1.4 Electric Power and Fuel Supply

1.4.1 National Electric Power Supply

(1) National Energy Consumption

In 1988/1989, the total consumption of energy in Sudan was estimated at 1.82 million tons of petroleum; equivalent to around 70 kg per capita.

The biomass such as natural forest, animal and crop residues is the main source of energy and constitutes 82% of total energy consumption. The balance occupies 17% by petroleum and 1% by electricity. The forest in Southern Sudan is foreseen to be exhausted in 15 years if the present high deforestation continues. While the petroleum is fully dependent on import and expends 55% of total import value, which amounts to 60% of export earnings. The supply of petroleum encounters difficulty under the current unfavorable economic condition for Sudan and is rationed to the public. The gap between the demand and supply is estimated at 15 - 20%.

The electric power supply covers about 332,000 consumers and the total power generated was 1,231 GWh in the same. The suppressed demand is estimated at 25% of the total power generation.

(2) Existing Power Supply System

The power supply system in the Sudan is constructed and managed by National Electricity Corporation (NEC) under administration of the Ministry of Energy and Mining. The power supply system of NEC covers the central region with Blue Nile Grid System and part of the Eastern Region with Eastern Grid System. Both systems supply electricity to 332,000 consumers, of which 308,000 consumers in Central Region, i.e., Khartoum and cities/towns southward spreading over the Blue Nile area between Sennar and Khartoum. The total power generated in 1988/1989 was 1,231 GWh, of which 98% is consumed in Blue Nile Grid. The main trunk line of Blue Nile Grid is a double circuit, 220 KV transmission line connecting Kilo-X Substation in a suburb of Khartoum and Roseires hydropower station with the total route length of 436 km. The national power supply system of NEC and its single line diagram are as shown in Fig. 1.8 and Fig. 1.9 respectively.

(3) Existing Power Generating Plants and Conditions

At present, the total installed generating capacity of NEC is some 540 MW, of which 280 MW by hydropower mostly at Roseires power station (252 MW), and the balance by thermal in and around Khartoum. The actual generating capacity is lowered considerably less than the rated, and the maximum output ever recorded was 240 MW in June 1989. The constraint on power generation is mainly attributed to:

i) Deterioration of output of thermal plants due to super-annuation and insufficient maintenance resulted from the lack of spare parts; and

ii) Seasonal fluctuation of available head and discharge for hydropower generation at Roseires hydropower station.

The total power generation in 1988/1989 was 1,231 GWh, of which 795 GWh corresponding to 65% of total power was by Roseires power station. Roseires dam, having an effective storage volume of 2.39 milliard m^3 completed in 1966, was constructed to secure irrigation water supply during dry season at the upper reach of the Blue Nile.

The Blue Nile can be characterized by its high rate sediment transportation and fluctuation of discharge. The present siltation level of the reservoir reaches up to LWL 467.0 m and the efficient storage volume is reduced to 2.28 milliard m^3. To minimize further siltation in the reservoir, during the period of high flood in July and August no water is kept stored by discharging through under-sluice gates. As a consequence the available head for power generation is considerably reduced and this results in the decrease in power output of Roseires power station. In August 1988, the Roseires encountered a heavy flood and the generating operation was shut down due to no available head and plugging up power intakes with drifted trees. While the later period of the dry season; March to May, the reservoir water level went down and the discharge from power turbines was restricted to secure the irrigation water supply. In 1989, the restriction of discharge for power generation at Roseires was made from February. The full output of Roseires power station was consequently obtainable in a quite limited period during the end of the flood season. During March to August, referred to as "critical months", the power supply falls into serious shortage, and NEC is obliged to conduct severe load shedding and power cut. The load shedding conducted in 1988/1989 amounted to 68 GWh, of which 52 GWh in critical months and 43 GWh in July and August.

The monthly maximum power and energy produced in Blue Nile Grid between 1986/1987 and 1988/1989 is as shown in Table 1.3 and Fig. 1.10. As can be seen in these figures, the annual maximum occurred in June; relatively stable period of discharge condition of Blue Nile, while the minimum in August of 1988/1989 due to severe flood. The main features of existing generating plants are summarized in Table 1.4.

(4) Power Balance and Development Programme

The power demand of the Blue Nile Grid in 1988/1989 was estimated at 313 MW in peak and 1,646 GWh in total energy, while those produced was 240 MW and 1,231 GWh, respectively.

The suppressed demand is estimated at 25% of total power generation. The present serious shortage of power supply is attributable to the delay of implementation of power development program by the financing problem.

NEC is currently planning the Generation/Transmission Development Program, in which a demand growth rate is estimated at 7.5% per annum over 1997/1998. The annual energy and maximum power demands are set out as shown below:

Fiscal Year	Energy (GWh)	Max. Demand (MW)
1989/1990	1,876	362
1990/1991	2,022	390
1991/1992	2,177	420
1992/1993	2,343	452
1993/1994	2,522	487
1994/1995	2,716	524
1995/1996	2,923	565
1996/1997	3,147	608
1997/1998	3,388	655

For overcoming such a serious situation, NEC is promoting the extension works of the existing thermal plants, together with the feasibility studies on large scale developments of hydro power resources; Roseires dam heightening project and Merowe dam projects.

The present power supply situation is expected to be improved by the augmentation of steam turbines in Khartoum North Power Station. It is, however, hardly possible to make up completely the gap between the demand and supply capacity by the augmentation only. The constraint of power supply will drastically be solved if Merowe or the other large scale development projects be implemented.

(5) Electric Power Supply for Irrigation

At present, the Ministry of Irrigation (MOI) operates 19 electrical pumping stations including 3 pumping stations being under construction along the Blue Nile. The total installed capacity is 76 MW and unit output of pump motor ranges from 270 KW to 1,700 KW. The power system for these pumping station is 50 Hz, single phase 220 V and three - phase 415 V or 11 KV. A voltage of 6.6 KV/3.3 KV is not applied since it is not included in the voltage system of NEC.

The power supply for these pumping stations is secured by NEC policy giving the top priority to irrigation use, even in the present power supply situation.

(6) Tariff System

NEC tariff system is classified into six categories as mentioned below:

i) Residential use
ii) Commercial use up to 100 KVA
iii) Small firm use up to 100 KVA
iv) Industrial, Big Agricultural use and Bakeries above 100 KVA
v) Bulk supply for all use other than (iv) above 100 KVA
vi) Street lighting

In 1988, the total billed consumption was 1,096 GWh, of which 429 GWh corresponding to 39% of total consumption was used for categories (iii) and (iv) above, and 553 GWh for residential use. Reflecting the serious shortage of power supply, the tariff system for residential use is set at a high rate to discourage consumption to some extent, while at a low rate for productive sectors especially for (iv) sectors since the agriculture is the mainstay of the Sudanese economy. The tariff system for (iv) and (v) includes seasonal rate; for critical months (Mar. to Aug.) and other months, and time rates; for peak demand time (7:00 to 14:00 and 18:00 to 22:00 hours) and off-peak demand time. The tariff system applied for (iv) is shown in Table 1.5.

1.4.2 Present Power Supply Network in and around Project Area

(1) General

The Project and its surrounding area is one of the most substantially electrified area following to Khartoum with 1,254 km overhead distribution line, of which 133 km by 33 KV, 431 km by 11 KV and the balance by 415 V. In 1989, total consumers number 30,053 and mostly are on the left bank of the Blue Nile in and around Wad Medani. The power supply for these distribution lines are made from Meringan Substation and Hag Abdallah Substation.

(2) Distribution Line

The electric power supply is not available in Project area. The power supply available around the Project area are:

- Terminal of 33 KV distribution line at Shabarga village approximately 12 km north of the Project area.
  This line supplies electricity from Meringan Substation to Gezira Textiles and villages on the right bank.

- This distribution line crosses over the Blue Nile with high steel towers for 110 KV transmission line connecting between Meringan Substation and Fau Substation, and branches off in the right bank; one for Gezira Textiles and another for Shabarga village. The conductors are all bare aluminum (AAC) and the size is 397.5 MCM with a cross section of 185 mm^2 between Meringan and Gezira Textiles, and 70 mm^2 between branched point and Shabarga. A 110 KV transmission line also passes by Shabarga village en route from Meringan Substation and Fau Substation.

- The terminal of 33 KV distribution line fed from Hag Abdallah Substation at El Biryab pumping station (Private Scheme) on the left bank opposite to the Project area about 7 km south of the Project area. The conductors are all bar aluminum with 19 strand wires construction having sectional area of 185 mm^2.
  The routes and locations of the above distribution lines and substations are as shown in Fig. 1.11 schematic diagram of which is presented in Fig. 1.12.

The conductor formation of these 33 KV lines is triangle for both straight and tension lines without overhead ground wire i.e., two conductors on horizontal cross arm and one conductor on the top of the support. Supports are steel reinforced concrete poles having a rectangular section. The standard height of the pole is 10.97 m (36 ft.) and 9.14 m (30 ft.) . The standard span of the poles is approximately 80 m. These poles are manufactured by NEC Wad Medani factory. Typical layout of 33 KV distribution line is as shown in Fig. 1.13

(3) Meringan Substation

Meringan Substation is located at 8 km south of Wad Medani. The main incoming feeders are: i) 220 KV double circuit transmission line from Sennar Junction continuing to Kilo-X Substation, and ii) 110 KV single circuit transmission line from Hag Abdallah Substation. There are 6 stepdown transmformers as shown below :

- two (2) 215/110/11 KV - 40/40/15 MVA
- one (1) 110/33/11 KV - 17.5/10/10 MVA
  (this transformer was damaged by earth fault and not in service from Dec. 28, 1990)
- one (1) 110/33/11 KV - 7.5/5/3.5 MVA
- one (1) 110/11 KV - 15 MVA
- one (1) 110/11 KV - 7.5 MVA

There are 13 outgoing feeders in total; 2 feeders of 110 KV, 2 feeders of 33 kV and 9 feeders of 11 KV. The existing demand of each outgoing feeders is as summarized in Table 1.6. The figures listed in the table exclude suppressed demands especially in 11 KV outgoing feeders to Wad Medani. While the increases in demand of the following factory feeders are scheduled:

- 33 KV outgoing Feeder to Elananggil : from 4.5 MVA to 10 MVA
- 11 KV outgoing Feeder to Alhoudih Factory : from 3.5 MVA to 10 MVA

To cope with such suppressed and increasing demands the extension work providing second 110/33/11 KV- 17.5/10/10 MVA was planned and in progress aiming at commissioning in 1991. During that extension work, existing 110/33/11 KV - 17.5/10/10 MVA was damaged beyond repair by earth fault on December 28, 1990. To overcome this, NEC decided to provide one 110/33/11 KV - 35/20/20 MVA transformer instead of second 110/33/11 KV - 17.5/10/10 MVA.

(4) Hag Abdallah Substation

Hag Abdallah Substation is located at 40 km southward from Wad Medani. The main incoming feeders are 110 KV single circuit transmission line from Sennar Power Station continuing on to Meringan Substation. At present, there is no transformer, because one 110/33/11 kV - 17.5/10/10 MVA transformer provided in this substation was relocated to Meringan Substation for substituting for the damaged one at Meringan Substation in March 1990, and this substation receives power supply with 33 kV distribution line from Sennar. There are 2 - 33 KV outgoing feeders; one feeder to El Biryab Pumping Station and another to Hag Abdallah Spinning Factory. The total demand of both outgoing feeders is 6 MVA in terms of contract demand, while the maximum recorded is 2.3 MVA in October 1989. According to the information of NEC one 110/33/ 11 KV -17.5/10/10 MVA transformer is scheduled to be provided in 1991.

1.4.3 Fuel Supply Condition

(1) Existing Fuel Supply System

At present, the fuel supply of Sudan fully depends on import. The total consumption is estimated at 1.82 million tons in 1988/1989. The sectorial distribution is evaluated at 75% for house hold, 9% for transportation, 8% for industry, 4% for service, 3% for agriculture and 1% for others. Port Sudan on the Red Sea, approximately 1,100 km away from Khartoum in route distance, is the handling port for fuel imports.

Although an oil pipe line of 200 mm in diameter connects between Port Sudan and Khartoum in total length of 816 km, 80% of total transportation relies on road transportation; this is one of the major constraint on a stable fuel supply.

(2) Fuel Supply for Irrigation

At present, the Ministry of Irrigation (MOI) operates some 220 diesel pumping stations, of which 170 are on the White Nile, 40 on the Blue Nile and 8 in the Gezira Area. The total fuel consumption by these pumping stations is estimated at approximately 34,000 m^3 per annum. Although such annual amount is secured by the government policy of giving top priority to the irrigation sector, the fuel supply to distributors is unstable and sometimes falls into shortage due to delayed delivery. The fuel procurement of MOI is made through the distributors in Khartoum, or sometimes at Port Sudan, which depends on the availability of fuel at distributors. In addition access to these pumping stations makes it difficult to secure regular delivery of fuel. To cope with such conditions, 20 tankers ; 4-25 kl, 6-14 kl and 10-7 kl are in operation for procurement and delivery of fuel to the pumping stations.

(3) Fuel Price

The fuel price for diesel is set at £S 4.05/Gallon (£S 0.89/l) at government rate, and the ones billed by MOI to the distributors are as follows:

- £S 5.947/gallon (£S 1.308/l) at Khartoum as of Dec.16,1990
- £S 5.747/gallon (£S 1.264/l) at Port Sudan as of Aug.19,1990.

2. ALTERNATIVE STUDY ON PUMPING STATION

2.1 Conditions for the Alternative Study

(1) General

The purpose of this alternative study is to choose optimum rehabilitation plan for the Schemes, on which a feasibility level study will be carried out.

The alternative study covers prime movers, pumps and appurtenant facilities, and pump houses. All figures employed herein are tentatively determined only for alternative study purpose, and hence subject to change in the course of feasibility level study.

(2) River Water Level

Description	Hurga	Nur El Din	Integrated
Flood water level	402.5	402.8	402.8
High water level	398.1	398.2	398.1
Lowest low water level	389.0	389.5	389.0
Low water level	390.5	390.6	390.5
Monthly mean water level		See. Table 2.1	

(3) Water Requirement

Pumping water requirement is estimated based on cropping pattern shown in Fig. E.1.1 and crop water requirement thereof presented in Table E.1.5 of Annex E, Gezira Rehabilitation and Modernization Project I, June 1982. Pumping water requirement thus computed is shown in Table 2.2 in terms of m^3/sec for both cases of 24 hrs/day and 18 hrs/day pumping.

(4) Discharge Elevation

Description	Hurga	Nur El Din	Integrated
Discharge water level			
- W/O booster pump	411.5	412.5	412.8
- W/ booster pump	-	411.7	412.0

In case of Nur El Din scheme, a booster pump will be examined as an alternative plan because the service area slopes down gently from southeast toward northwest. In this alternative study, however, a plan without booster pump is employed.

(5) Pump Operation Hours

The peak operation hours are assumed to be 18 hrs according to the practices prevailing in the existing pump schemes in the Gezira area; 6 hrs pre-operation for filling water in the irrigation canals and succeeding 12 hrs for watering to the field between 6:00 am and 6:00 pm. Thus the operation time of pump is between 0:00 am and 6:00 pm, and this could avoid the evening peak demand of electricity between 6:00 pm and 10:00 pm.

2.2 Conceivable Plans

Aiming to formulation of optimum rehabilitation plan of the pumping station for the Project, preliminary comparative study is carried out on all conceivable alternative plans. The main factors composing alternative plans consist of: i) kind of prime mover of pumps; ii) type of pumps; and iii) pump house. The alternative plans conceivable for this Project are discussed hereunder.

(1) Prime mover

Kinds of prime mover conceivable are:

A1;	Existing diesel engines	:	to utilize existing diesel engines
A2;	Diesel driven	:	to replace existing diesel engines with new ones
A3;	Diesel- electric driven	:	to apply electric motors driven by diesel engine generators
A4;	Electrically driven	:	to apply electric motors with extending existing power distribution line of NEC

(2) Pumps

The pumps are classified into three types depending on the streamline inside the pump impeller, i.e., volute (centrifugal) type, mixed-flow type and axial-flow type pump. The axial-flow type pump is generally employed in case of the discharge head less than 4 m, and hence is not conceivable for the Project.

The remaining two types are further classified into vertical shaft and horizontal shaft types. In case of horizontal shaft pump, the prime mover is to be placed at the same level with the pumps unless gear units or belt/pulley is provided. This type is therefore applied in case pump setting level is free from inundation as a rule. In this Project, fluctuation of water level likely reaches to around 12 m, and it is impossible to install the prime mover 12 m above the pumps without gear unit or belt/pulley, which is not recommendable because of transmission loss and increase of maintenance requirement. The alternative plans conceivable for the Project are therefore:

B1; Vertical shaft volute pump
B2; Vertical shaft mixed-flow pump

(3) Pump Houses

C1; Existing pump house	:	to utilize existing pump houses with rehabilitation
C2; New pump house, individual	:	to construct new pump houses around the existing ones
C3; New pump house, integrated	:	to construct an integrated pump house

2.3 First Screening

Prior to proceeding to thorough comparative study including cost evaluation, promising alternative plans are chosen through first screening as mentioned below:

(1) Prime movers

A1; Discarded because this option dose not meet the required output for any options of pump.

A2; Proceed to further comparative study.

A3; Discarded because this option is apparently expensive compared with option A2.

A4; Proceed to cost comparison

(2) Pumps

In case option B2(vertical shaft mixed-flow pump) is adopted for option C1 (existing pump house), this combination requires; i) lowering the floor of existing suction chamber and inlet channel as well for the Hurga pump house, and ii) lowering the floor of existing pump rooms, provision of new inlet channel, modification of substructure from present pump room to suction chamber for the Nur El Din pump house. These modifications entail technical difficulty in implementation and call for obviously high rehabilitation costs compared with the other combination of B1+C1 (vertical shaft volute pump + existing pump house).

B1; Proceed to further comparative study in combination with option C1, C2 or C3.

B2; Discarded for the case of option C1.
Proceed to further comparative study in combination with option C2 or C3.

(3) Pump houses

C1; Proceed to further comparative study.

C2; Discarded due to high costs compared with option C1 or C3.

C3; Proceed to further comparative study.

Among three options above, option C2 (new individual pump houses) is discarded because it is apparently expensive compared with options C1 (existing pump house with rehabilitation) and C3 (new integrated pump house). Other than the above options, an option of integrated pumping station with expansion of either existing pump house was conceived. However, this option was discarded due to the reasons that:

i) Spaces of the existing suction chambers of the Hurga pump house are insufficient to accommodate volute type pumps with an integrated capacity ; and

ii) Use of the Nur El Din pump house for this purpose is not recommendable because suction head (about 5.5 m) is marginal at lowest low water stage.

(4) Alternative plans

Through the first screening discussed above, the following alternative plans are chosen for further comparative studies:

Alt-1d; A2+B1+C1 ;	New diesel engine driven vertical shaft volute pumps in each existing pump house.
Alt-2d; A2+B1+C3 ;	New diesel engine driven vertical shaft volute pumps in a new integrate pump house.
Alt-3d; A2+B2+C3 ;	New diesel engine driven vertical mixed-flow pumps in the new integrated pump house.
Alt-1e; A4+B1+C1 ;	New electrically driven vertical shaft volute pumps in each existing pump house.
Alt-2e; A4+B1+C3 ;	New electrically driven vertical shaft volute pumps in the new integrated pump house.
Alt-3e; A4+B2+C3 ;	New electrically driven mixed-flow pumps in new integrated pump house.

The suffixes "d" and "e" attached to the code of alternative plans symbolize the kind of prime mover employed in the alternative plans, i.e., "d" means diesel engine driven and "e" means electrically driven.

2.4 Comparative Study

2.4.1 Pumps

(1) Units of pumps

In general, less unit numbers with larger discharge capacity of pumps is economical compared with those more units numbers with smaller discharge capacity in respect of both initial and running costs so far as reliability of water supply is assured, which depends on:

i) available time for maintenance and/or repair of pumps; and

ii) coverage ratio of discharge capacity to water demand at a peak water requirement period in the event of unexpected mechanical failure of pumps.

It is the most likely option to provide a spare unit of pump for securing reliability of water supply. In the case of the alternative study, however, no provision of the spare unit of pump is considered due to the reasons that:

i) Water requirements of the Project largely fluctuate seasonally and required annual total operating hours are roughly estimated at around 3,300 hrs per pump unit corresponding to 38% plant factor. Assuming that required spare parts are secured at site any time, this plant factor seems to be low enough to appropriate for either maintenance or repair works.

ii) Since the discharge capacity of the pumps for the Project is determined based on 18 hrs/day operation, water supply capacity could be maintained at a certain extent against the peak water demand by extending operation hours to 24 hrs/day even in case one unit of pump falls inoperable. Supposing that two unit of pumps out of three are operational, a 89% (2/3 x 24/18) of water demand could be secured.

Proposed unit number of pumps for each alternative plan are thus determined to be:

- 3 units each for individual pumping stations; and
- 3 units for integrated pumping station.

(2) Salient features of tentatively proposed pumps

Description	Hurga	Nur El Din	Integrated	
Type of pump	B1*	B1	B1	B2**
Design head (m)	21.0	21.5	22.0	22.0
Rated discharge (m^3/min/set)	100	65	160	160
Q'ty of pump (set)	3	3	3	3
Dia. of pump (mm)	900 x 700	700 x 600	1,000 x 800	1,100
Required output (kW/set)	500	350	800	800
(PS/set)	700	500	1,200	1,200

* ; vertical shaft double suction volute pump
**; vertical shaft mixed-flow pump

2.4.2 Electric Power Supply System

(1) Source of Electric Power Supply

Taking into account the present electric power supply system of National Electricity Corporation (NEC) around the Project area discussed in the previous subchapter 1.4 Survey on Electric Power Supply and Fuel Supply and shown in Fig. 2.1, the following two options are conceived as source of electric power supply for the Project:

Case-1 : Extending from 33 kV line terminal at Shabarga village fed from Meringan Substation

Case-2 : Extending from 33 kV line terminal at El Biryab Pump Station fed from Hag Abdallah Substation

Case-2 includes the construction of high steel tower to cross over the Blue Nile at Rabwa village located just downstream of confluence of the Dinder river. The span of high steel tower is some 350 m, and its height is approximately 25 m. The total extension distance of the distribution line is: i) 10.5 km in the case of Alt-1e, and ii) 9.5 km in the cases of Alt-2e and -3e.

Case-1 requires the distribution line of: i) 14.0 km in the case of Alt-1e, and ii) 13.0 km in the cases of Alt-2e and -3e.

According to the information of NEC, future peak demand of 33 kV outgoing feeders of the Meringan Substation is expected to increase from present 9.9 MVA to 20 MVA immediately after present supply capacity of 5.0 MVA is augmented to 20 MVA by extension work of 110/33/11 kV - 35/20/20 MVA transformer.

Considering the above, Case-2 is taken up as the source of electric power supply.

(2) Salient Features of Tentatively Proposed Electric Power Supply System

The following are the tentatively proposed electric power supply system for the pumping station of the Project.

Description	Hurga	Nur El Din	Integrated
a) Distribution line, 33 kV	95 mm^2 x	10.5 km	95 mm^2 x 9.5 km
b) Substation equipment			
- Switchgear, 33 kV	1 lot	1 lot	1 lot
- Main transformer	33/3 kV 2,000 kVA	33/3 kV 1,500 kVA	33/3 kV 3,000 kVA
- Cubicle, 3.3 kV (set)	6	6	6
- Control panel (set)	3	3	3
- Service transformer (set)	1	1	1
- AC-DC panel (set)	1	1	1
- Battery and charger (set)	1	1	1

2.4.3 Rehabilitation Plan of the Existing Pump House

(1) Basic Concepts of Rehabilitation Plan

The following are basic concepts for formulating rehabilitation plan of the existing pump houses for alternative study purpose.

a) To meet present river condition; i.e., originally designed lowest low water level should be lowered to some 2 m to meet recent degradation of the Blue Nile.

b) To minimize additional load against foundation of sub- structure.

c) To protect the electrical facilities from dust.

d) To maximize reliability of the structure.

(2) Hurga Pump House

Rehabilitation plan will be made for the case of volute pumps.

a) Motor floor

Case-M1; Utilize the existing floor without rehabilitation
Case-M2; Demolish the existing floor
Case-M3; Replace the existing floor with new one to meet new pumps

Case	Advantages/disadvantages and Selection
M1	- Hardly possible to use present opening for new pumps. - This plan is discarded.
M2	- Motor should be placed in the dry wells (pits). - This plan entails expansion of present space for pumps. - This plan is not recommendable.
M3	- Costly compared with M1 and M2, but superior to M1 and M2. - This plan is selected.

b) Wet wells (Suction chamber) to dry well (Pump room)

Case-W1; Utilization of the existing front curtain wall with closure of the inlet opening and reinforcement.

Case-W2; Demolish the existing front curtain wall and provision of new wall at about one meter ahead of the present position.

Case	Advantages/disadvantages and Selection
W1	- Pump rooms is not wide enough to install new pumps. - Not sure if the wall is safe against water pressure after the wet wells become dry because the existing wall might be constructed as pressure free.
W2	- Pump room could be extended to meet required space for new pumps. - The wall could be designed to be safe against water pressure. - Load increase could be minimized. - Costly compared with the above case. - This plan should be selected.

Thus the rehabilitation plan for the Hurga pump house consists of:

- Replacement of the existing motor floor;
- Replacement of the existing front curtain wall; and
- Replacement of the existing building including overhead crane.
- Grouting for reinforcing foundation in case foundation of the substructure is of sandy soil.
- Reinforcement of foundation, which is subject to results of detailed investigations on the foundation structure and underlying ground in due course.

General layout of the preliminary rehabilitation plan is shown in Fig. 2.2.

(3) Nur El Din pump house

Since volute type pumps are presently installed in the dry wells and the same type is proposed in this study, comparative study for rehabilitation of the Nur El Din is geared toward :

- motor floor; and
- civil works entailed by replacement of suction pipes.

a) Motor floor

Case-M1; provision of new motor floor
Case-M2; provision of no motor floor

Case	Advantages/disadvantages and Selection
M1	- Increase of load by floor. - Careful construction will be required to joint the new floor with existing brick wall of the dry well.
M2	- Motors are obliged to be placed in the dry wells. This should be avoided because originally the dry wells were not constructed to do so, and hence this concept should be followed by rehabilitation plan. Not recommendable.

b) Civil work entailed by replacement of suction pipes

Case-C1; demolishing entire river side wall of the dry well and restoring same type wall after installation of new pipes

Case-C2; demolishing around the existing suction pipes and refilling the gaps after installation of new pipes

Case	Advantages/disadvantages and Selection
C1	- Costly compared with C2. - Safety against leakage from this wall would be secured. - Implementation would be easier than C2.
C2	- Care would be required when demolishing so that secondary damage is not given to the remaining part of the wall. - Care would be required when refilling so as to secure safety against water leakage. - A protection work would be needed against possibility of leakage from the remaining part of the wall.

It should be noted that:

- It is hardly possible to estimate degradation of quality of bricks by the lapse of time, and it is also hardly possible to assure further durability of bricks in the remaining part of the existing sub-structure;
- A protection work against possibility of leakage would be needed in both cases for the other three sides of the dry wells.

Proposed rehabilitation plan consists mainly of:

- Provision of motor floor;
- Replacement of the existing building including overhead crane;
- Restoration of the river side brick wall of the pump room;
- Provision of protection work against leakage; and
- Provision of the slope protection after backfillling the outside of the said brick wall.

General layout of the preliminary rehabilitation plan is shown in Fig. 2.3.

2.4.4 Plan of New Integrated Pumping Station

(1) Site Selection

The proposed site of the integrated pumping station is located at about 700 m upstream of the existing Hurga pumping station and 1,500 m downstream of the Nur El Din pumping station on the right bank of the Blue Nile.

This proposed site is judged most suitable for construction of the pumping station taking topographical, geological and river conditions into account. Low flow channel at the proposed site seems to be quite stable as lower portion of the right bank consists of stiff clay. The river conditions at the proposed site are:

- forming concave bank;
- stable water route running along the right bank;
- less possibility of river bed change and bank erosion;
- graded stream portion; and
- neither sediment nor sand bar both upstream and downstream.

(2) Pump House

As discussed previously two options, i.e. vertical mixed flow pumps and double suction volute pumps, are considered for alternative study purpose. Therefore, pump house is also examined for both type of pumps.

The foundation of the proposed site is assumed to be stiff clay or underlying stratum where the allowable bearing capacity is estimated at about 19 to 35 tons/m^2. The superstructure is designed so as to protect electrical equipment and facilities from dust and to maintain appropriate ambient temperature. A simple and solid structure is considered to avoid frequent repair works and to expect simple maintenance works.

The pump house for vertical volute type pumps consists of a reinforced concrete dry well (pump room) built into river bank and reinforced concrete pump shed. Suction pipes are extended to the river and hence no suction chamber is provided.

The pump house for mixed flow pumps is composed of three reinforced concrete suction chambers built into the river bank and a reinforced concrete pump shed. A slide gate is provided for each of suction chamber for the purposes of maintenance and emergency repair of pumps. Inlet basin surfaced by concrete lining is provided. A berm is provided on an inside slope for the sake of removing sediment by heavy equipment.

2.5 Cost Estimate for Comparative Study

2.5.1 Conditions and Assumptions

The construction costs of alternative plans consist of those for electric power supply system, pumps and appurtenant structures and construction/rehabilitation of pump house including link canal in case of the option of integrated pumping station.

The construction cost for pumping equipment and appurtenant facilities including electrical equipment is roughly estimated refering to the costs of past similar projects. While the construction cost for civil works is estimated only for major work items based on the preliminary layout which was prepared only for the alternative study purpose with unit costs prevailing in Sudan.

Basic conditions of the cost estimate are as follow:

i) Price level; December 1990;

ii) All costs are presented in £S equivalent with a currency exchange rate of; £S 4.5 = US$1.00 = J.Yen 130

iii) Materials and equipment to be imported;
- pumps and appurtenant equipment,
- electrical control and substation equipment,
- materials for 33 kV distribution line,
- steel materials, cement, concrete forms, and metals.

iv) Import tax and duty on the imported materials and equipment are not included;

v) Price and physical contingencies are not included;

vi) Operation and maintenance costs comprise energy consumption costs and replacement costs;

vii) Electric power consumption cost is based on NEC tariff;
- Power rate in critical months (March through August)
  £S 0.59/kWH (average of peak and off-peak rate)
- Power rate in other months
  £S 0.27/kWH (average of peak and off-peak rate)

viii) Fuel consumption cost for diesel; £S 5.947/gallon;

ix) Replacement cost;

- Civil and architectural structures; 50 years
- Pumping and appurtenant equipment; 25 years
- Electrical controls and motors ; 25 years
- 33 kV distribution line and substation equipment; 25 years
- Diesel engine; 15 years

2.5.2 Cost Comparison for Prime Mover

The six alternative plans worked out through the first screening are classified into two groups in respect of prime movers since difference between Alt-1d and -1e (Alt-2d and -2e; Alt-3d and -3e) is only their prime mover as stated previously and recapitulated below:

- Diesel engine ; Alt-1d, -2d, and -3d
- Electric motor ; Alt-1e, -2e, and -3e

If cost comparison between diesel prime mover and electrical one is made and economical option for prime mover is selected in advance, consequent cost comparison could be made among three alternative plans with either prime mover. Therefore, costs for those two options are estimated and compared in terms of present value (PV) as summarized below. Electrical prime mover is selected as the preferable option as a result.

Summary of Cost Comparison, PV

(Unit; £S x 10^6)

		Electric Motor	Diesel Engine
Alt-1	- Initial cost	18.8	11.3
	- Annual cost	14.3	34.9
	Total	33.1	46.2
Alt-2	- Initial cost	13.3	11.5
	- Annual cost	14.6	35.0
	Total	27.9	46.5
Alt-3	- Initial cost	14.1	11.5
	- Annual cost	14.6	35.0
	Total	28.7	46.5

The conditions and assumptions employed in this cost comparison are as follows:

i) Initial cost covers the costs of equipment related to prime mover only.

Electrical prime mover option ; motors, electrical control equipment, substation equipment and 33 kV distribution line.

Diesel prime mover option ; Diesel engines and gear units

ii) Annual costs covers the energy consumption costs and replacement costs.

iii) A discount rate of 10 % is employed to convert annual cost for 50 years into present value (PV).

2.5.3 Cost Estimate for Alternative Plan

The construction costs and annual operation costs including replacement costs for Alt-1e, -2e and -3e are estimated based on the conditions and assumptions discussed previously.

a) Construction Costs

Figs. 2.4, 2.5 and 2.6 show the preliminary layouts of each alternative plan, which is used for cost estimation.

The construction costs for each alternative plan is summarized as follows:

(Unit; £S x 10^6)

Work Items	Alt-1e	Alt-2e	Alt-3e
Civil works	14.9	25.4	27.6
Pump & Electrical Equipment	33.6	23.6	24.1
Total	48.5	49.0	51.7

The breakdown of the above are shown in Table 2.3.

b) Annual Power Consumption Costs

The annual electric power consumption costs of each alternative plan are:

- Alt-1e ; £S 1,437 x 1,000
- Alt-2e & -3e ; £S 1,471 x 1,000

c) Replacement Costs

The replacement costs of equipment is estimated based on the economic life stated previously.

2.6 Conclusion

2.6.1 Evaluation of Alternative Plans

(1) Cost Evaluation

Cost comparison among Alt-1e, -2e and -3e is made in terms of PV as summarized below:

Present value

(Unit; £S x 10^6)

Work Items	Alt-1e	Alt-2e	Alt-3e
Initial cost	48.5	49.0	51.7
Annual cost	14.3	14.6	14.6
Total PV	62.8	63.6	66.3

(2) Technical Feasibility of each Plan

Technical advantages and disadvantages are enumerated for each of alternative plans hereunder:

i) Alt-1e

- This plan involves uncertainties to some extent on structural strength and durability of existing concrete and brick works where left intact.
- Workability in demolishing and restoration is less than new construction works. Close attention is required in preparation of work schedule as well as in construction.
- Suction head of Nur El Din pumps is marginal at lowest water stage.
- No desilting work is needed at intake.
- The pumps employed in this plan require priming of pumps during low water stage, which is estimated to last 4 months from November through February for Nur El Din P/S.
- Unit number of pumps is double of the other alternative plans, and different sizes of pumps, motor and appurtenant equipment are needed between Hurga and Nur El Din P/Ss. This entails inconvenient operation and maintenance works compared with other alternative plans.
- During the construction period, certain negative benefit of crops in the Project area could be expected due to stoppage of irrigation water supply.

ii) Alt-2e

- Suction pipes are placed above designed low water level and hence construction under wet condition could be minimized. This would give a free hand to a certain extent in preparation of construction schedule compared with the other alternative plans.
- Desilting work is not needed at intake, but needed in delivery channels.

- The pumps employed in this plan require priming of pumps during low water stage, which is estimated to last 4 months from November through February.

iii) Alt-3e

- No priming of pumps is needed.
- Periodical desilting is required at inlet channel.

2.6.2 Preferable Alternative Plan

The result of cost evaluation indicates that negligible difference is recognized between Alt-1e and -2e, and that total PV of Alt-3e is highest but the difference between the highest and the lowest one is as small as 5%.

Alt-1e would impose some 700 numbers of the tenants who presently rely on water supply by the existing pumps to raise sorghum under rainfed condition during the implementation period.

Existing pumping stations with the same type with Alt-3e suffer from a heavy siltation at the inlet channel. Such unfavorable experiences suggest that priming operation of pumps seems to be better choice than periodical desilting at inlet channel.

From both economical and technical points of views, therefore, Atl-2e is considered to be the most preferable option among the three for the Project.

3. BASIC DESIGN

3.1 General Condition

In the preceding alternative study, the main frameworks of the most preferable rehabilitation plan of the pumping station are formulated as summarized below:

- Pump house	:	integrated new pump house at about 700 m upstream of the existing Hurga Pumping Station
- Prime mover of pump	:	electric motor with extending the existing 33 kV distribution line of NEC
- Pump type	:	vertical shaft double suction volute pump

This section describes the further detailed study for the preliminary design of pumping station and power supply based on the definite design data and conditions.

3.2 Basic Design of Pumping Station

3.2.1 Design Conditions

The design conditions for the basic design of pumping station are as follows:

(1) River Water Level

- Flood water level (100-year probable)	:	EL. 402.11
- High water level	:	EL. 398.64
- Low water level	:	EL. 391.02
- Lowest low water level	:	EL. 389.02
- Monthly mean water level	:	See Table 3.1

It is to be noted that these water levels are those which have been adjusted to meet the arbitrary bench mark employed for the topographic map of the Project area. More concretely, the elevations derived from the Sudanese Standard datum, so called Irrigation Datum, were lowered by about 80 cm, on which detailed discussion is made in ANNEX-A; TOPOGAPHY AND GEOLOGY.

(2) Water Requirement

Pumping water requirement in terms of m^3/sec is shown in Table 3.1 and Fig. 3.1 for the pumping operation of 18 hrs per day.

(3) Discharge Water Elevation

Without booster pumping station	:	EL. 413.30
With booster pumping station	:	EL. 412.50

3.2.2 Basic Design Concept

(1) General

The following outline the basic design concepts for the preliminary design of pumping station and include:

- Booster pumping station,
- Spare pump unit,
- Numbers of pump unit,
- Type of pump,
- Setting elevation of pump and motor,
- Piping works, and
- Valves.

(2) Booster Pumping Station

As referred in previous alternative study, a booster pump is conceived as an alternative plan for Nur El Din Scheme. This alternative plan is discarded finally due to the reasons that:

i) The static head difference of intake pump between "with" and "without" booster pumping stations is as small as 0.8 m against the maximum pump head of 24.28 m, and hence;

   - the construction cost of intake pumping station is almost the same for both alternatives, while "with" booster plan involves the additional construction costs of booster pumping station and branching power distribution line of approximately 2 km in length.

   - the benefit of energy consumption cost by introducing booster pump is marginal compared with "without" booster plan.

ii) The plan "with" booster entails inconvenient operation and maintenance works.

(3) Spare Pump Unit

The provision of spare pump is not included in the previous alternative study considering the available time for maintenance and repair of pump, and the high coverage ratio of water supply capacity by extending operation hours of pump to 24 hrs/day in the event of unexpected failure of pumps.

One spare pump unit is, however, proposed for the Project from the following view points:

i) The peak water requirement fall in June, July and August, which correspond to "critical month" of electric power supply. In such critical month, 24 hrs' operation of pump is not necessarily secured due to unstable power supply condition.

ii) It would take rather longer time for procurement of spare parts.

(4) Unit Number of Pump

In the preceding alternative study, the rehabilitation plan was examined for three pump units without spare pump units. In case of three pump units, the total installed capacity of pump becomes 150% of the required capacity if one pump unit is alotted for spare pump. This seems that a ratio of installed capacity for the spare pump to the required one is so big as to entail the high construction cost.

To select optimum unit numbers of pump, the following two (2) cases are considered:

Case 1 : four pump units including one spare pump
Case 2 : five pump units including one spare pump

The construction costs of pumping equipment for both cases are as follows:

Case 1 : £S 89.5 x 10^6
Case 2 : £S 87.6 x 10^6

As seen above, no difference is recognized between two cases. The construction cost of civil structures for Case 2 is apparently higher than Case 1 to accommodate more pump units, and Case 1 has an advantage on the total construction cost.

In the Project, minor canals are designed to have a function to store the balance of inflow to and outflow from the minor canal. This storage capacity enables the simple discharge control by operation numbers and hours of pump for both cases, and either distinctive advantage or disadvantage is not found between two cases in operation.

Case 1 is selected as an optimum plan from both economical and technical view points.

(5) Type of Pump

The volute type pump is structurally classified into two (2) types, i.e., single suction type and double suction type. The single suction type volute pump is simple in the constructions and mainly applied for small and medium discharge capacity. This type can be applied for both the negative and positive suction conditions, but generally positioned in positive suction condition for medium discharge capacity due to less suction performance.

The double suction type volute pump is generally compact in size compared with the single suction type and applied for medium and large discharge capacity. This type has a superior suction performance and generally used in negative suction condition with priming equipment. Since the pumps are designed to be placed above low water level, and it calls for pump operation under negative suction condition for a certain period of a year, the double suction type volute pump is proposed for the Project.

(6) Setting Elevation of Pump and Motor

The setting level of the pump is planed to be above low water level to minimize the construction works under wet condition, and overall construction cost of pumping station consequently. The setting elevation of the pump is at EL. 391.5 m so as to avoid breaking out of cavitation phenomena at the lowest low water level of EL. 389.02. The elevation of motor is set at EL. 402.5 m so as to have sufficient freeboard against a 100-year probable flood.

(7) Piping Works

The proposed piping works for the pump is composed of:

i) horizontal suction pipes for each pump unit,
ii) vertical discharge pipes within pump house, and
iii) one discharge pipeline with a manifold type confluence pipe.

As an alternative plan for (ii) above, an arrangement of the inclined discharge pipes connecting between pumps and manifold type confluence pipe shown in Fig. 3.2 is conceivable. This alternative plan could reduce the hydraulic head losses by about 0.5 m in bend pipes. This is, however, discarded due to the reasons that:

- The construction works of pump house including backfilling works could be completed prior to the arrival of piping materials in case of vertical pipes arrangement. On the other hand, the alternative plan requires longer construction period because backfilling works of the pump house should be made after installation of the inclined pipes, and it is hardly possible to conduct inspection and maintenance of the buried pipes;
- To avoid such inconvenience for inspection and maintenance, it is conceivable that inclined discharge pipes (the alternative plan) are installed in the pumphouse. This plan, however, entails higher construction costs of civil works than those for the proposed plan;
- The pipes could be designed and manufactured to withstand both the internal and negative pressures; and
- Difference of running costs between the proposed and alternative plans to be caused by difference in said hydraulic head is negligible.

An integrated discharge pipeline with manifold type confluence pipe is applied to reduce the construction cost of piping works.

Any screen or trashrack would not be provided at the inlet of suction pipes since the damage of pump and valves by trash is not likely to occur judging from the following points:

- the substance injurious to pumps and valves such as hard broken piece of trees having 40 mm or more in size is expected to be negligible in low water level condition due to the natural environmental condition around the Project area, and
- the submerged depth of suction pipes is deep enough to avoid sucking injurious floating trash into pumps in high water level condition.

(8) Valves

For the operation and maintenance of pumping equipment, the following valves would be provided for each pump unit:

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

As the discharge pipes of all pump units would be combined into one with the manifold pipe, a check valve would be provided at the discharge outlet of each pump unit to prevent reverse flow to the rest pump unit.

The sluice valve and butterfly valve would be provided for the purpose of maintaining each pump unit without stopping the other pump unit. The butterfly valve would be positioned at just downstream of check valve to minimize the required time for priming of pump. The butterfly valve would also be used to keep the discharge of pump within the design capacity of main canal during high river water level in August and September.

3.2.3 Basic Design

(1) Pumping Equipment

The basic design of pumping equipment is worked out in accordance with the design concepts mentioned above. The general layout of proposed pumping station is shown in Fig. 3.3. The main features of pumping equipment are as summarized hereunder and as in detail in Table 3.2.

- Type of pump : vertical shaft double suction volute pump
- Rated discharge per unit : 2.4 m^3/sec
- Rated design head : 24 m
- Diameter of pump : 1,000 mm x 800 mm
- Number of pump unit : 4 sets
- Motor output : 750 kW

The expected characteristic curve of pump and the system curve for pump operation are shown on Fig. 3.4 and Fig. 3.5 , respectively. The system curve for pump operation is prepared based on the characteristic curve of pump, and head loss calculation is tabulated in Table 3.3.

(2) Pumping Station

The pump house consists of pump room in base structure and motor room, cubicle room and erection bay in superstructures. The base structure is water-proof construction made of reinforced concrete. The superstructure is dust-proof construction made of reinforced concrete framed brick masonry walls. The foundation load of pump house is estimated at around 15 tf/m^2 and mat foundation is applied for the house.

3.3 Electric Power Supply System

(1) General

Electric power required for the Project would be supplied from the existing Hag Abdullah substation at 33 kV, through the existing 33 kV distribution from Hag Abdullah substation to El Biryab. To receive power, 33 kV distribution line would be extended in 9.5 km long from El Biryab to pumping station site. A conventional 33 kV outdoor switchyard would be constructed with 3,000 kVA main transformer near by pump house. Secondary voltage of the transformer would be adopted at 11 kV to be directly connected to the pump motors. A single line diagrams of the pump substation is illustrated in Fig. 3.6.

(2) Design of Electrical Equipment

The main features of electrical equipment are as follows:

a) Transformer

One (1) set of 3,000 kVA transformer would be installed in the outdoor switchyard. The transformer would be of 3-phase, oil immersed, natural air cooling, outdoor use type. The voltage ratio of the transformer is selected at the no load ratio of 33/11 kV.

The transformer winding would be connected in star-delta, vector symbol Yd1 (IEC Pub. 76, 1967) and the neutral point of the 33 kV windings would be grounded solidly.

b) 33 kV switchgear

The following major equipment would be installed for 33 kV outdoor switchgear.

Circuit breaker: One (1) set of circuit breaker for 33 kV incoming feeder would be of three-phase, high speed tripping and vacuum type.

Disconnecting switch: One (1) set of disconnecting switch for 33 kV incoming feeder would be of three-phase, single-throw, outdoor and hand operated type and provided with manually operated earthing device.

Lightning Arrester: Three (3) lightning arresters would be placed at 33 kV incoming feeder to protect switchgear equipment and transformer from lightning or other surge phenomena.

Potential devices and current transformer: Three potential devices and three current transformers would be installed for requirement of measurement and protection.

c) 11 kV switchgear

11 kV circuits for main pump motors and station service transformer would be arranged in self-supporting indoor type metal-clad cubicle and installed in the cubicle room.

d) Control boards and others

Control of the pumping equipment together with the substation facilities would be made by the control boards to be installed in the control room of the pump house. The control boards will be of vertical, self-standing and steel sheet panels.

(3) 33 kV Distribution Line

A 33 kV distribution line will be constructed to supply electric power to the pumping station. The power would be transmitted through the existing 33 kV line between Hag Abdullah substation and El Biryab, and the 33 kV distribution line to be constructed under this project from El Biryab to pumping station. The design of the 33 kV distribution line is mentioned hereunder:

a) Outline

The following are outline of the main features of the distribution line obtained as results of the engineering studies.

Voltage	:	33 kV
No. of circuit	:	Single circuit
Route length	:	Approx. 9.5 km
Support		
For river crossing	:	Galvanized steel structures of single circuit
For over-land	:	Pre-cast concrete poles of single circuit
Conductor	:	Aluminium Conductor Steel Reinforced, 95 mm^2

Insulators

Suspension set	:	Solid-core porcelain post insulator
Tension set	:	254 mm porcelain disc insulators of ball and socket type

b) Route selection

The route of 33 kV distribution line would start from El Birgab pumping station which is located at left bank of the Blue Nile. After few hundred meters the route would turn to the right to cross over the Blue Nile river of approx. 300 m wide where steel towers would be adopted. Then the route would run toward North on the right bank of the Blue Nile up to the pumping station. Total length of line is approximately 9.5 km.

c) Conductor

Though AAC conductors (All Aluminium Conductor) are normally used for 33 kV distribution line system of NEC, Aluminium Conductor Steel Reinforced (ACSR) is selected for river crossing section because higher tensile strength in conductor has to be required to obtain enough clearance of conductor above flood water level in such long span. Size of conductor is selected as 95 mm^2 which would secure voltage drop at pumping station within 5%.

d) Support

Pre-cast concrete pole would be employed in over-land section, which would be manufactured at site. For this purpose the necessary quantities of cement and steel reinforcing bars shall be imported. For river crossing section, the self-supporting, galvanized steel towers with the sufficient height would be constructed.

TABLES

Table 1.1 (1/4) SPECIFICATIONS OF EXISTING PUMPING EQUIPMENT AND APPURTENANT FACILITIES

1. HURGA PUMP STATION

1. Pump

Type of pump	: vertical shaft single-stage mixed-flow pump.
Diameter of pump	: 800 mm
Rated head	: 20.5 m
Rated discharge	: 90 cu. m/min.
Length of pump	: 15.925 m
Revolution speed	: 600 rpm.
Specific speed	: 591 (m-min.)
Shaft power	: 360 KW (490 P.S)
Quantity	: three (3) Sets
Manufacturer	: Ruhrpumpen G.m.b.H, Witten - Annen

2. Diesel Engine

Type	: horizontal shaft 4-cycle single-acting vertical cylinder
Rated output	: 600 P.S
Speed	: 500 rpm.
Number of cylinder	: 8 Nos.
Cylinder bore	: 280 mm
Cylinder stroke	: 400 mm
Starting system	: by compressed air
Cooling system	: forced water cooling with heat exchanger
Quantity	: three (3) sets
Manufacturer	: Bohn & Kehler

3. Gear Unit

Type	: vertical-axis single stage bevel gear
Increasing ratio	: 1: 1.2875 (32 : 39)
Cooling system	: raw water from pump
Quantity	: three (3) sets
Manufacturer	: Flender

4. Discharge Pipe

Type	: concrete saddle supported, welded steel pipes with flange joint
Diameter	: 800 mm
Length	: Ca. 57 m
Quantity	: three (3) lanes

5. Overhead Crane

Type	: manually operated, double girder type geared chain hoist
Hoisting capacity	: 10 tf
Span	: 11.55 m
Lift	: 6.8 m from diesel engine floor
Stroke	: 8.085 m
Quantity	: one (1) set

Table 1.1(2/4) SPECIFICATIONS OF EXISTING PUMPING EQUIPMENT AND APPURTENANT FACILITIES

6. Fuel Oil Tank

Type	: outdoor, riveted steel tank
Diameter	: 7.63 m
Height	: 5.17 m
Volume	: Ca. 200 kl
Shell plate thickness	: 6 mm

7. Discharge Valve

Type	: inside screw type manually operated sluice valve
Diameter	: 800 mm
Sealing	: double sides metal touch sealing
Quantity	: three (3) sets

8. Outlet Valve

Type	: single leaf upper hinged flap valve
Diameter	: 1,000 mm
Sealing	: metal-touch seal
Quantity	: three (3) sets

Table 1.1 (3/4) SPECIFICATIONS OF EXISTING PUMPING EQUIPMENT AND APPURTENANT FACILITIES

II. NUR EL DIN PUMP STATION

1. Pump

Type of pump	: horizontal shaft single-stage mixed-flow volute
Diameter of pump	: 600 mm
Rated head	: 21.03 m (69 ft)
Rated discharge	: 60.0 cu.m/min (13,200gal/min.)
Revolution speed	: 800 rpm.
Specific speed	: 631 (m-min.)
Shaft power	: 255 KW (342 H.P)
Quantity	: three (3) Sets
Manufacturer	: Ruhrpumpen G.m.b.H, Witten - Annen

2. Diesel Engine

Type	: horizontal shaft 4-cycle single-acting vertical cylinder
Rated output	: 450 P.S
Speed	: 500 rpm.
Number of cylinder	: 6 Nos.
Cylinder bore	: 280 mm
Cylinder stroke	: 400 mm
Starting system	: by compressed air
Cooling system	: forced water cooling with heat exchanger
Quantity	: three (3) sets
Manufacturer	: Bohn & Kehler

3. Power Transmission Unit

Type	: plain belt pulley Increasing ratio:1:1.549 (dia of pulley: drive 1,100 mm, pump 710 mm)
Quantity	: three (3) sets

4. Discharge Pipe

Type	: Concrete saddle supported, welded steel pipes
Diameter	: 700 mm
Length	: Ca. 45 m
Quantity	: three (3) lanes

5. Overhead Crane

Type	: manually operated, double girder type geared
Hoisting capacity	: 10 tf
Span	: 11.55 m
Lift	: 5.0 m from diesel Engine floor
Stroke	: 8.65 m
Quantity	: one (1) set

Table 1.1 (4/4) SPECIFICATIONS OF EXISTING PUMPING EQUIPMENT AND APPURTENANT FACILITIES

6. Fuel Oil Tank

Type	: welded steel tank
Diameter	: 7.00 m
Height	: 8.6 m
Volume	: Ca. 300 kl
Shell plate thickness	: not measured

7. Discharge Valve

Type	: outside screw type manually operated sluice valve
Diameter	: 600 mm
Sealing	: double sides metal touch sealing
Quantity	: three (3) sets

8. Outlet Valve

Type	: single leaf upper hinged flap valve
Diameter	: 700 mm
Sealing	: metal-touch seal
Quantity	: three (3) sets

9. Suction Valve

Type	: inside screw type manually operated sluice valve
Diameter	: 600 mm
Quantity	: three (3) sets

Table 1.2 OPERATION RECORD OF HURGA AND NUR EL DIN PUMPING STATION

		HURUGA				NUR EL DIN			
Year	Month	Operation Hour (hrs)	Fuel Consumption (l)	Lub. Oil Consumption (l)	No. of Pump operated (set)	Operation Hour (hrs)	Fuel Consumption (l)	Lub. Oil Consumption (l)	No. of Pump operated (set)
1980	Jul	289	26,279	400	2	567	38,668	727	2
	Aug	350	31,826	-	2	420	28,643	546	2
	Sept	608	55,285	200	2	450	30,689	500	2
	Oct	-	-	-	-	225	15,344	477	2
1981	Jun	18	3,276	400	2	-	-	-	-
	Jul	614	55,831	800	2	150	10,230	546	2
	Aug	788	71,653	400	2	460	31,371	682	2
	Sept	506	46,011	800	2	240	16,367	637	2
	Oct	884	80,382	459	2	460	31,371	727	2
1982	Jul	68	6,183	-	2	732	49,602	746	2
	Aug	537	48,829	400	2	918	62,605	400	3
	Sept	716	65,106	-	2	757	51,535	818	2
	Oct	560	50,921	-	2	753	50,898	764	2
1983	Jul	151	13,735	-	2	-	-	-	-
	Aug	850	77,291	-	2	984	67,106	818	3
	Sept	894	81,291	-	2	816	55,649	782	3
	Oct	624	56,740	-	2	960	65,470	1,082	3
1984	Jul	295	26,824	200	2	121	8,252	400	2
	Aug	769	69,925	500	2	159	10,843	164	2
	Sept	339	30,825	564	2	563	38,395	614	3
	Oct	220	20,005	527	3	1,200	81,837	1,223	3
1985	Jul	828	74,835	600	3	424	28,916	341	3
	Aug	173	15,731	600	3	649	44,260	682	3
	Sept	877	79,746	1,491	3	658	44,874	946	3
	Oct	39	3,546	527	2	-	-	-	-
1986	Jul	31	2,819	473	2	275	18,754	232	1
	Aug	324	29,461	327	2	227	15,481	341	3
	Sept	488	44,374	482	2	180	12,276	450	2
	Oct	500	45,465	664	2	421	28,711	477	2
1987	Jul	130	11,821	591	2	344	23,460	546	2
	Aug	546	49,648	400	2	460	31,371	546	2
	Sept	544	49,466	891	2	576	39,282	614	2
	Oct	498	45,283	518	2	453	30,893	491	2
1988	Jul	4	364	400	2	3	177	200	1
	Aug	455	41,373	787	2	318	18,795	1,059	2
	Sept	394	35,826	518	2	239	14,126	546	2
	Oct	281	25,551	505	2	224	13,239	323	3
1989	Jul	12	1,091	400	2	-	-	-	-
	Aug	150	13,640	200	2	43	2,932	400	2
	Sept	314	28,552	300	2	177	12,071	136	2
	Oct	414	37,645	482	2	304	20,732	246	2
1990	Jul	107	9,730	518	2	-	-	-	-
	Aug	464	42,192	236	2	225	15,344	359	2
	Sept	538	48,920	882	2	494	33,690	891	2
	Oct	322	29,279	568	2	474	32,326	768	2
Total		18,513	1,684,576	19,010		18,103	1,226,585	23,247	

SOURCE : MOI WAD MEDANI

Table 1.3 MONTHLY MAXIMUM POWER AND ENERGY OF BLUE NILE GRID

in MW

Fiscal year	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annual Maximum
1986/1987	209.0	216.0	216.0	217.0	218.0	198.0	206.0	213.0	222.0	223.0	219.0	223.0	223.0
1987/1988	234.0	222.0	227.0	227.0	224.0	207.0	217.0	215.0	235.0	238.0	237.0	238.0	238.0
1988/1989	233.0	156.5	203.3	215.2	222.0	213.0	202.5	202.5	220.5	231.5	235.5	240.0	240.0

in GWh

Fiscal year	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annual Total
1986/1987	106.0	110.0	108.0	118.0	106.0	93.0	96.0	98.0	112.0	110.0	114.0	113.0	1,284.0
1987/1988	123.0	106.0	122.0	125.0	116.0	100.0	98.0	98.0	122.0	125.0	118.0	125.0	1,378.0
1988/1989	101.6	58.7	89.3	114.4	107.0	98.6	93.4	87.5	106.4	123.5	123.5	126.8	1,230.7

SOURCE : NEC ANNUAL REPORT 1990

Table 1.4 (1/2) EXISTING POWER GENERATING PLANT OF NEC

Station	Unit No.	Type	Year installed	Output (MW) Rated	Actual	Remarks
Roseires	1	Hydro	1971	30.0	30.0	Seasonal
	2	Hydro	1971	30.0	30.0	
	3	Hydro	1972	30.0	30.0	
	4	Hydro	1979	40.0	40.0	
	5	Hydro	1984	40.0	40.0	
	6	Hydro	1984	40.0	40.0	
	7	Hydro	1989	40.0	40.0	
Roseires Service	1	Hydro	1966	1.0	0.0	Inoperable due to siltation at intake
	2	Hydro	1966	1.0	0.0	
	Sub-total			252.0	250.0	
Sennar	1	Hydro	1962	7.5	7.5	Seasonal
	2	Hydro	1962	7.5	7.5	
	Sub-total			15.0	15.0	
Khartoum North	1	Steam	1985	33.0	30.0	
	2	Steam	1985	33.0	30.0	
	Sub-total			66.0	60.0	
Burri	1	Steam	1956	5.0	3.5	Restriction due to cooling and feed systems
	2	Steam	1956	5.0	3.5	
	3	Steam	1958	10.0	7.0	
	4	Steam	1961	10.0	7.0	
	5	Diesel	1966	3.0	1.5	Under rehabilitation
	6	Diesel	1966	3.0	1.5	Under rehabilitation
	7	Diesel	1966	3.0	0.0	Under rehabilitation
	8	Diesel	1966	3.0	0.0	Under rehabilitation
	9	Diesel	1966	3.0	0.0	Under rehabilitation
	10	Diesel	1981	5.0	4.0	Lack of spare parts
	11	Diesel	1981	5.0	4.0	Lack of spare parts
	12	Diesel	1981	5.0	4.0	Lack of spare parts
	13	Diesel	1984	10.0	8.0	Lack of spare parts
	14	Diesel	1984	10.0	8.0	Lack of spare parts
	15	Diesel	1984	10.0	8.0	Lack of spare parts
	16	Diesel	1984	10.0	0.0	Lack of spare parts
	17	Diesel	1990	10.0	10.0	
	18	Diesel	1990	10.0	10.0	
	19	Gas	1985	15.0	14.0	
	Sub-total			135.0	94.0	

Table 1.4 (2/2) EXISTING POWER GENERATING PLANT OF NEC

Station	Unit No.	Type	Year installed	Output (MW) Rated	Actual	Remarks
Kuku	1	Gas	1985	10.0	9.0	Lack of spare parts
	2	Gas	1985	15.0	12.0	Lack of spare parts
	Sub-total			25.0	21.0	
Kilo X	1	Gas	1969	15.0	10.0	Superannuation
	Sub-total			15.0	10.0	
Kassala	1	Diesel	1963	1.4	0.0	
	2	Diesel	1963	1.4	0.0	
	3	Diesel	1963	1.4	0.9	
	4	Diesel	1984	3.0	2.8	
	5	Diesel	1990	3.5	3.5	
	Sub-total			10.7	7.2	
El Girba	1	Hydro	1961	2.0	2.0	
	2	Hydro	1961	2.0	2.0	
	3	Hydro	1961	2.0	2.0	
	4	Hydro	1963	3.3	2.0	
	5	Hydro	1963	3.3	2.0	
	6	Diesel	1984	3.0	2.8	
	7	Diesel	1990	3.5	3.5	
	8	Diesel	1990	3.5	3.5	
	Sub-total			22.6	19.8	
Kilo 3	1	Gas	1984	2.5	2.5	
	Sub-total			2.5	2.5	
Total				543.8	479.5	

SOURCE :NEC ANNUAL REPORT 1990

Table 1.5 TARIFF SYSTEM

Application : This tariff is applicable for supplies of declared service capacity in excess of 100 KVA, intended to be used only for industrial, agricultural and bakeries.

1. 33 KV Supplies (2.500 KVA & Above)

(1) Base Charge

i)	Max. demand charge	: LS 3.0/KVA
ii)	Service capacity charge	: LS 1.0/KVA

(2) Consumption Charge

i)	For Critical Months,	
	Off peak rate	: LS 0.34/KWH
	Peak rate	: LS 0.98/KWH
ii)	For other Months	
	Off peak rate	: LS 0.08/KWH
	Peak rate	: LS 0.56/KWH

2. 11 KV Supplies (1.000 KVA & Above) : Omitted

3. 415 KV Supplies (100 KVA to 1.000 KVA) : Omitted

Notes: Critical Month : March, April, May, June, July & August

Peak Hours : 7:00 to 14:00 and 18:00 to 22:00 hours

Table 1.6 EXISTING DEMAND OF OUTGOING FEEDER OF MERINGAN SUBSTATION

1)	110 KV Outgoing Feeders	: 25 MVA
	- Hassa Heisa Substation	: 20 MVA
	- Fau Substation	: 5 MVA
2)	33 KV Outgoing Feeders	: 9.9 MVA
	- Gezira Textiles	: 5.4 MVA (See Note 1)
	- Elananggil	: 4.5 MVA (See Note 2)
3)	11 KV Outgoing Feeders	: 28.5 MVA
	- Wad Medani (2 Feeders)	: 7.5 MVA
	- Blue Nile Textiles	: 5.0 MVA
	- Tanner Factory	: 5.0 MVA
	- Alhoudik Factory	: 3.5 MVA (See Note 3)
	- Dargig Area Electrification	: 6.0 MVA
	- Alhoush Area Electrification	: 1.5 MVA
	- Factories Feeder	: 6.0 MVA

Notes:

1. This maximum demand was recorded on May 1990 the contract demand of Gezira Textiles is 5 MVA while the actual maximum demand is estimated at 3.5 MVA.

2. The maximum demand is expected to be increased by 10 MVA for commencement of power supply to mil and flour factories in 1991.

3. The maximum demand is expected to be increased by 10 MVA after completion of extension works of factory in 1991.

Source; NEC Wad Medani office

Table 2.1 MONTHLY MEAN WATER LEVEL
(FOR ALTERNATIVE STUDY ONLY)

Month	10-DAY	Water Level (EL) at Hurga P/S	Water Level (EL) at Nur El Din P/S	Water Level (EL) at Integrated P/S
Jan	1	390.5	390.7	390.5
	2	390.5	390.7	390.5
	3	390.5	390.7	390.5
Feb	1	390.5	390.6	390.5
	2	390.5	390.6	390.5
	3	390.5	390.6	390.5
Mar	1	390.5	390.6	390.5
	2	390.5	390.6	390.5
	3	390.5	390.6	390.5
Apr	1	390.8	390.9	390.8
	2	390.8	390.9	390.8
	3	390.8	390.9	390.8
May	1	390.9	391.0	390.9
	2	390.9	391.0	390.9
	3	390.9	391.0	390.9
Jun	1	391.5	391.6	391.5
	2	391.5	391.6	391.5
	3	391.5	391.6	391.5
Jul	1	394.6	394.7	394.6
	2	394.6	394.7	394.6
	3	394.6	394.7	394.6
Aug	1	398.1	398.2	398.1
	2	398.1	398.2	398.1
	3	398.1	398.2	398.1
Sept	1	397.0	397.1	397.0
	2	397.0	397.1	397.0
	3	397.0	397.1	397.0
Oct	1	394.4	394.5	394.4
	2	394.4	394.5	394.4
	3	394.4	394.5	394.4
Nov	1	391.9	392.0	391.9
	2	391.9	392.0	391.9
	3	391.9	392.0	391.9
Dec	1	390.8	390.9	390.8
	2	390.8	390.9	390.8
	3	390.8	390.9	390.8

Table 2.2 PUMP WATER REQUIREMENT
(FOR ALTERNATIVE STUDY PURPOSE ONLY)

Month	10-Day Period	24 hrs operation Hurga 13,900 fd (m3/s)	24 hrs operation NurElDin 8,720 fd (m3/s)	24 hrs operation Total 22,620 fd (m3/s)	18 hrs operation Hurga 13,900 fd (m3/s)	18 hrs operation NurElDin 8,720 fd (m3/s)	18 hrs operation Total 22,620 fd (m3/s)
Jan	1	2.94	1.84	4.78	3.92	2.46	6.37
	2	2.88	1.81	4.68	3.84	2.41	6.25
	3	2.77	1.74	4.51	3.70	2.32	6.02
Feb	4	2.22	1.39	3.61	2.96	1.86	4.81
	5	1.67	1.05	2.72	2.23	1.40	3.62
	6	1.19	0.75	1.94	1.59	1.00	2.59
Mar	7	0.62	0.39	1.01	0.83	0.52	1.34
	8	0.00	0.00	0.00	0.00	0.00	0.00
	9	0.00	0.00	0.00	0.00	0.00	0.00
Apr	10	0.00	0.00	0.00	0.00	0.00	0.00
	11	0.00	0.00	0.00	0.00	0.00	0.00
	12	0.00	0.00	0.00	0.00	0.00	0.00
May	13	0.00	0.00	0.00	0.00	0.00	0.00
	14	0.00	0.00	0.00	0.00	0.00	0.00
	15	0.00	0.00	0.00	0.00	0.00	0.00
Jun	16	1.73	1.09	2.81	2.31	1.45	3.75
	17	2.33	1.46	3.79	3.10	1.95	5.05
	18	1.99	1.25	3.23	2.65	1.66	4.31
Jul	19	0.56	0.35	0.90	0.74	0.46	1.20
	20	0.61	0.39	1.00	0.82	0.51	1.33
	21	1.18	0.74	1.92	1.58	0.99	2.56
Aug	22	1.72	1.08	2.80	2.29	1.44	3.73
	23	1.05	0.66	1.71	1.40	0.88	2.29
	24	1.15	0.72	1.87	1.53	0.96	2.49
Sep	25	1.96	1.23	3.19	2.61	1.64	4.25
	26	2.09	1.31	3.40	2.79	1.75	4.54
	27	2.21	1.38	3.59	2.94	1.84	4.78
Oct	28	3.00	1.88	4.88	4.00	2.51	6.50
	29	3.29	2.06	5.35	4.38	2.75	7.13
	30	2.69	1.69	4.38	3.59	2.25	5.84
Nov	31	3.03	1.90	4.92	4.03	2.53	6.57
	32	2.96	1.85	4.81	3.94	2.47	6.41
	33	3.14	1.97	5.11	4.18	2.62	6.81
Dec	34	2.86	1.79	4.66	3.81	2.39	6.21
	35	2.92	1.83	4.75	3.89	2.44	6.34
	36	3.10	1.95	5.05	4.14	2.60	6.74

Table 2.3 CONSTRUCTION COSTS

(Unit : 1,000 LS)

Work Item	Rehabilitation Plan (Alt-1e) Hurga P/S	Nur El Din P/S	Total	Integrated Plan (Alt-2e & 3e) Alt-2e 1) DSVP	Alt-3e 2) MFP
	(1,000 LS)	(1,000 LS)	(1,000 LS)	(1,000 LS)	(1,000 LS)
A. Civil Works	6,600	8,300	14,900	25,400	27,600
1 . Super Structure	1,800	4,200	6,000	1,700	1,000
(1) Earth Works	10	90	100	0	0
(2) Concrete Works	1,070	3,390	4,460	1,440	840
(3) Brick Works	120	130	250	150	130
(4) Other Works	620	630	1,250	70	70
2 . Sub Structure	2,400	3,200	5,600	10,500	12,400
(1) Earth Works	0	340	340	3,060	3,750
(2) Concrete Works	1,070	360	1,430	5,750	8,630
(3) Other Works	1,370	2,470	3,840	1,780	0
3 . Discharge Sump & Pipe	900	900	1,800	600	600
(1) Earth Works	60	60	120	60	60
(2) Brick Works	420	420	840	450	450
(3) Other Works	450	450	900	40	40
4 . Suction Pipe	0	0	0	100	0
(1) Concrete Works	0	0	0	120	0
6 . Inlet Channel	0	0	0	0	4,600
(1) Earth Works	0	0	0	0	460
(2) Concrete Works	0	0	0	0	4,080
(3) Other Works	0	0	0	0	70
6 . River Works	1,500	0	1,500	3,400	0
(1) Earth Works	1,130	0	1,130	430	0
(2) Concrete Works	0	0	0	820	0
(3) Other Works	320	0	320	2,140	0
7 . Link Canal	0	0	0	9,000	9,000
(1) Earth Works	0	0	0	8,950	8,950
B. Pump & Appurtenant Facilities	19,210	14,340	33,550	23,620	24,120
1 . Pumping & Mechanical Equipment	13,710	10,400	24,110	17,970	18,470
2 . Electrical Equipment	4,060	3,940	8,000	4,290	4,290
3 . 33 KV Distribution Line	1,440	-	1,440	1,360	1,360
Total (A. Civil Works)	6,600	8,300	14,900	25,400	27,600
Total (B. Pump & Appurtenant Facilities)	19,210	14,340	33,550	23,620	24,120
Grand-Total (A + B)	25,810	22,640	48,450	49,020	51,720

Notes : a) Double Suction Volute Pump
b) Mixed Flow Pump

Table 3.1 DESIGN DATA OF INTAKE PUMPING STATION

Month	10-DAY	(1) Discharge (m3/sec)	(2) Suction level (EL)	(3) Discharge level (EL)	(4) Static pump head (m)
Jan	1	4.83	391.07	413.3	22.23
	2	4.54	391.07	413.3	22.23
	3	4.14	391.07	413.3	22.23
Feb	1	3.61	391.02	413.3	22.28
	2	3.18	391.02	413.3	22.28
	3	2.12	391.02	413.3	22.28
Mar	1	1.09	391.02	413.3	22.28
	2	0.00	391.02	413.3	22.28
	3	0.00	391.02	413.3	22.28
Apr	1	0.00	391.29	413.3	22.01
	2	0.00	391.29	413.3	22.01
	3	2.23	391.29	413.3	22.01
May	1	2.65	391.42	413.3	21.88
	2	3.26	391.42	413.3	21.88
	3	3.84	391.42	413.3	21.88
Jun	1	4.66	391.99	413.3	21.31
	2	5.69	391.99	413.3	21.31
	3	6.49	391.99	413.3	21.31
Jul	1	6.34	395.11	413.3	18.19
	2	7.86	395.11	413.3	18.19
	3	6.60	395.11	413.3	18.19
Aug	1	6.45	398.64	413.3	14.66
	2	6.50	398.64	413.3	14.66
	3	6.87	398.64	413.3	14.66
Sept	1	8.17	397.50	413.3	15.80
	2	7.44	397.50	413.3	15.80
	3	6.75	397.50	413.3	15.80
Oct	1	7.05	394.88	413.3	18.42
	2	5.98	394.88	413.3	18.42
	3	5.89	394.88	413.3	18.42
Nov	1	5.32	392.41	413.3	20.89
	2	5.26	392.41	413.3	20.89
	3	4.18	392.41	413.3	20.89
Dec	1	4.50	391.33	413.3	21.97
	2	4.73	391.33	413.3	21.97
	3	4.90	391.33	413.3	21.97

Notes :

(1) as 18 hrs operation per day
(2) average water level between 1974-1990
(4) static head ((3)-(2))

Design Condition of Pump :

FWL : EL 402.11 (100-year probable)
HWL : EL 398.64
LWL : EL 391.02
L.LWL : EL 389.02 (June 1990)
Setting EL of Motor : EL 402.50

Table 3.2 MAIN FEATURES OF PUMPING EQUIPMENT

1. PUMP

Type of Pump	: vertical shaft double suction volute pump
Diameter of Pump	: 1,000 mm X 800 mm
Rated Discharge	: 148 m3/min. per unit
Rated Design Head	: 24 m
Specific Speed	: 460 rpm-m
Quantity	: 4 sets

2. MOTOR

Type	: totally enclosed self-cooling vertical shaft squirrel cage induction motor
Output	: 750 kW
Voltage	: 11 kV
Number of Pole	: 10 poles
Speed	: 580 rpm (including 3% slip)
Quantity	: 4 sets

3. OVERHEAD CRANE

Type	: electrically operated,wire rope hoist with travelling and transverse gear unit
Capacity	: 15 tons
Quantity	: 1 set

4. SUCTION PIPE

Type	: concrete encased welded steel pipe
Diameter	: 1,100 mm to 1,000 mm
Length	: approx. 22 m
Quantity	: 4 lanes

5. DISCHARGE PIPE

Type	: concrete supported welded steel pipe with manifold type confluence pipe
Diameter	: 800 mm,900 mm,1,500 mm,and 1,800 mm
Length	: approx.60 m
Quantity	: 4 lanes for each pump unit and 1 lane of confluence discharge pipe

6. SUCTION VALVE

Type	: manually operated sluice valve
Diameter	: 1,000 mm
Quantity	: 4 sets

7. DISCHARGE VALVE

Type	: electrically operated butterfly valve
Diameter	: 800 mm
Quantity	: 4 sets

8. CHECK VALVE

Type	: swing type check valve
Diameter	: 800 mm
Quantity	: 4 sets

Table 3.3 HEAD LOSS CALCULATION

Description of Loss	Flow (m3/sec)	Diameter of Pipe (mm)	Flow Velocity (m/sec)	Coefficient of Loss	Head Loss (m)
Suction Loss					
-Inlet (Bellmouth)	2.4	1,100	2.526	0.400	0.130
-90 deg Bend (D/R=1.00	2.4	1,100	2.526	0.294	0.096
-Taper Pipe (Convergent	2.4	1,100-1,000	3.056	0.000	0.000
-Sluice Valve	2.4	1,000	3.056	0.050	0.024
-Friction of Pipe l=21m,c=130	2.4	1,100	2.526	0.004	0.088
Sub-total					0.337
Discharge Loss					
-Taper Pipe (Divergent)	2.4	900	3.773	0.135	0.007
D1=900 D2=800	2.4	800	4.775		
-Check Valve	2.4	900	3.773	0.500	0.363
-90 deg Bend	2.4	900	3.773	0.294	0.213
-Butterfly Valve	2.4	900	3.773	0.300	0.218
-90 deg Bend	2.4	900	3.773	0.294	0.213
-Friction of Pipe l=17m,c=130	2.4	900	3.773	0.011	0.187
-Taper Pipe (Divergent)	2.4	1,350	1.677	0.135	0.030
D1=1350 D2=900	2.4	900	3.773		
-Confluence at T-pipe	2.4	1,350	1.677	0.468	0.191
D1=1350 D2=1800	7.2	1,800	2.830		
-45 deg Bend	7.2	1,800	2.830	0.208	0.085
-45 deg Bend	7.2	1,800	2.830	0.208	0.085
-Friction of Pipe l=50m,c=130	7.2	1,800	2.830	0.003	0.146
-Taper Pipe (Divergent)	7.2	2,400	1.592	0.135	0.011
D1=1800 D2=2400	7.2	1,800	2.830		
-Outlet	7.2	2,400	1.592	1.000	0.129
Sub-total					1.879
Total					2.216

FIGURES

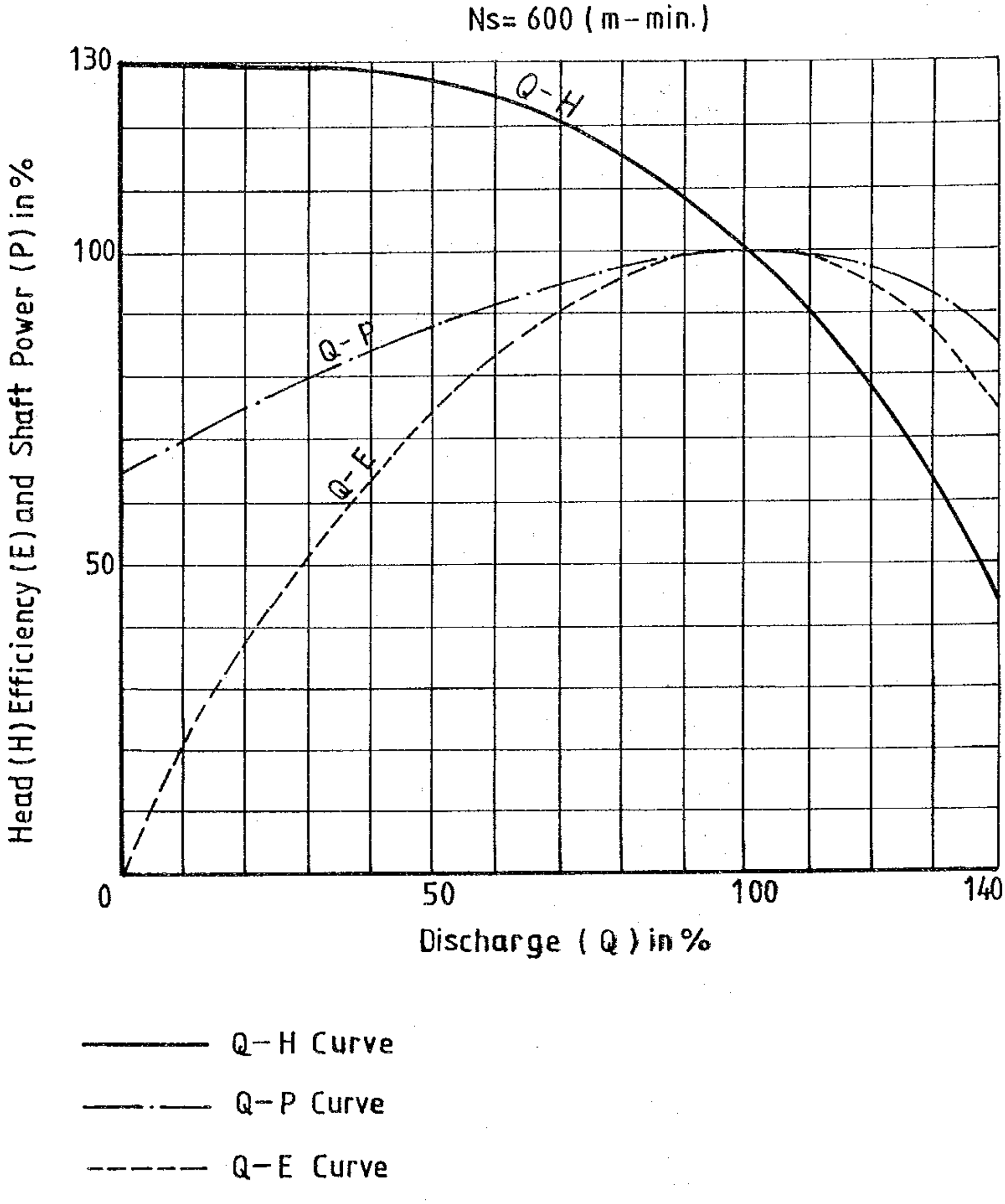


Fig. 1.1 CHARACTERISTIC CURVE OF PUMP

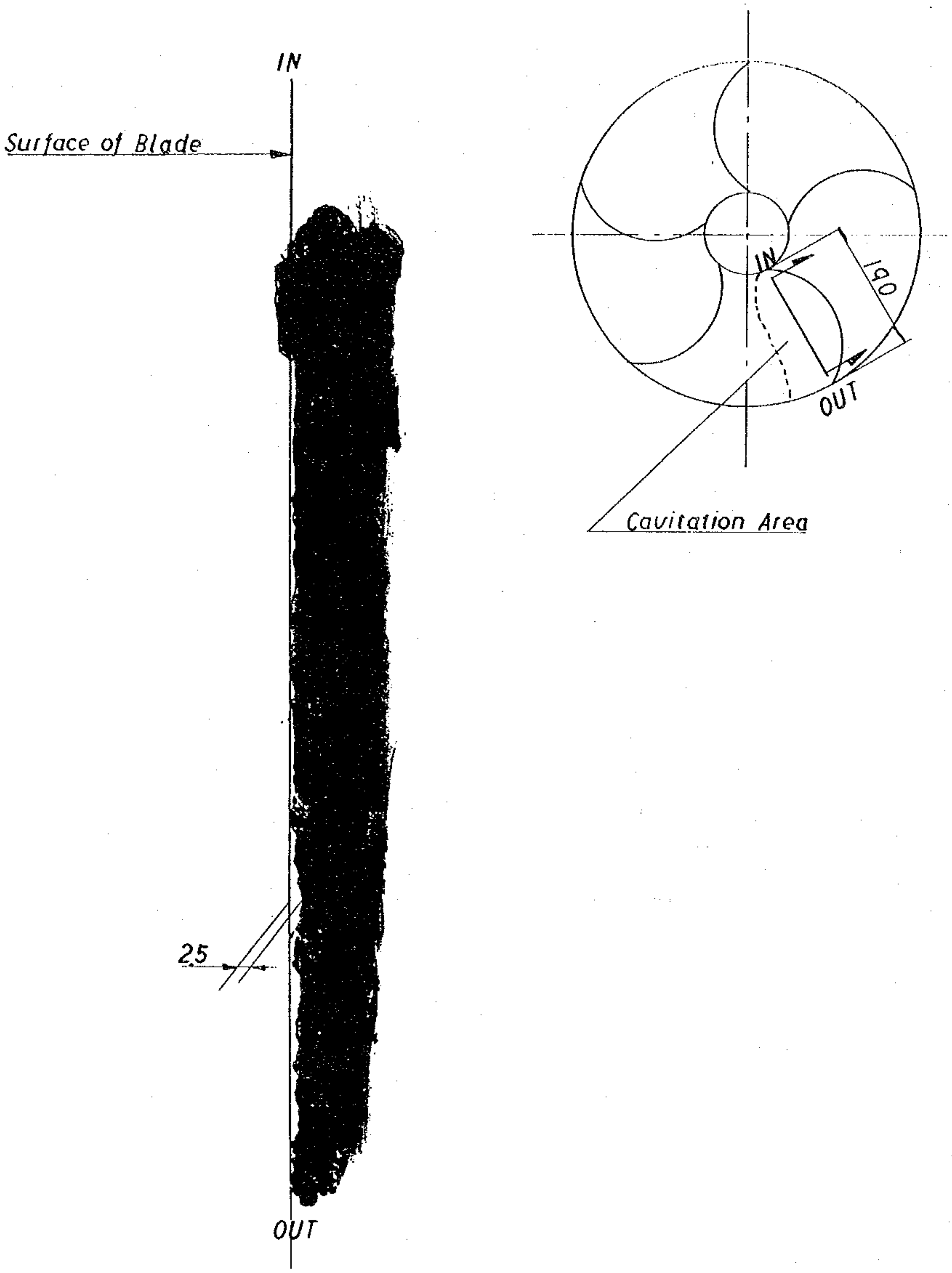


Fig. 1.2 CAVITATION OF IMPELLER

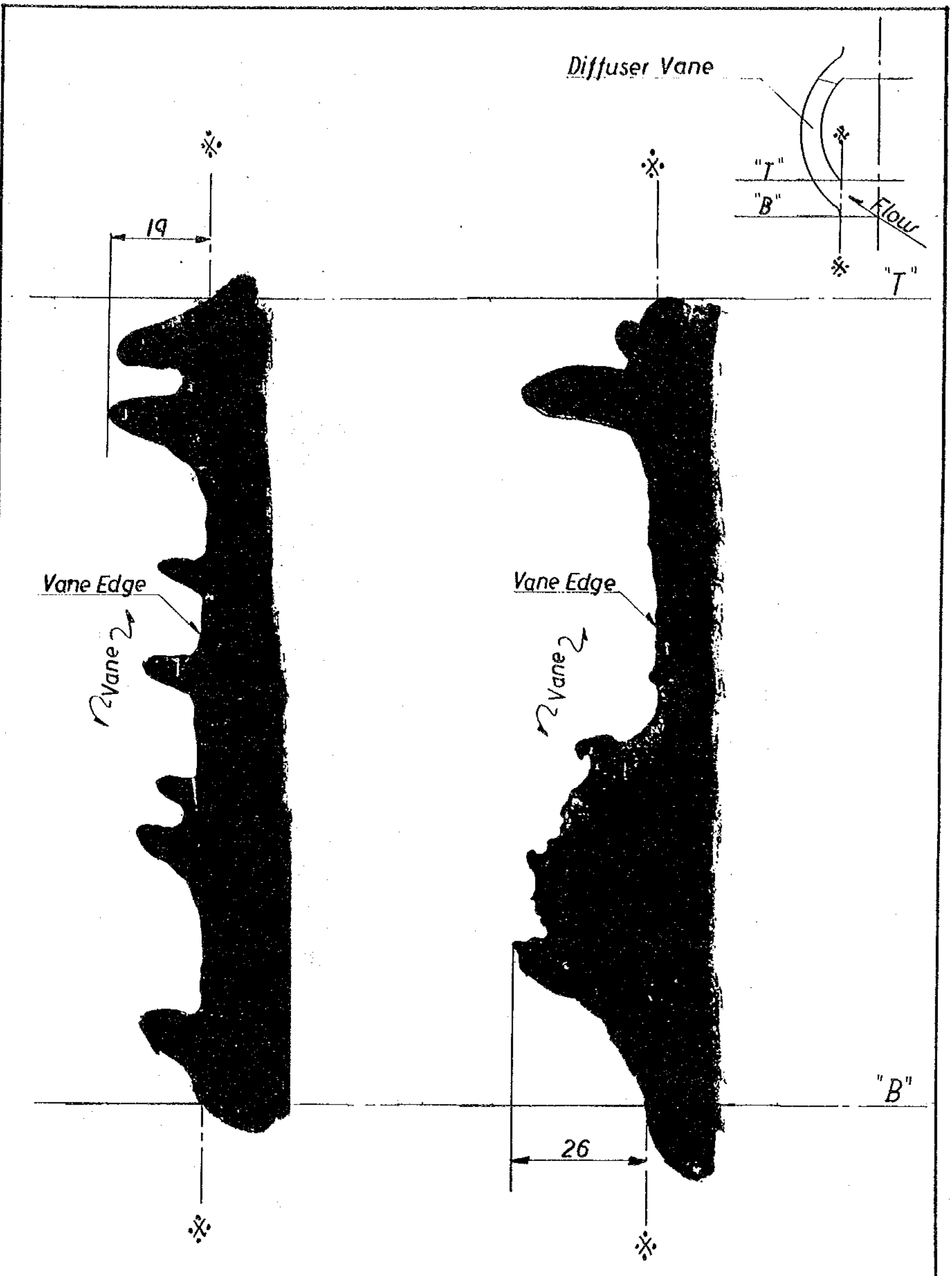


Fig. 1.3 EROSION OF DIFFUSER VANE

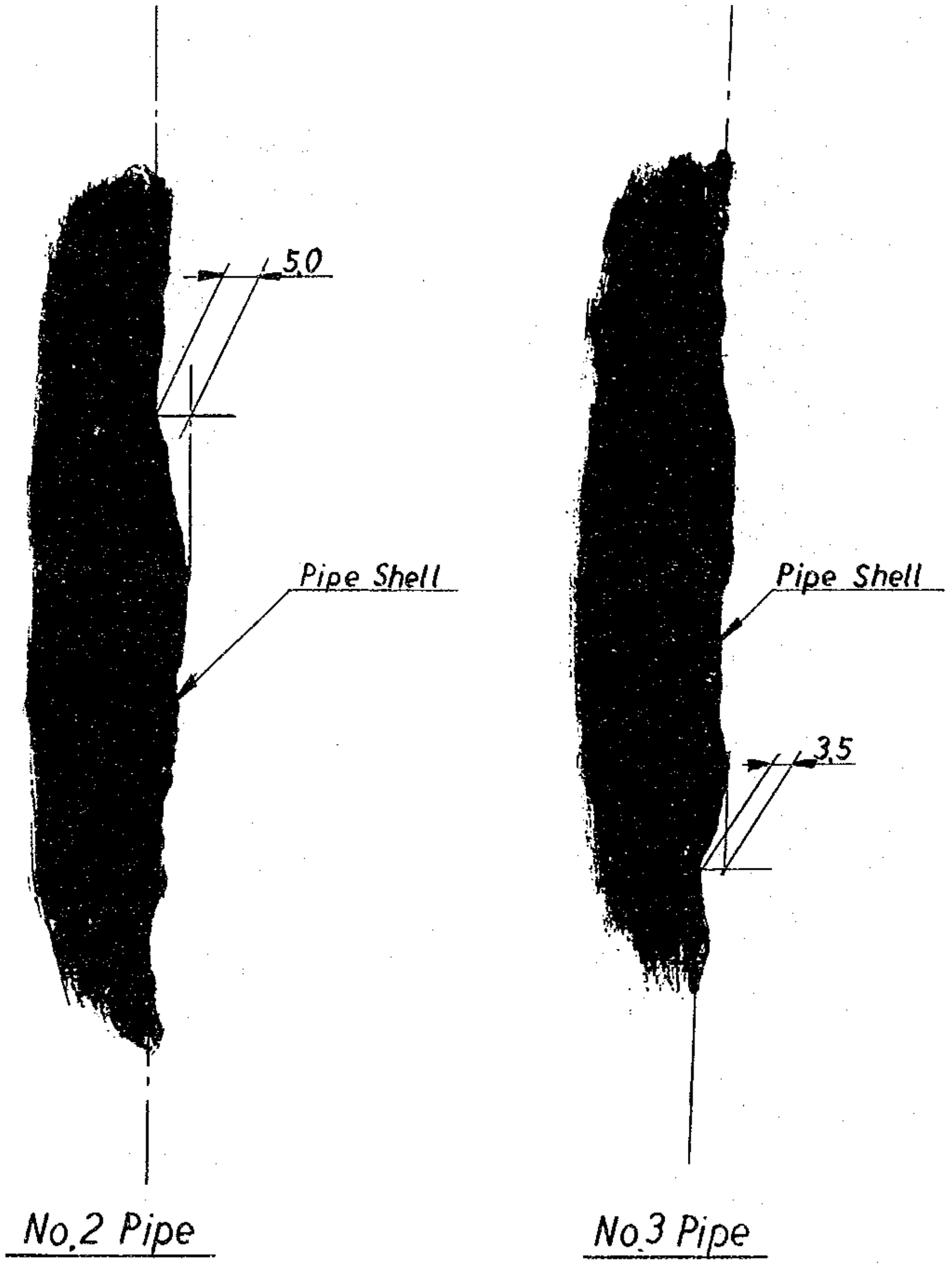


Fig. 1.4 HURGA DISCHARGE PIPE

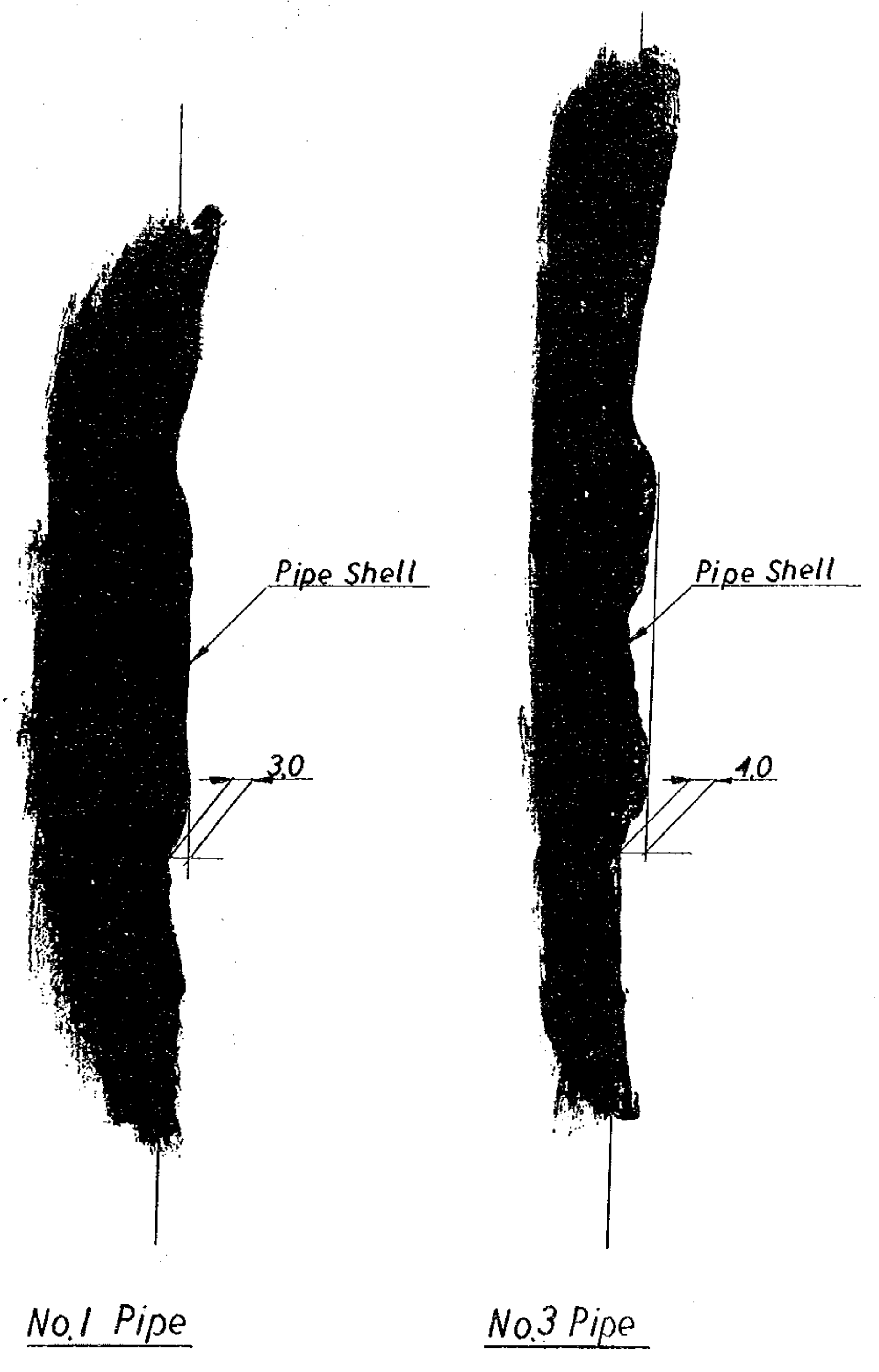


Fig. 1.5 NUR EL DIN DISCHARGE PIPE

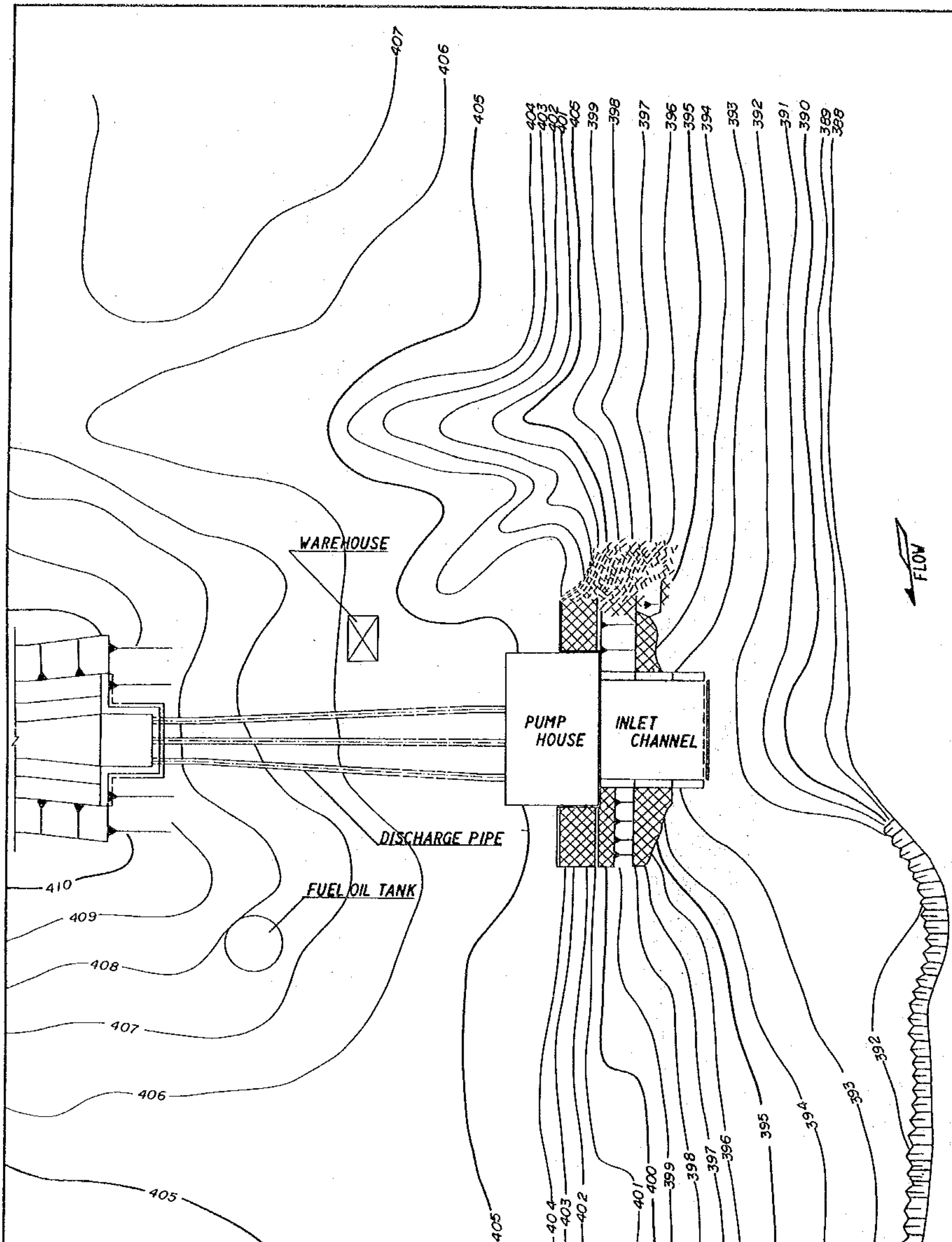


Fig. 1.6 (1/3) GENERAL LAYOUT OF EXISTING HURGA PUMPING STATION

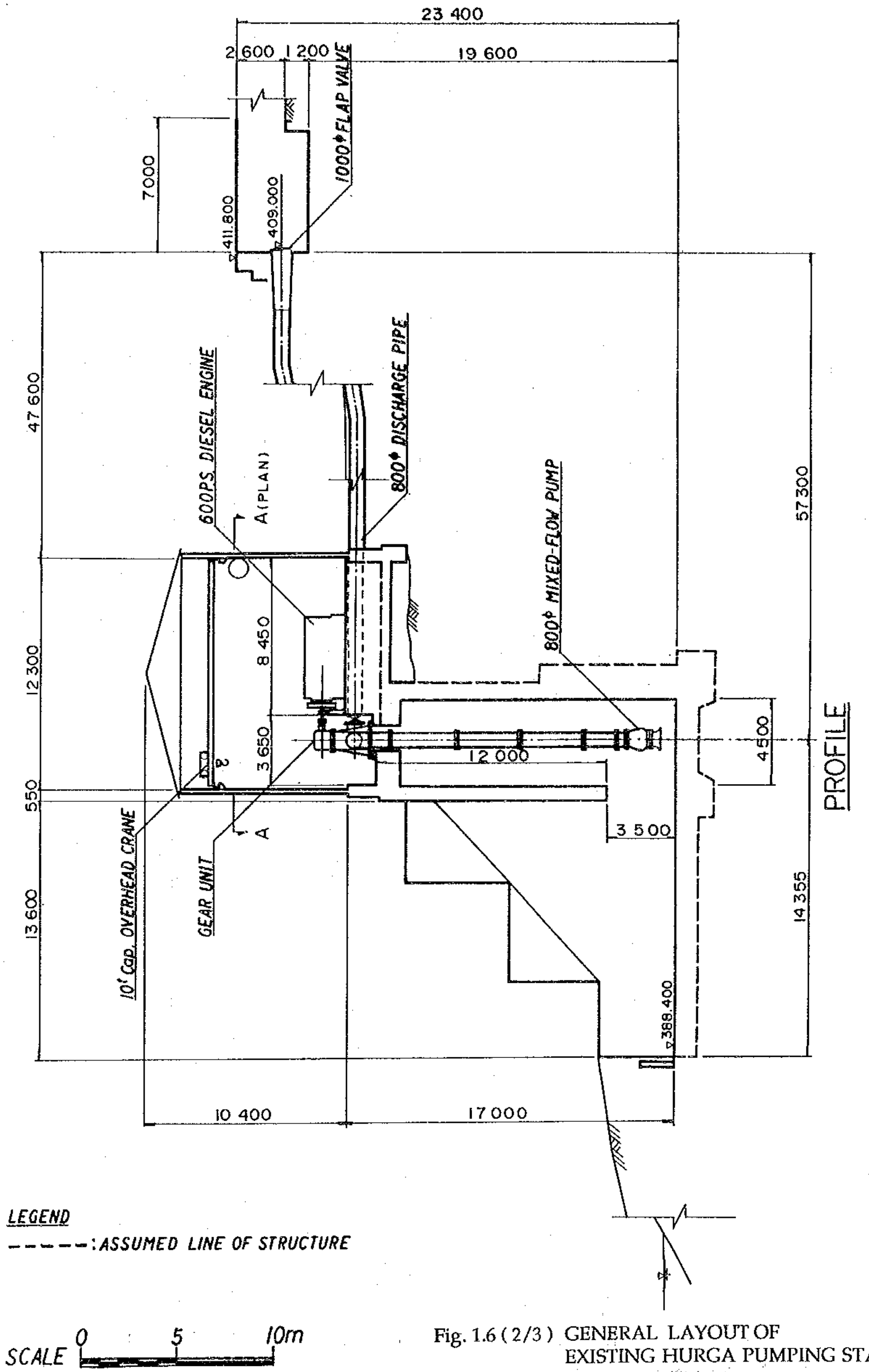


Fig. 1.6 (2/3) GENERAL LAYOUT OF EXISTING HURGA PUMPING STATION

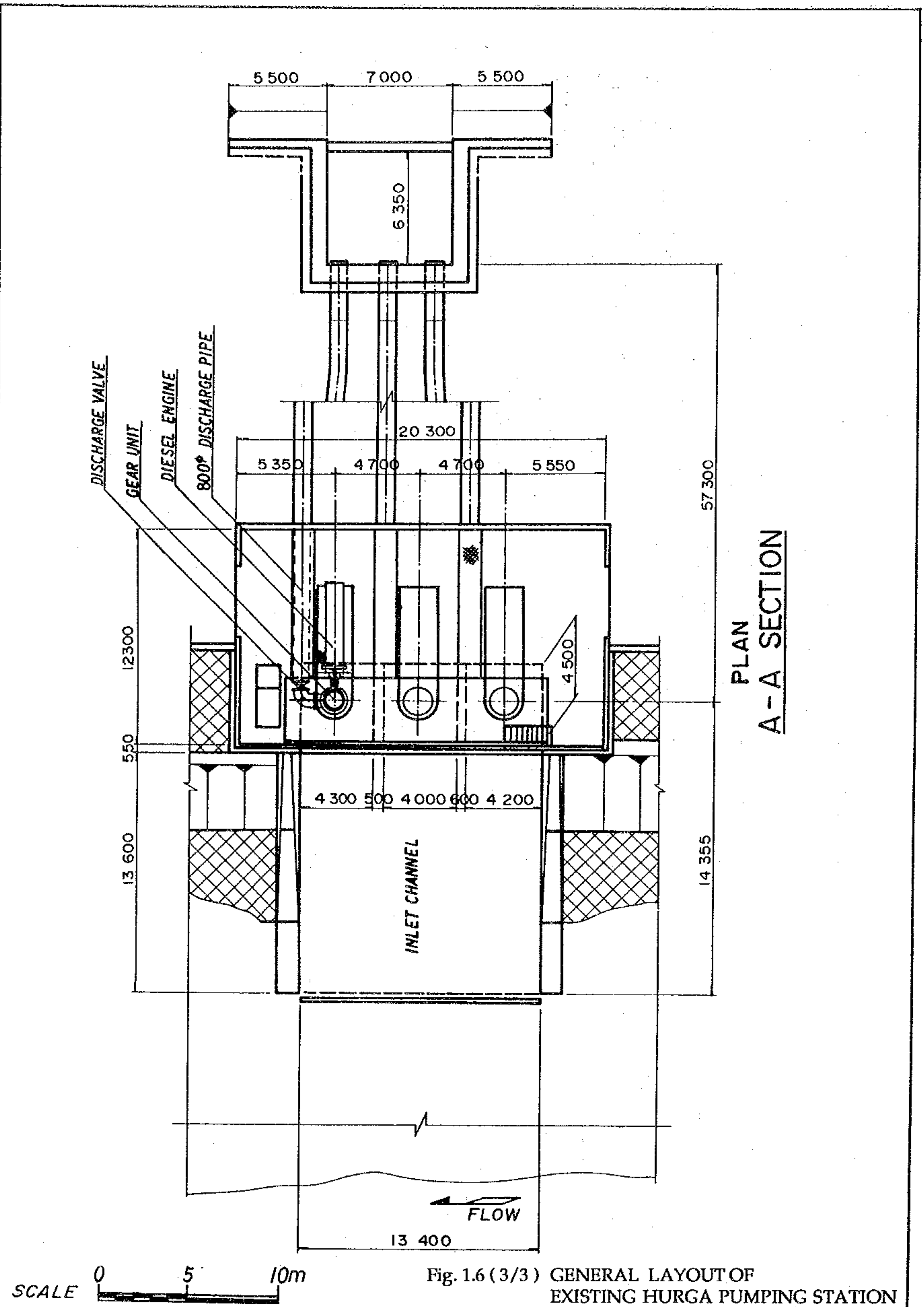


Fig. 1.6 (3/3) GENERAL LAYOUT OF EXISTING HURGA PUMPING STATION

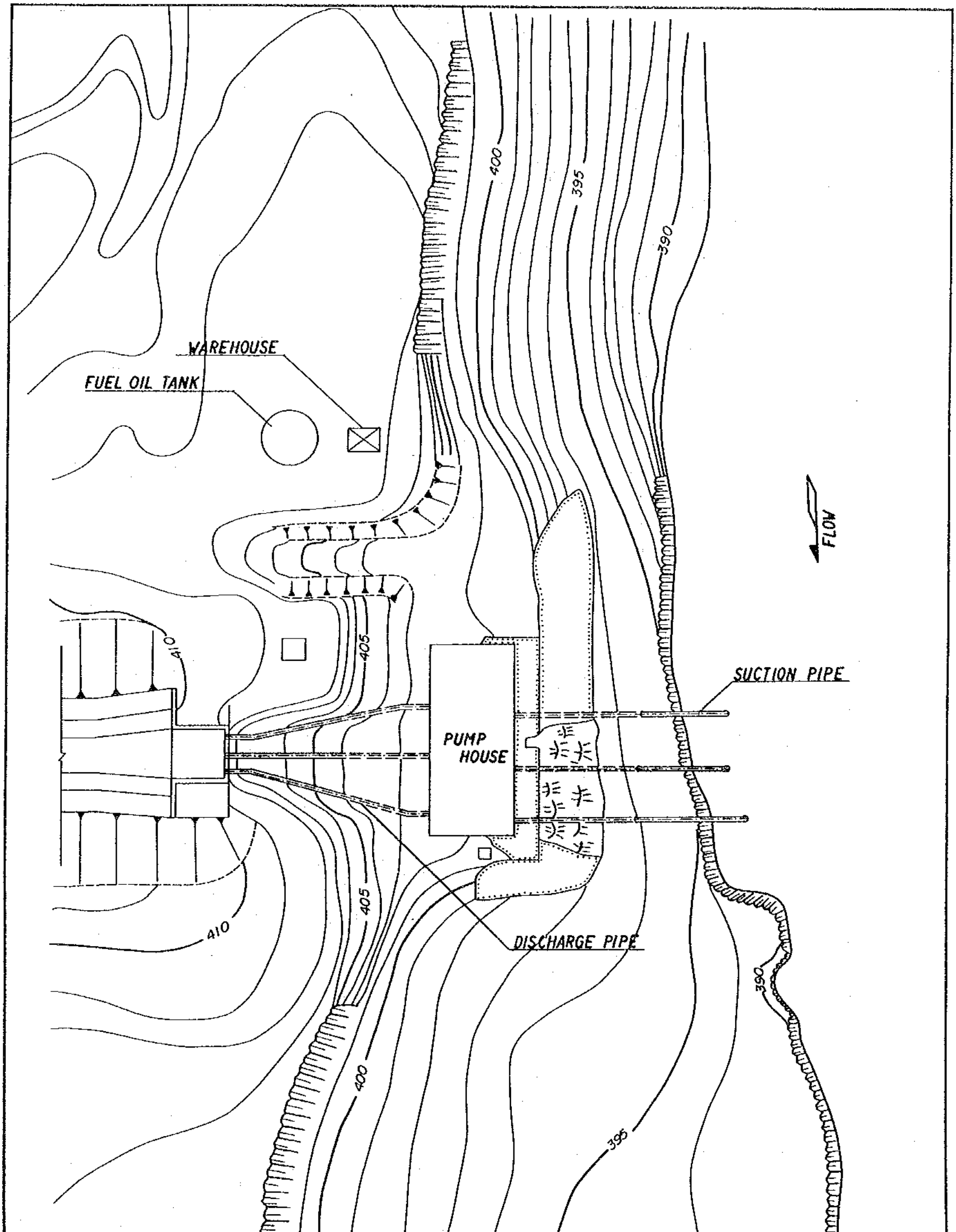


Fig. 1.7 (1/3) GENERAL LAYOUT OF EXISTING NUR EL DIN PUMPING STATION

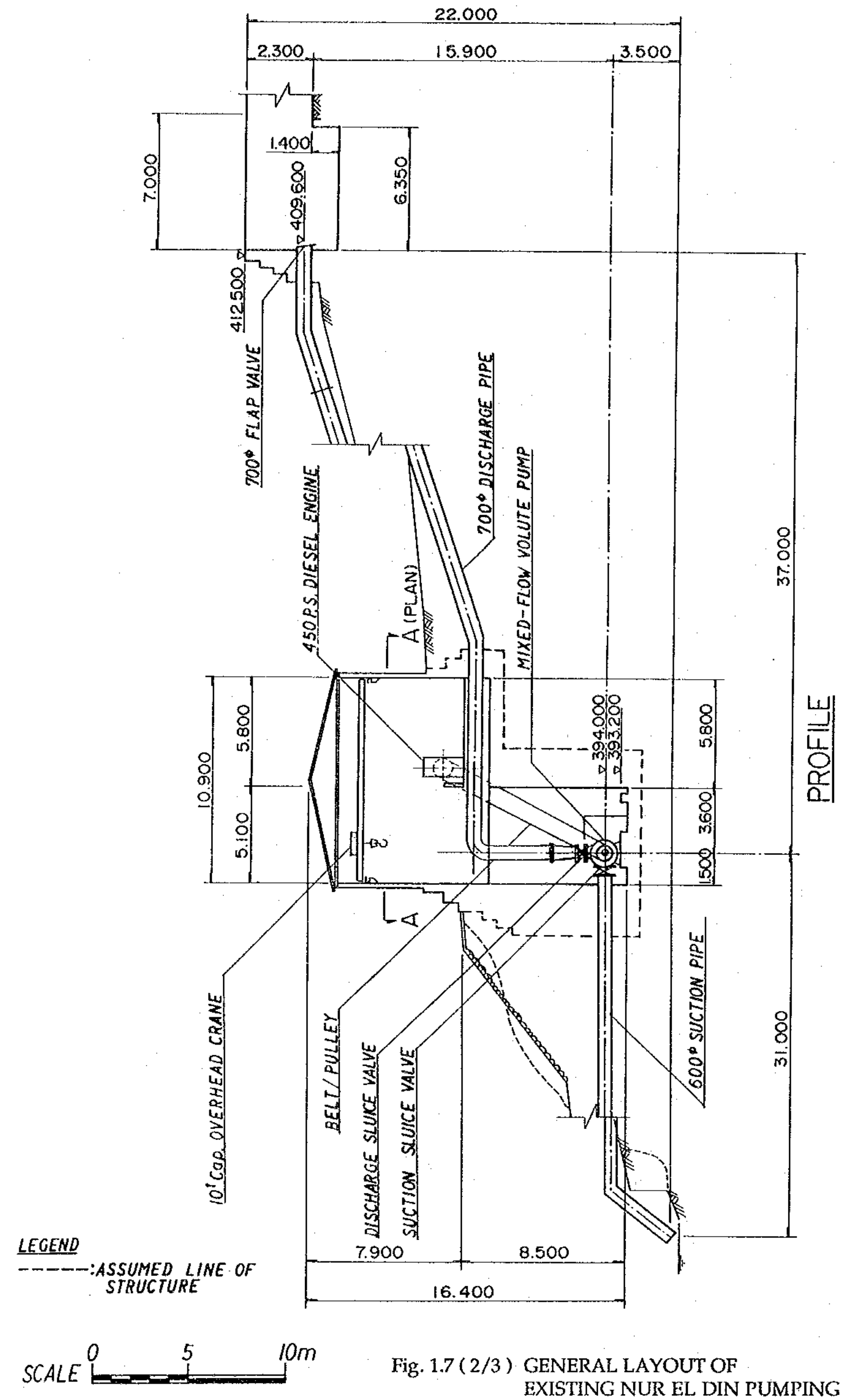


Fig. 1.7 (2/3) GENERAL LAYOUT OF EXISTING NUR EL DIN PUMPING STATION

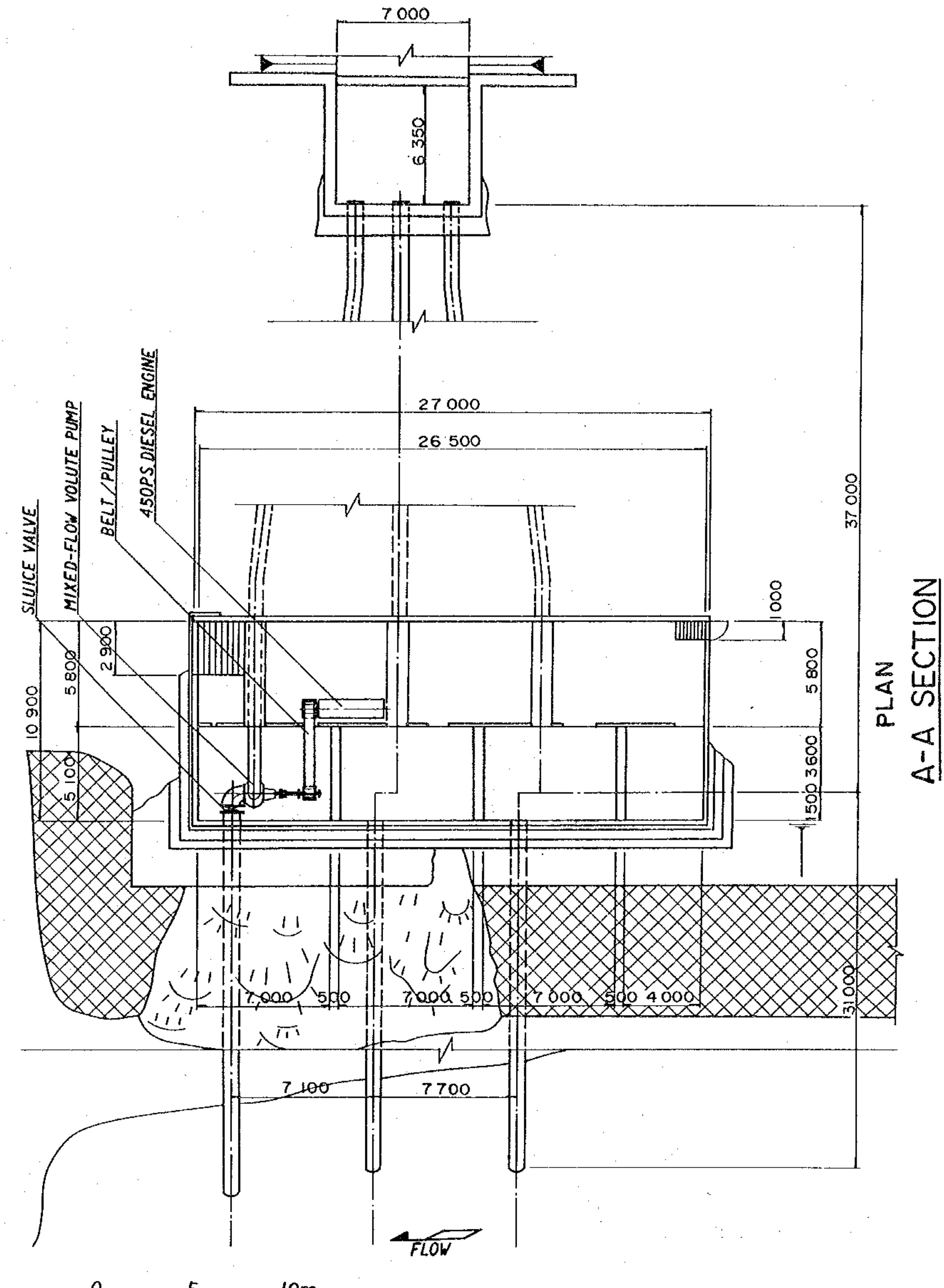


Fig. 1.7 (3/3) GENERAL LAYOUT OF EXISTING NUR EL DIN PUMPING STATION

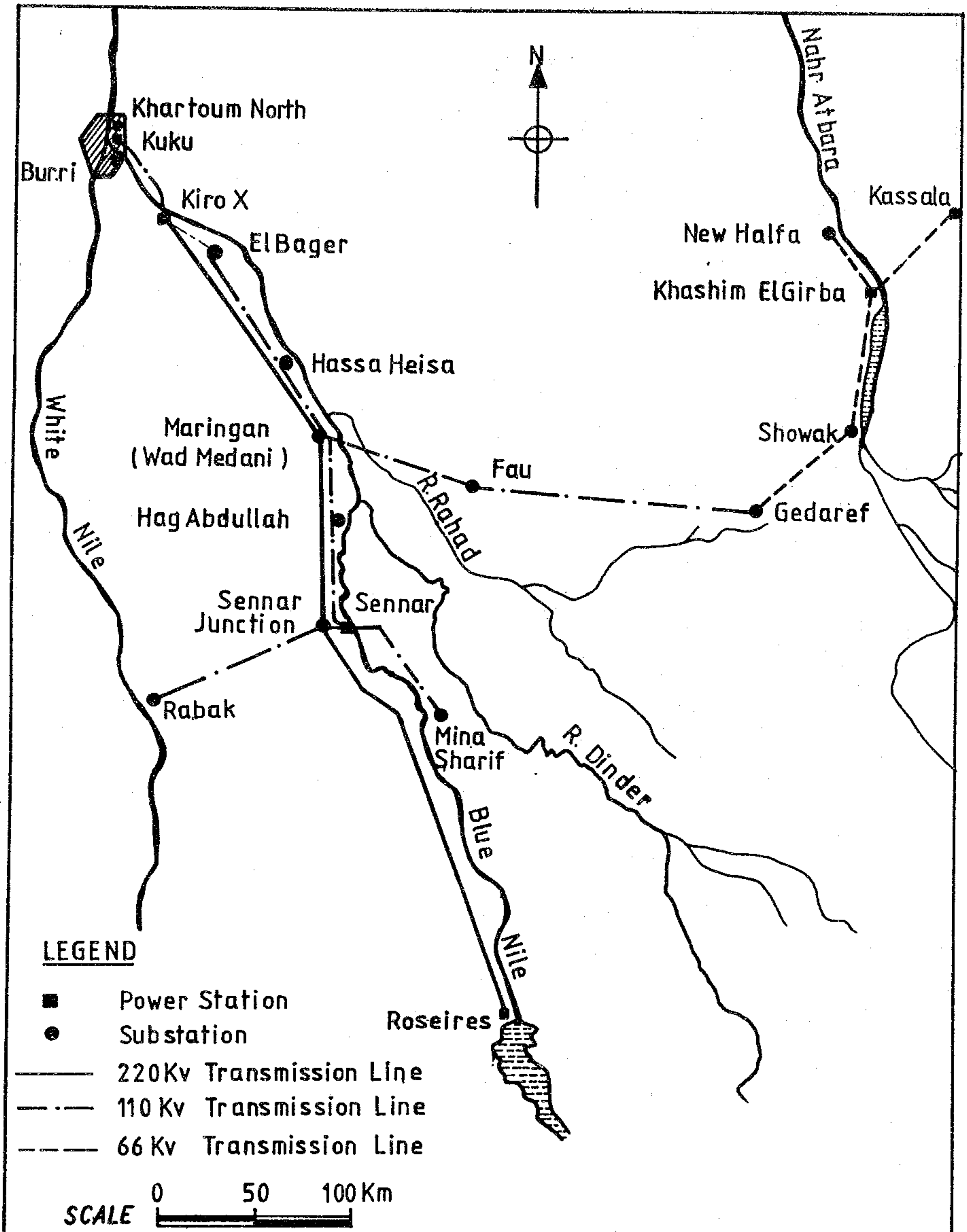


Fig. 1.8 EXISTING NATIONAL POWER SUPPLY SYSTEM

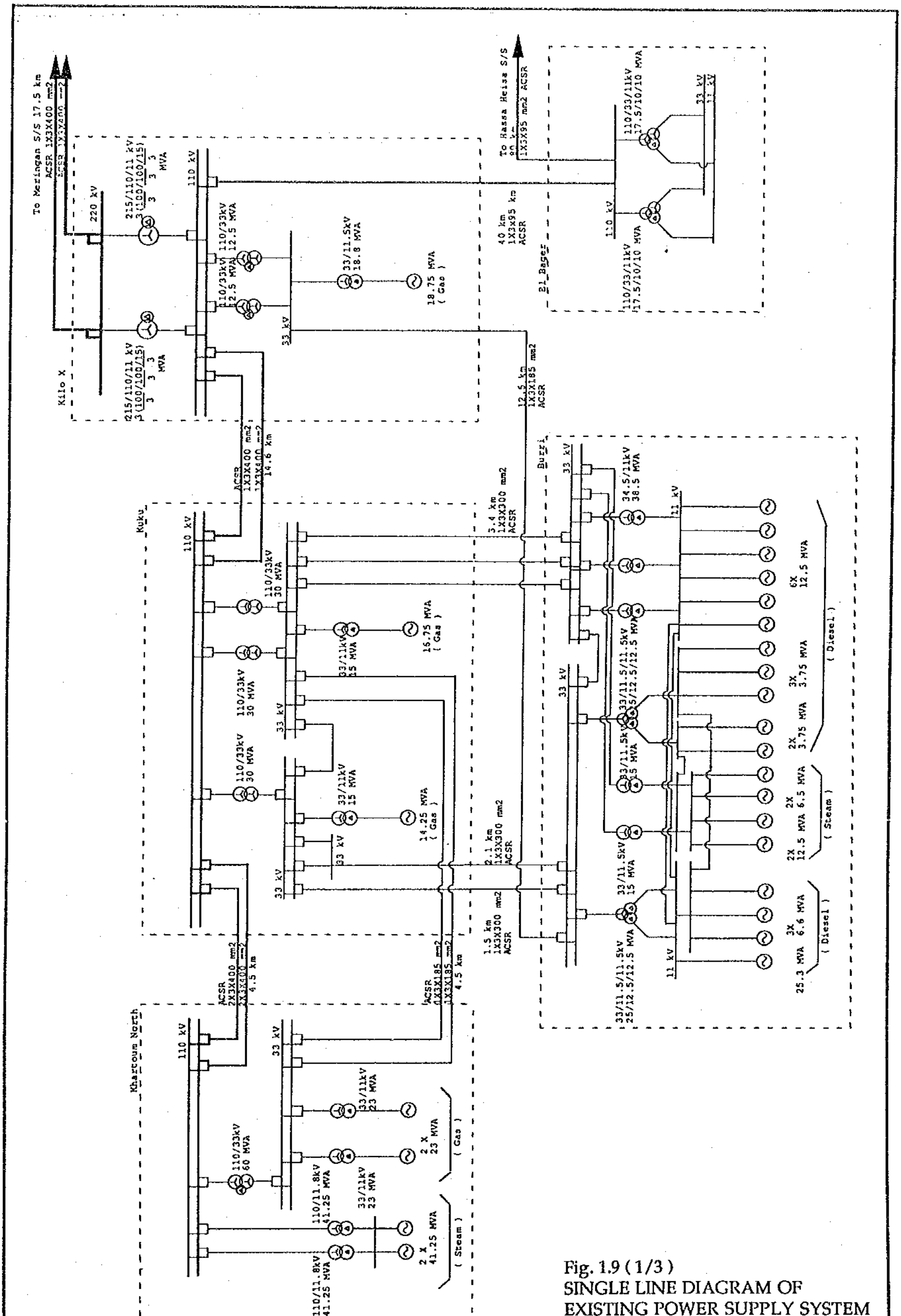


Fig. 1.9 (1/3)
SINGLE LINE DIAGRAM OF
EXISTING POWER SUPPLY SYSTEM

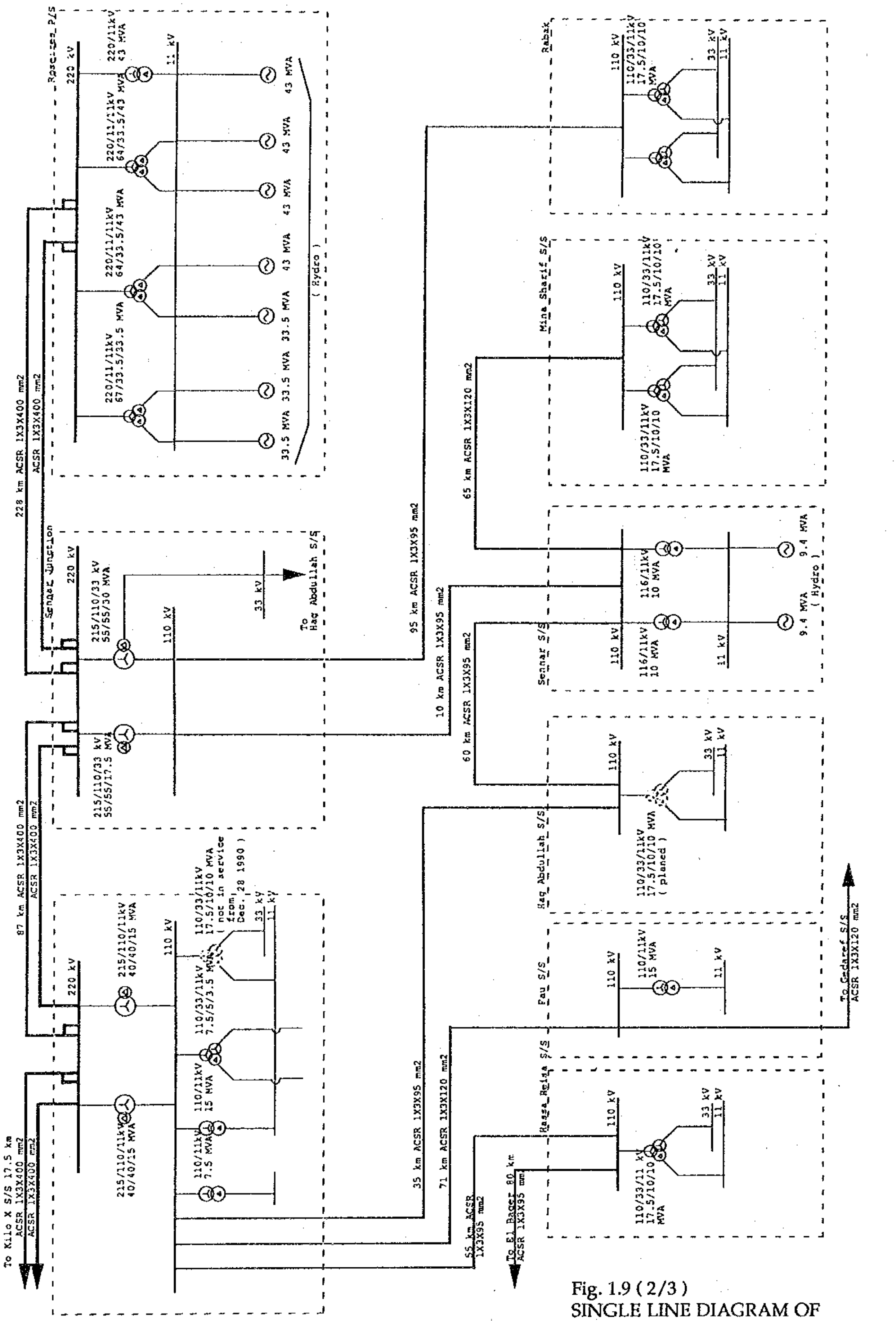


Fig. 1.9 (2/3)
SINGLE LINE DIAGRAM OF
EXISTING POWER SUPPLY SYSTEM

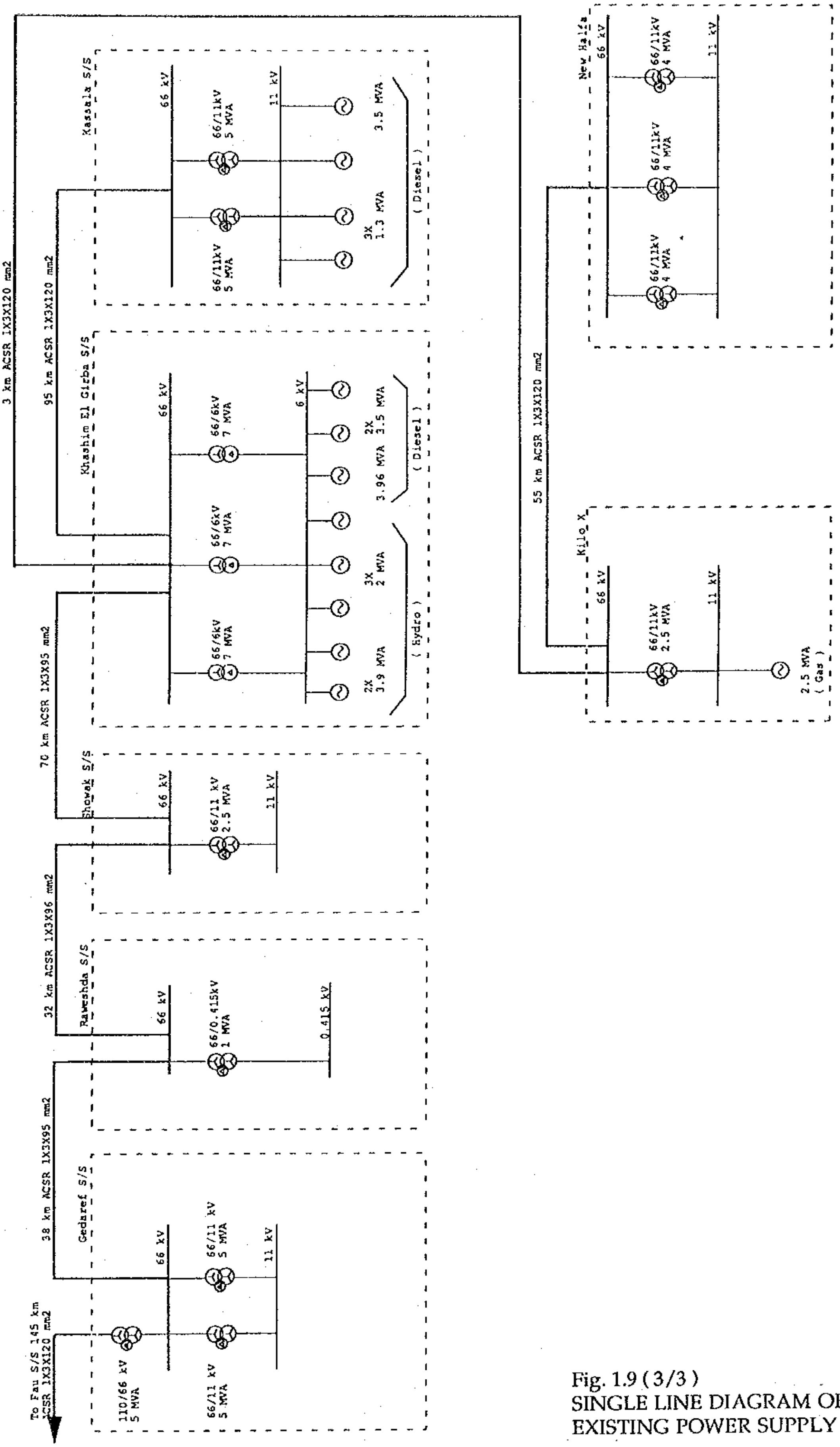
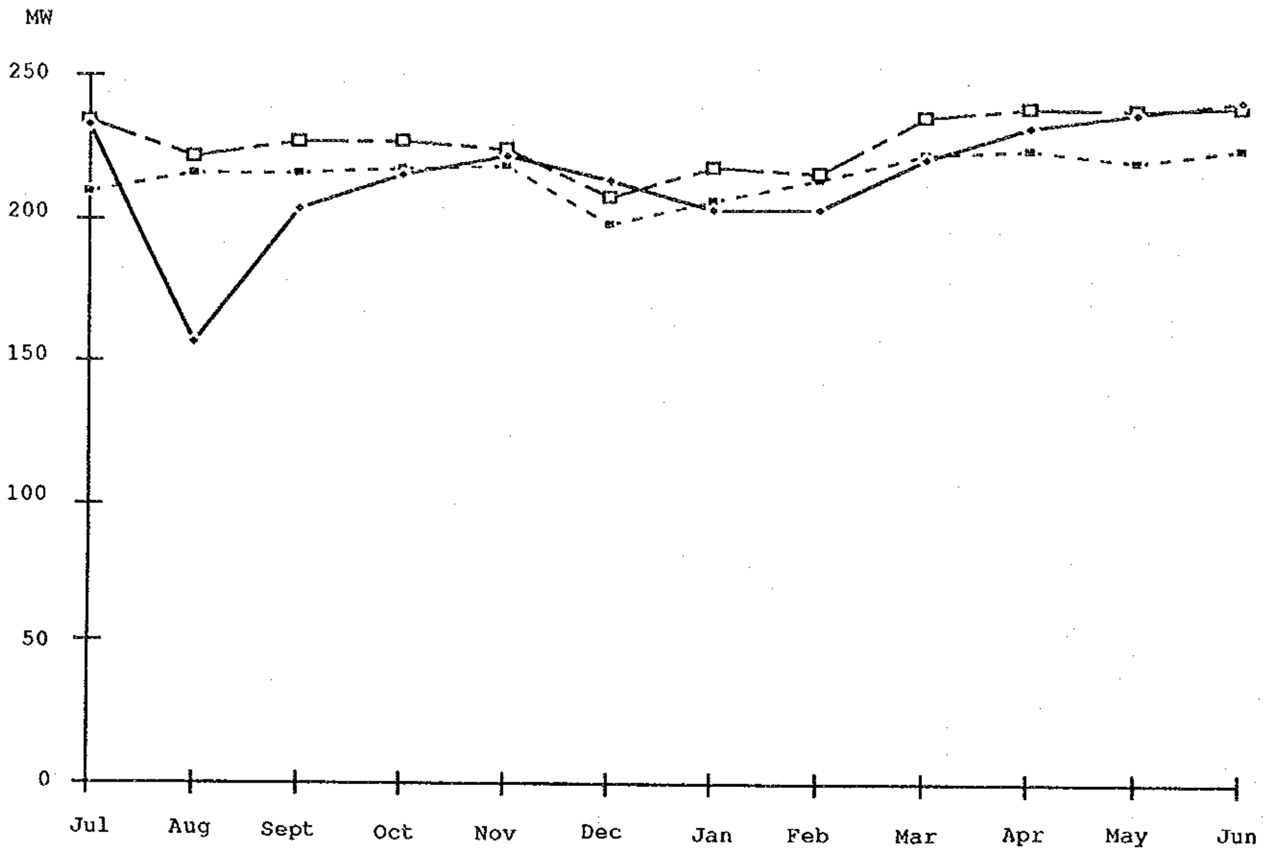
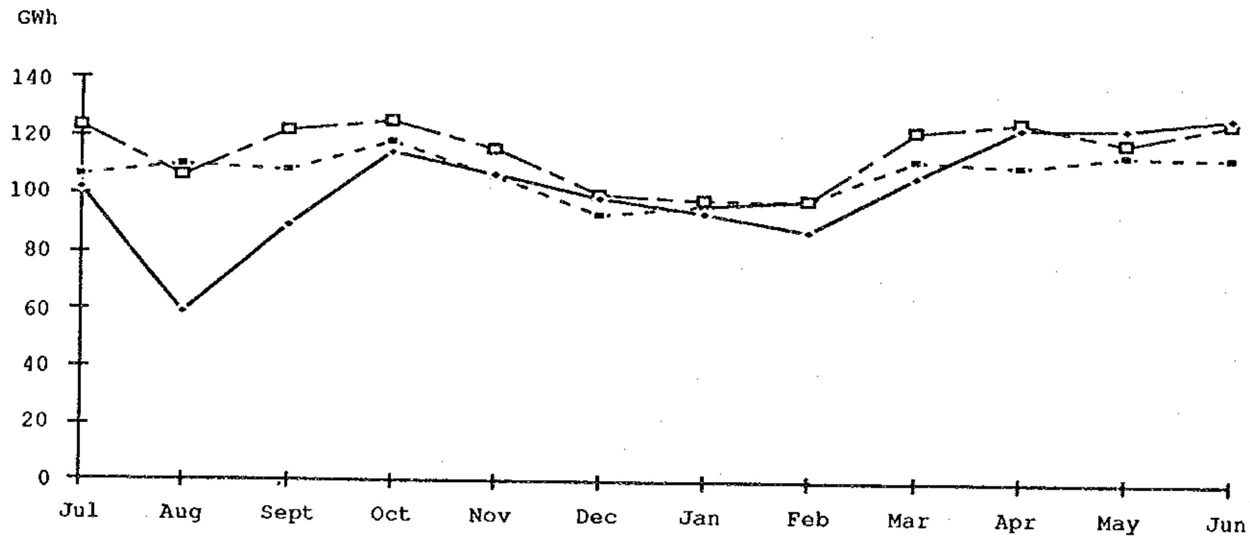


Fig. 1.9 (3/3)
SINGLE LINE DIAGRAM OF
EXISTING POWER SUPPLY SYSTEM



Monthly Maximum Power



Monthly Maximum Energy

NOTE:

FY 1986/1987

FY 1987/1988

FY 1988/1989

Fig. 1.10 GENERATION OF BLUE NILE GRID

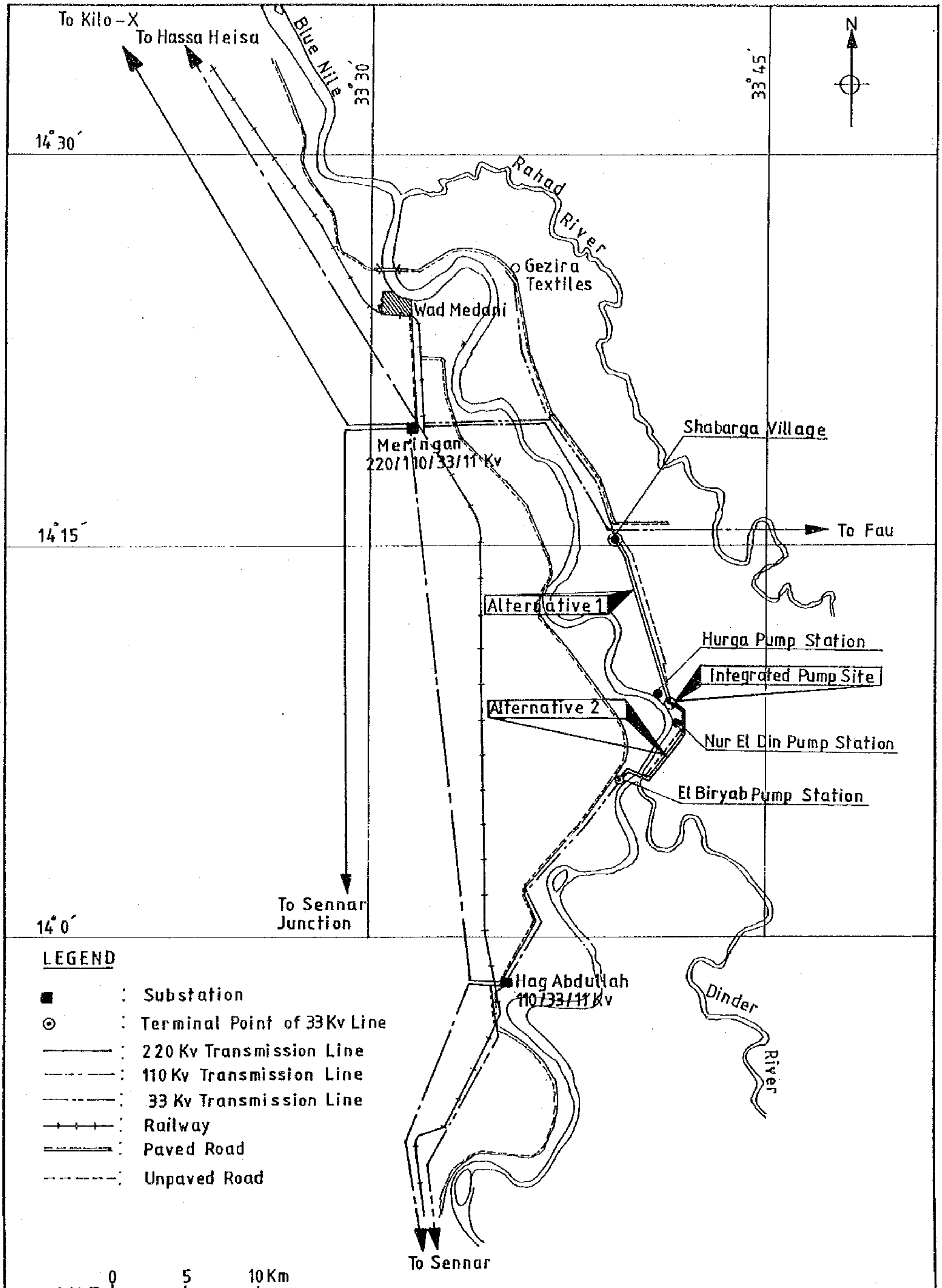


Fig. 1.11 EXISTING POWER SUPPLY SYSTEM IN PROJECT AREA

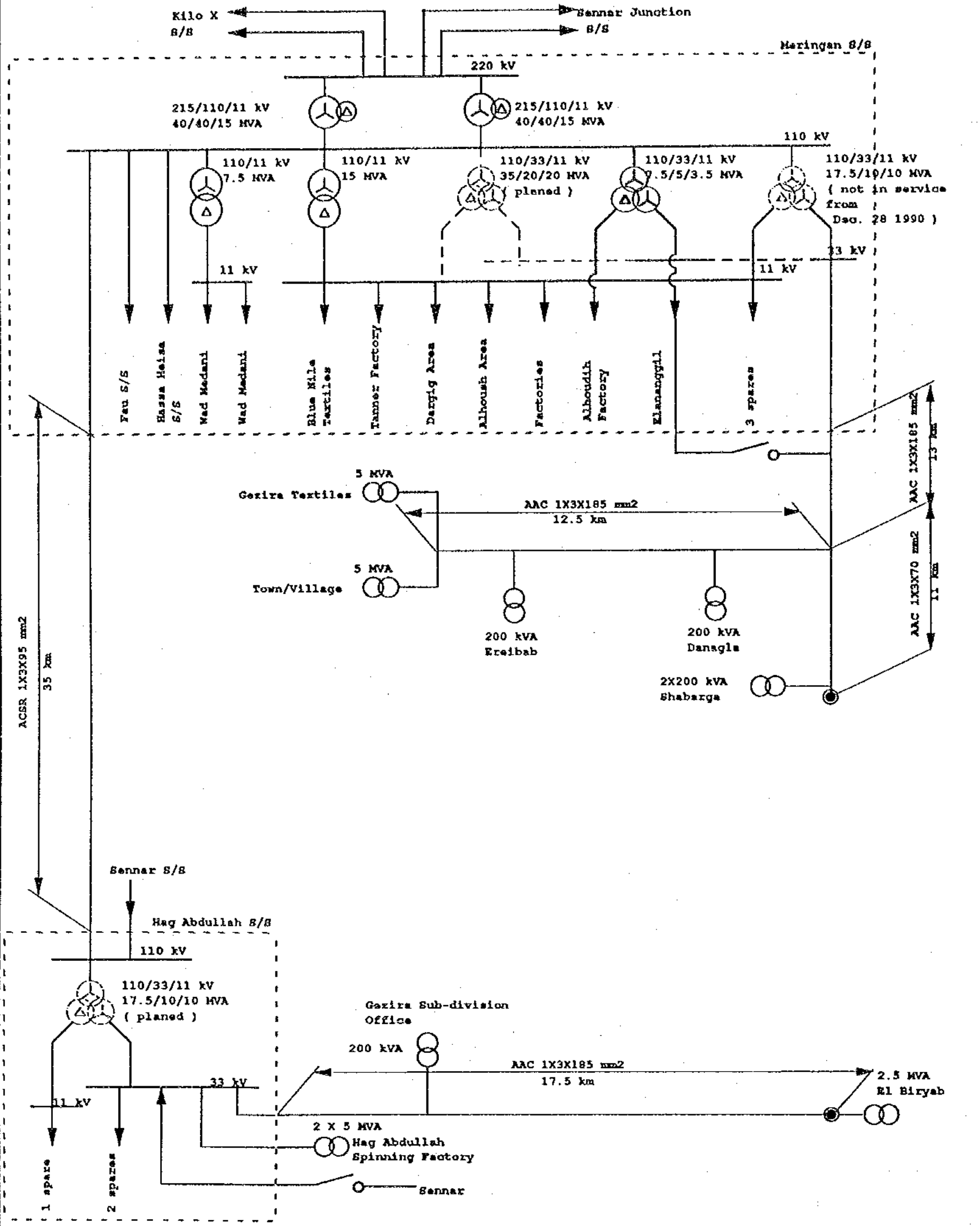


Fig. 1.12 SINGLE LINE DIAGRAM OF EXISTING POWER SUPPLY SYSTEM IN PROJECT AREA

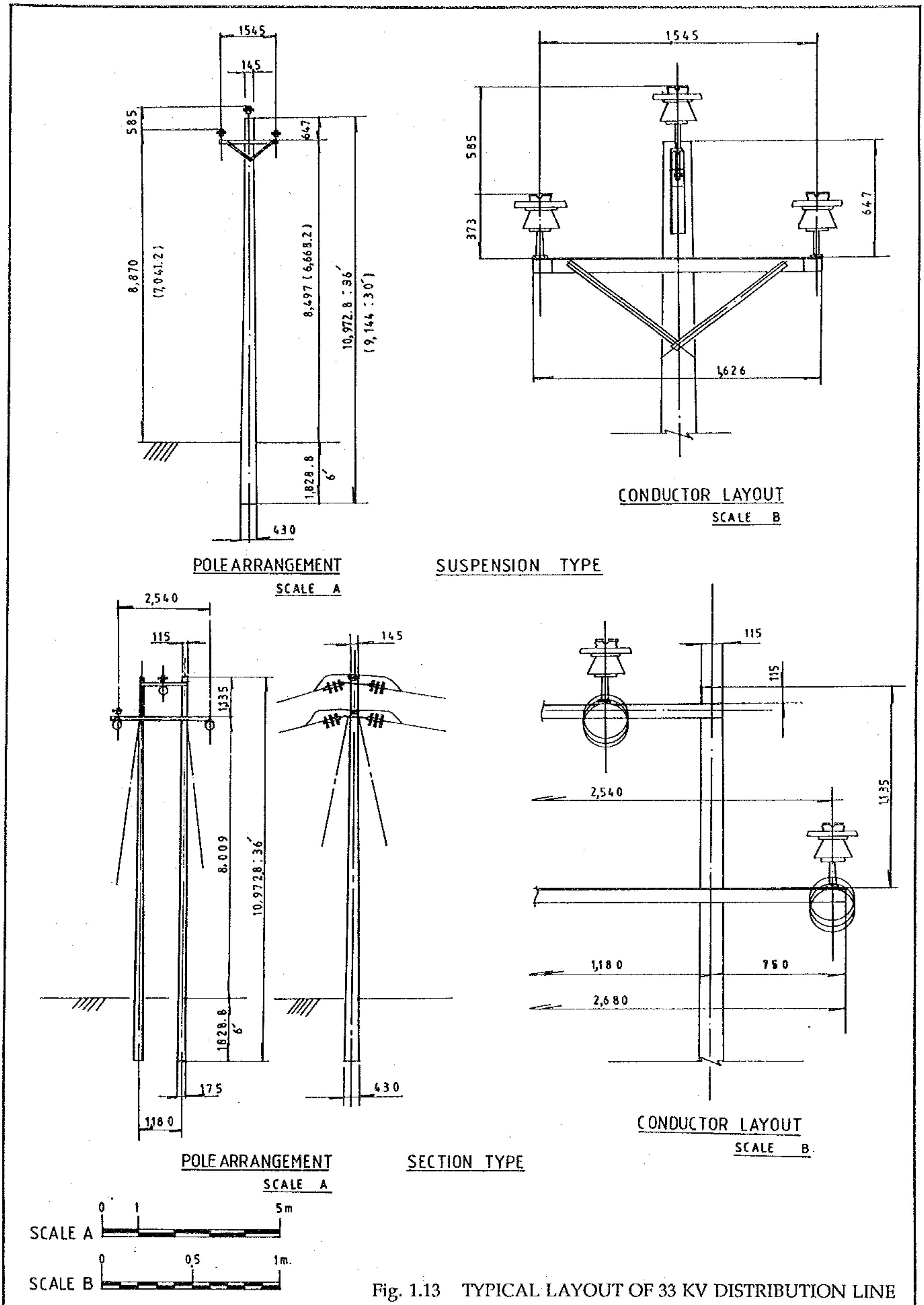


Fig. 1.13 TYPICAL LAYOUT OF 33 KV DISTRIBUTION LINE

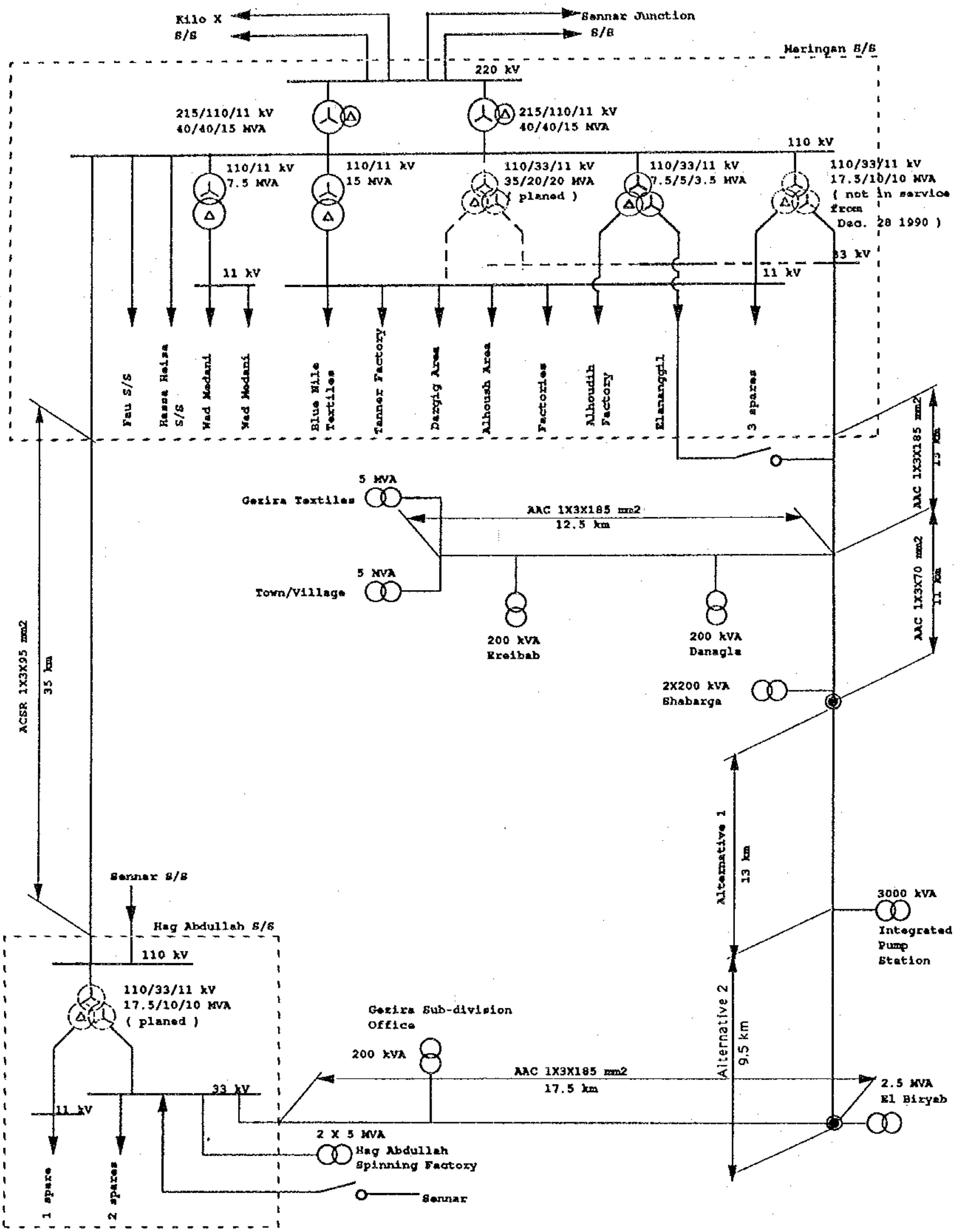


Fig. 2.1 ALTERNATIVE PLAN OF POWER SUPPLY

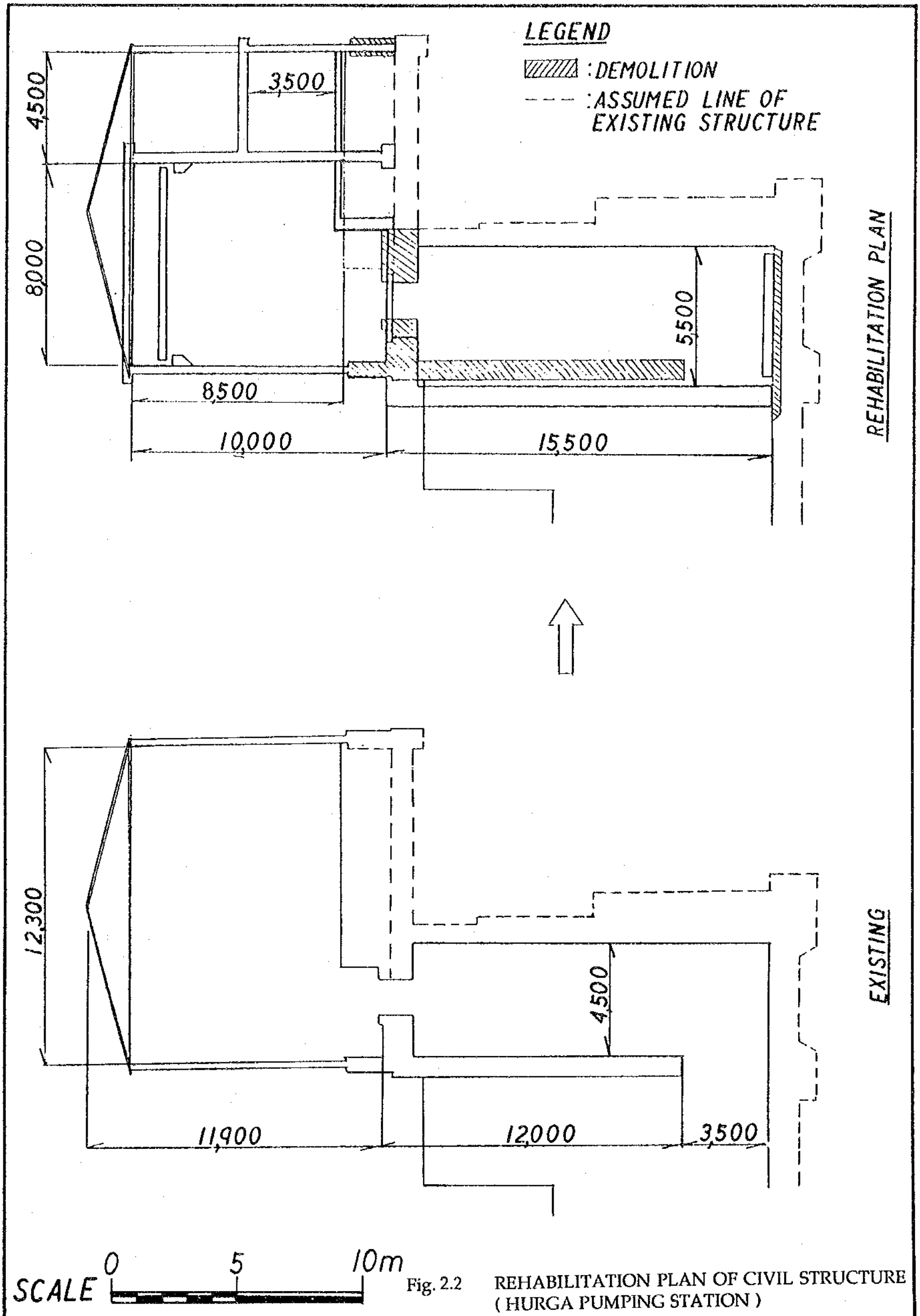
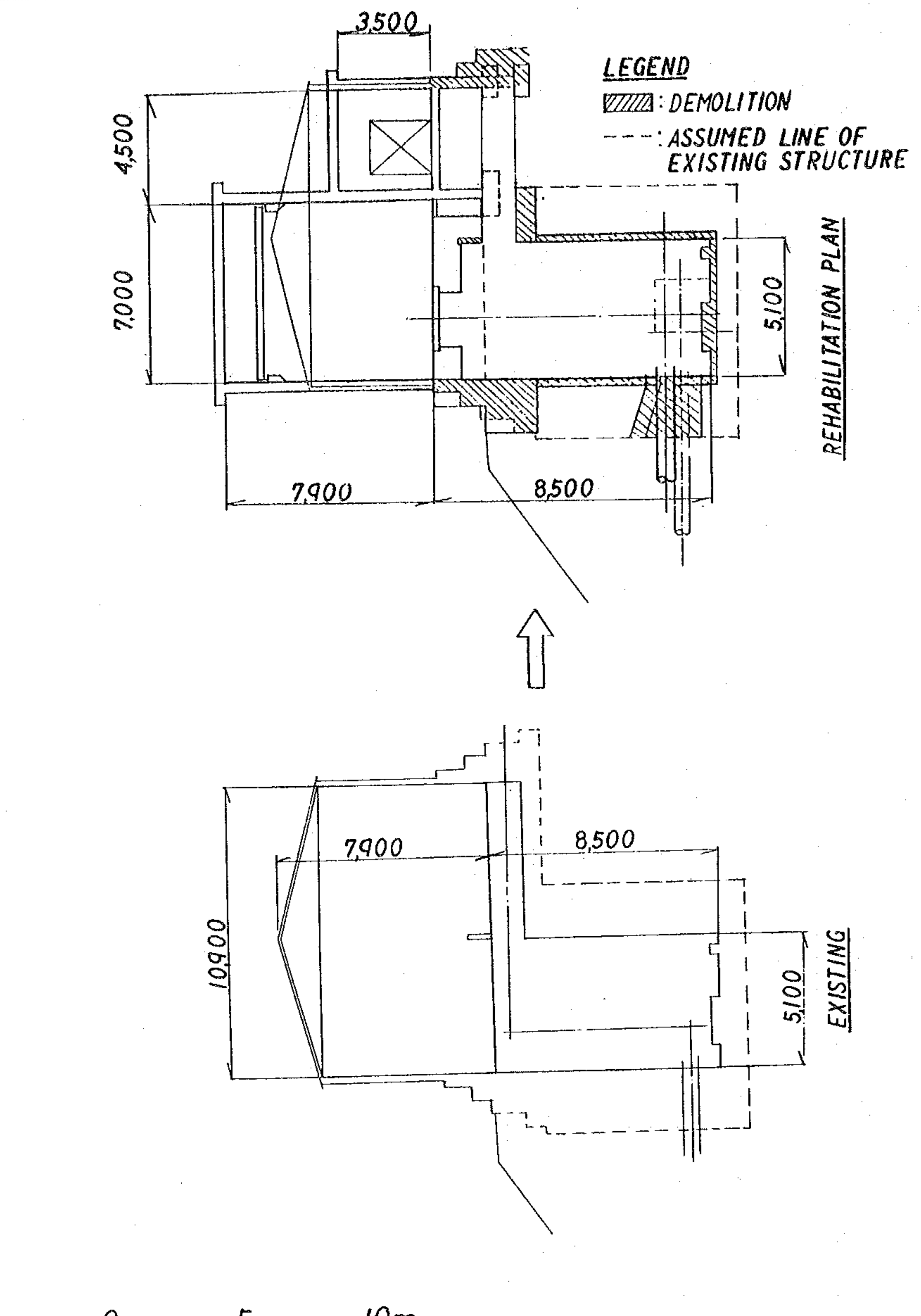


Fig. 2.2 REHABILITATION PLAN OF CIVIL STRUCTURE
(HURGA PUMPING STATION)



SCALE 0 5 10m

Fig. 2.3 REHABILITATION PLAN OF CIVIL STRUCTURE
(NUR EL DIN PUMPING STATION)

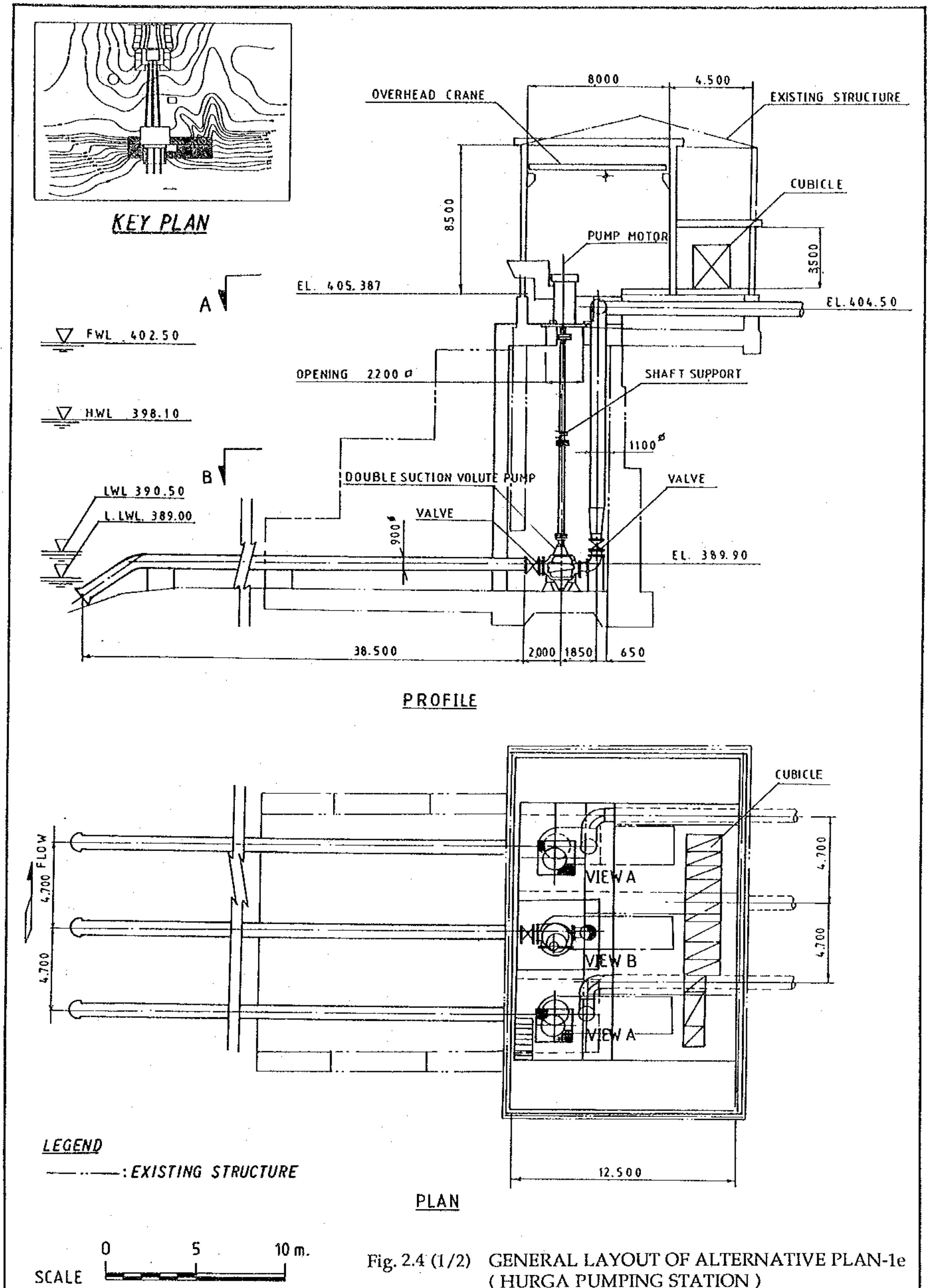


Fig. 2.4 (1/2) GENERAL LAYOUT OF ALTERNATIVE PLAN-1e
(HURGA PUMPING STATION)

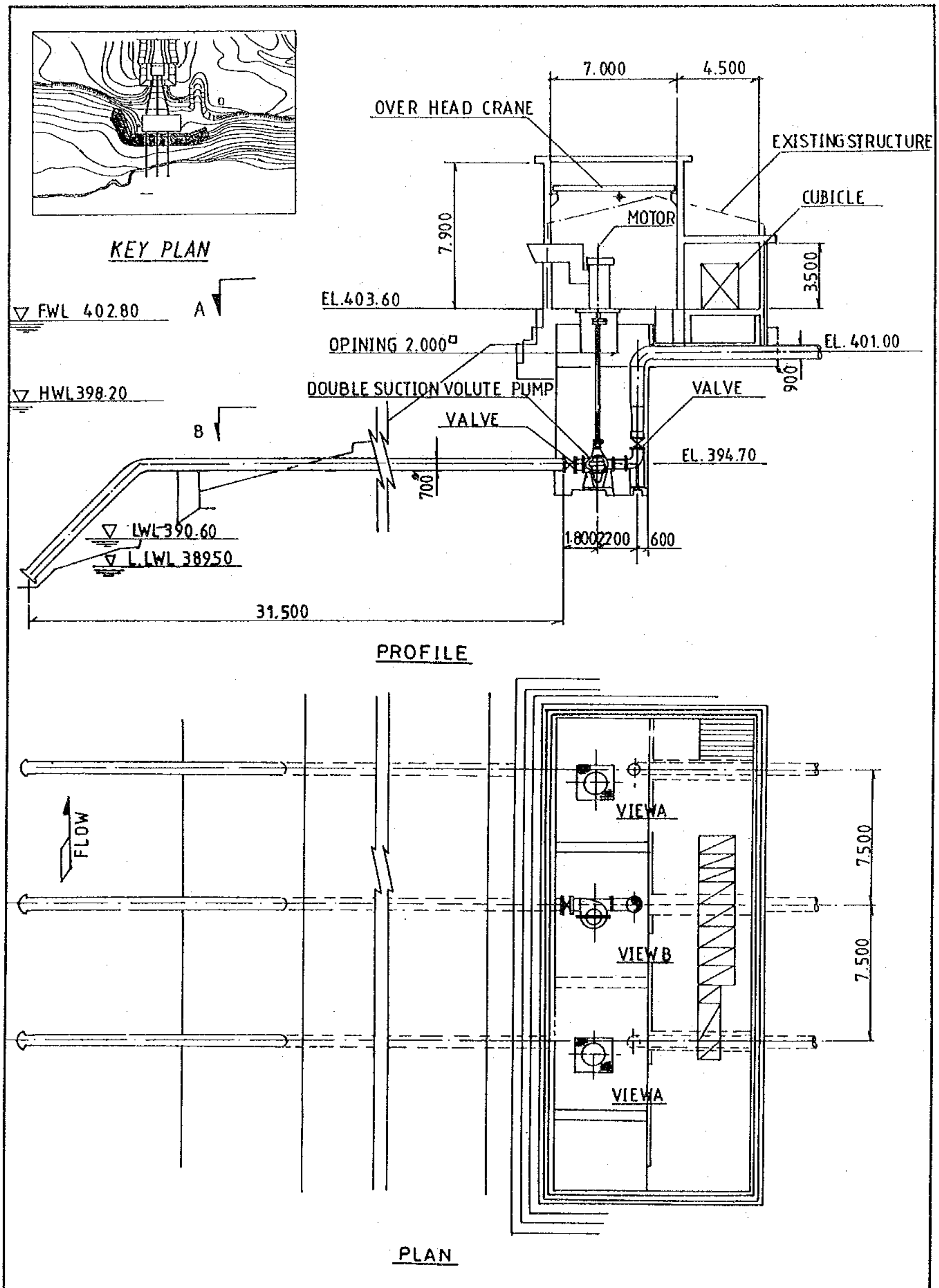


Fig. 2.4 (2/2) GENERAL LAYOUT OF ALTERNATIVE PLAN-1e
(NUR EL DIN PUMPING STATION)

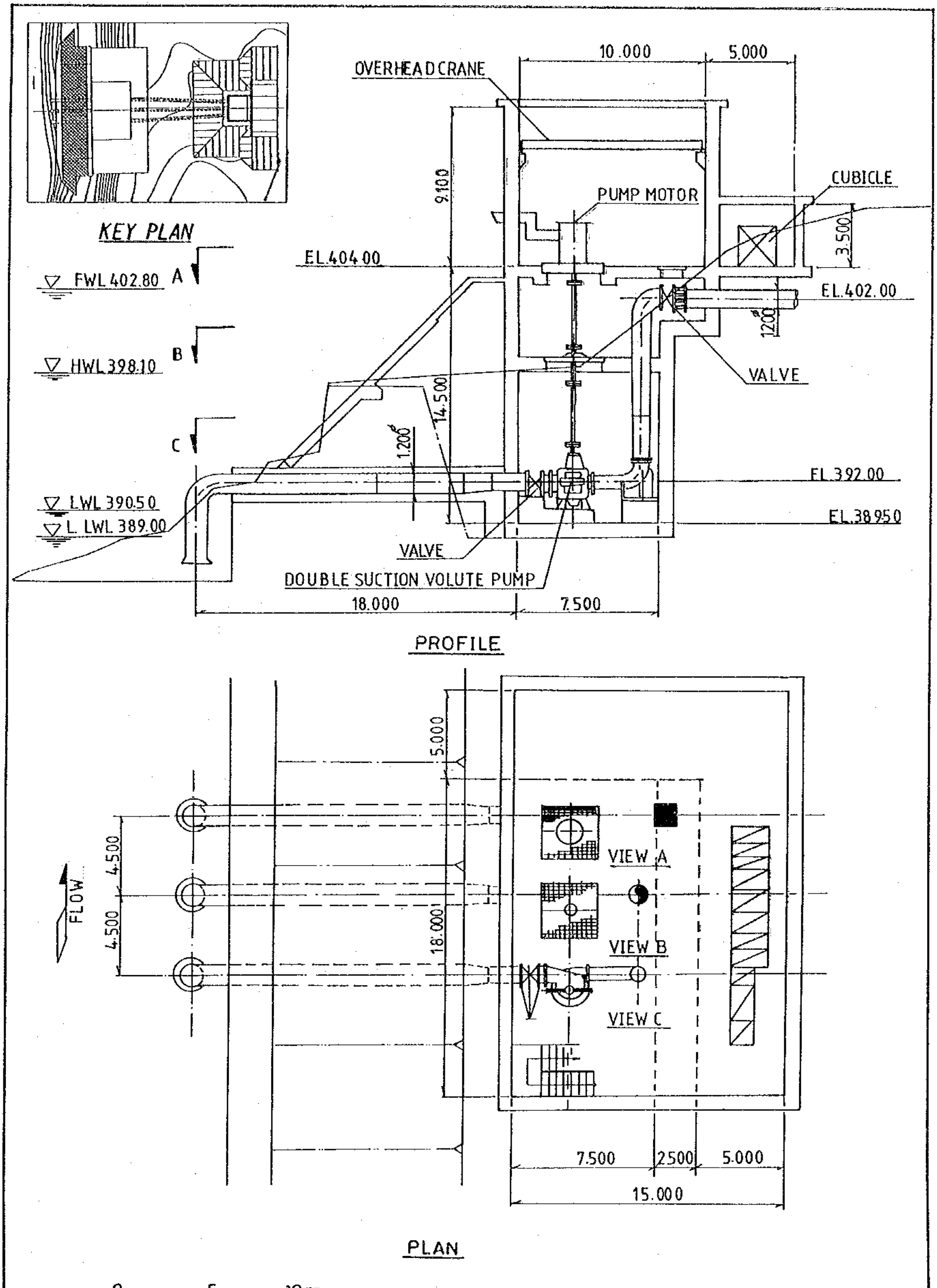


Fig. 2.5 GENERAL LAYOUT OF ALTERNATIVE PLAN-2c

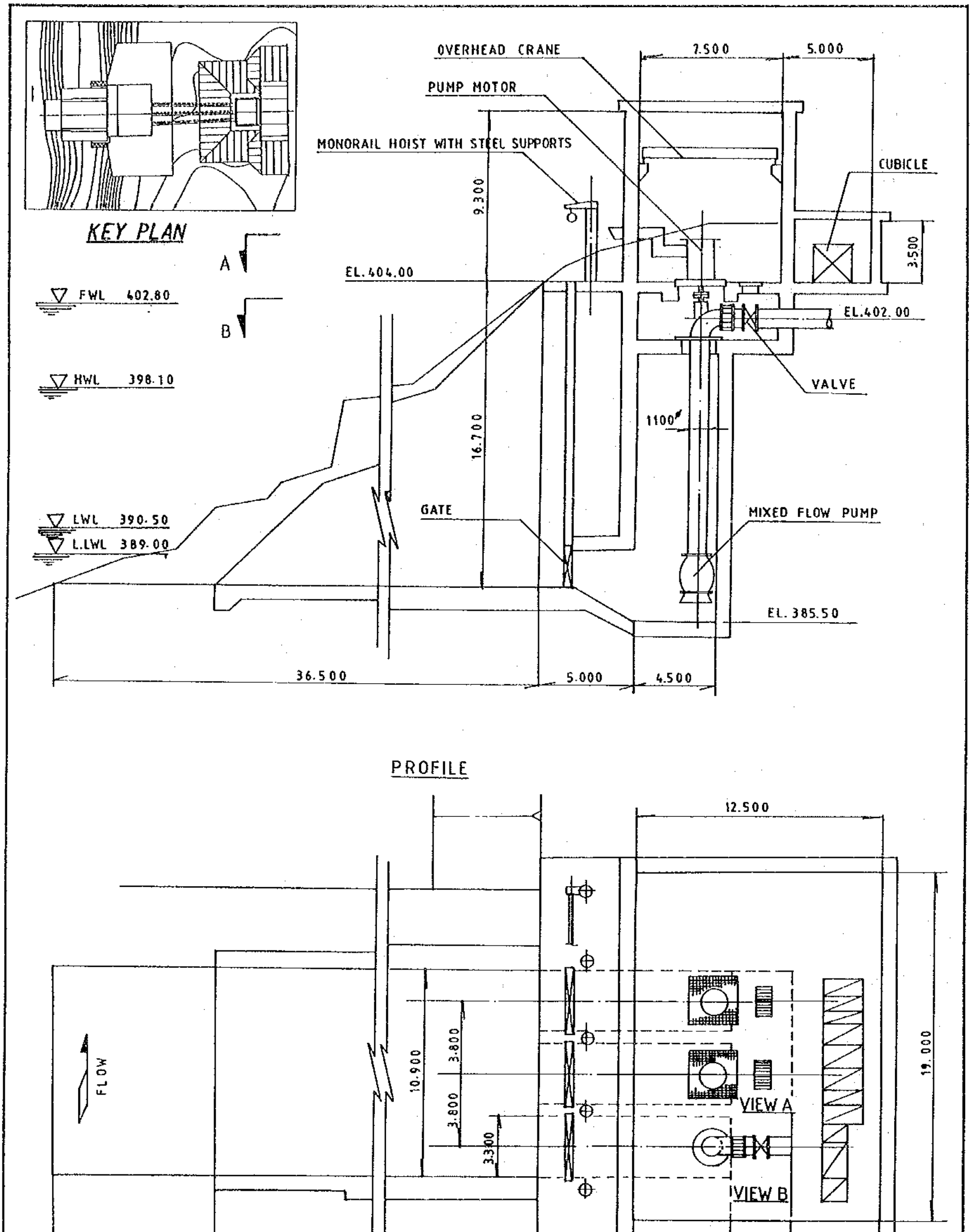


Fig. 2.6 GENERAL LAYOUT OF ALTERNATIVE PLAN-3e

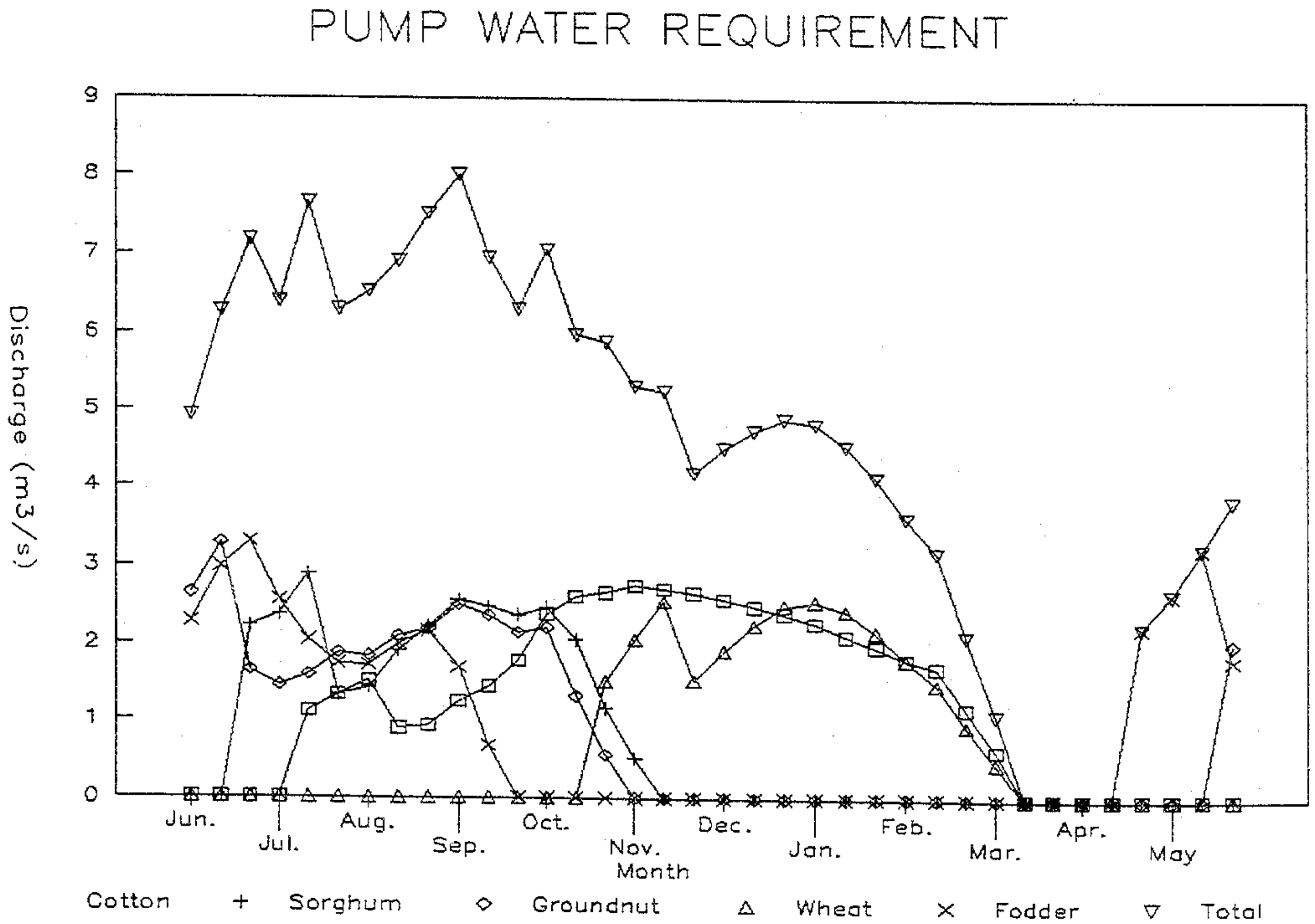


Fig.3.1 PUMP WATER REQUIREMENT

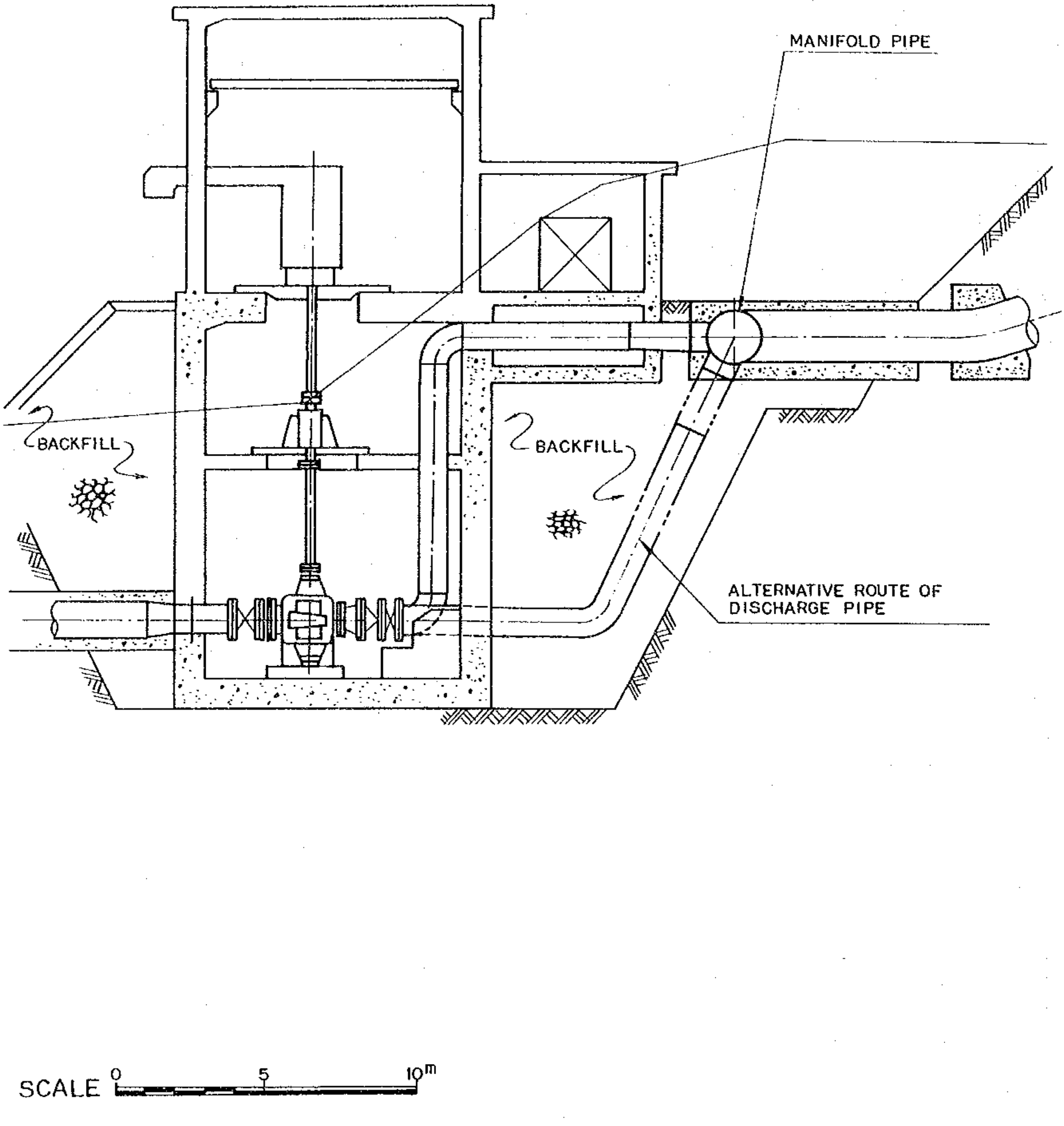


Fig. 3.2 ALTERNATIVE PLAN OF DISCHARGE PIPE

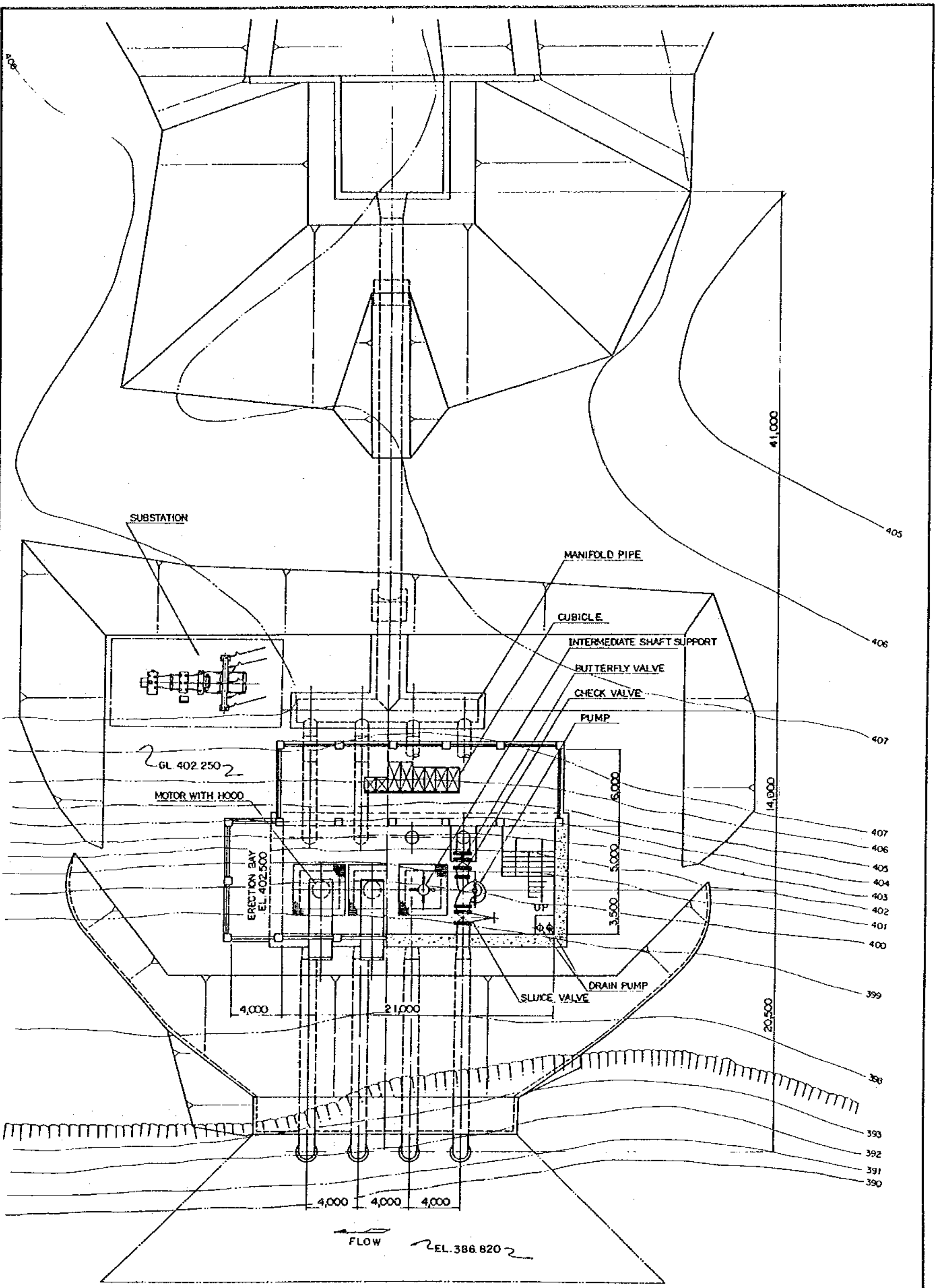


Fig. 3.3 (1/2) GENERAL LAYOUT OF PROPOSED PUMPING STATION

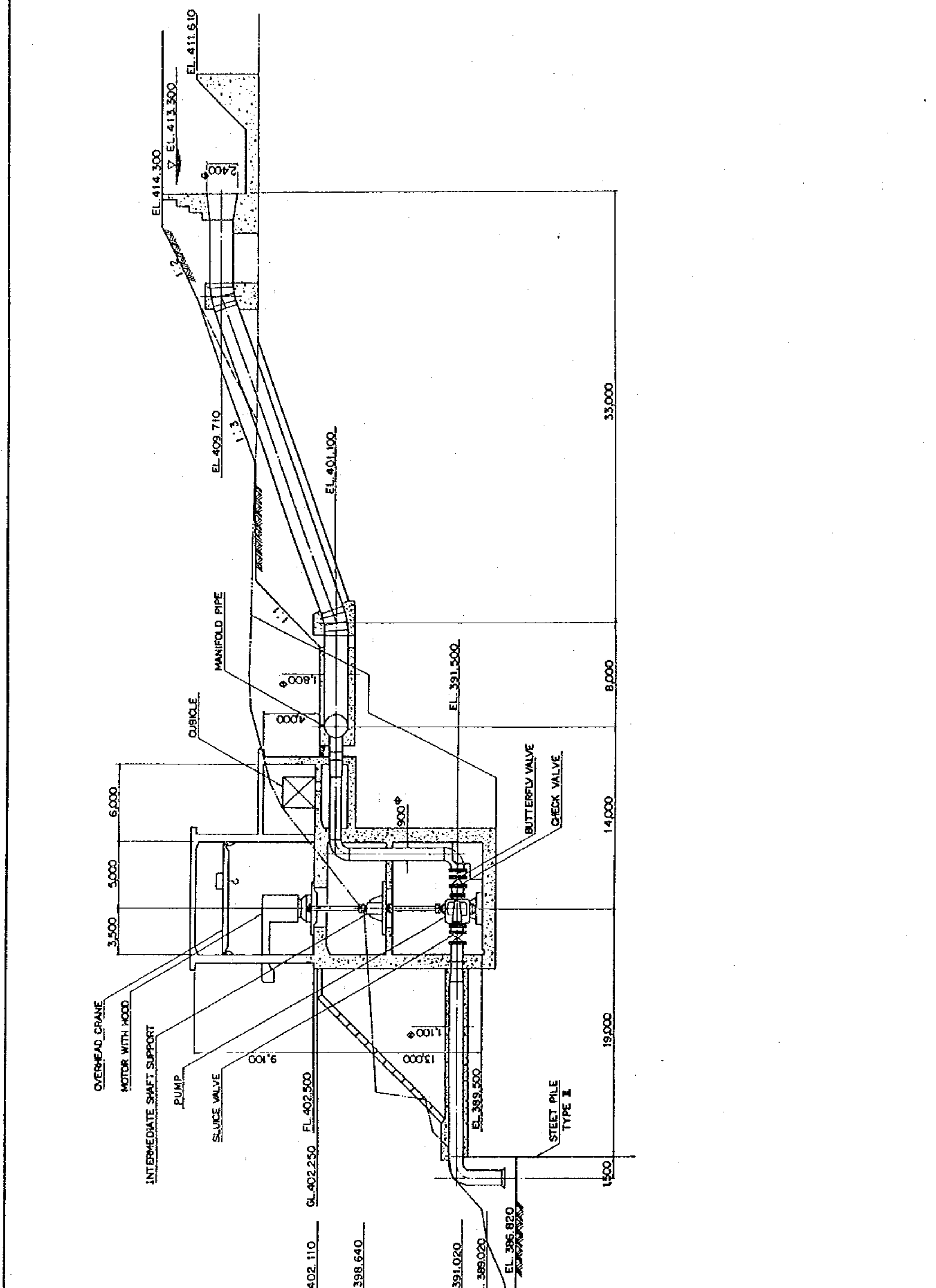


Fig. 3.3 (2/2) GENERAL LAYOUT OF PROPOSED PUMPING STATION

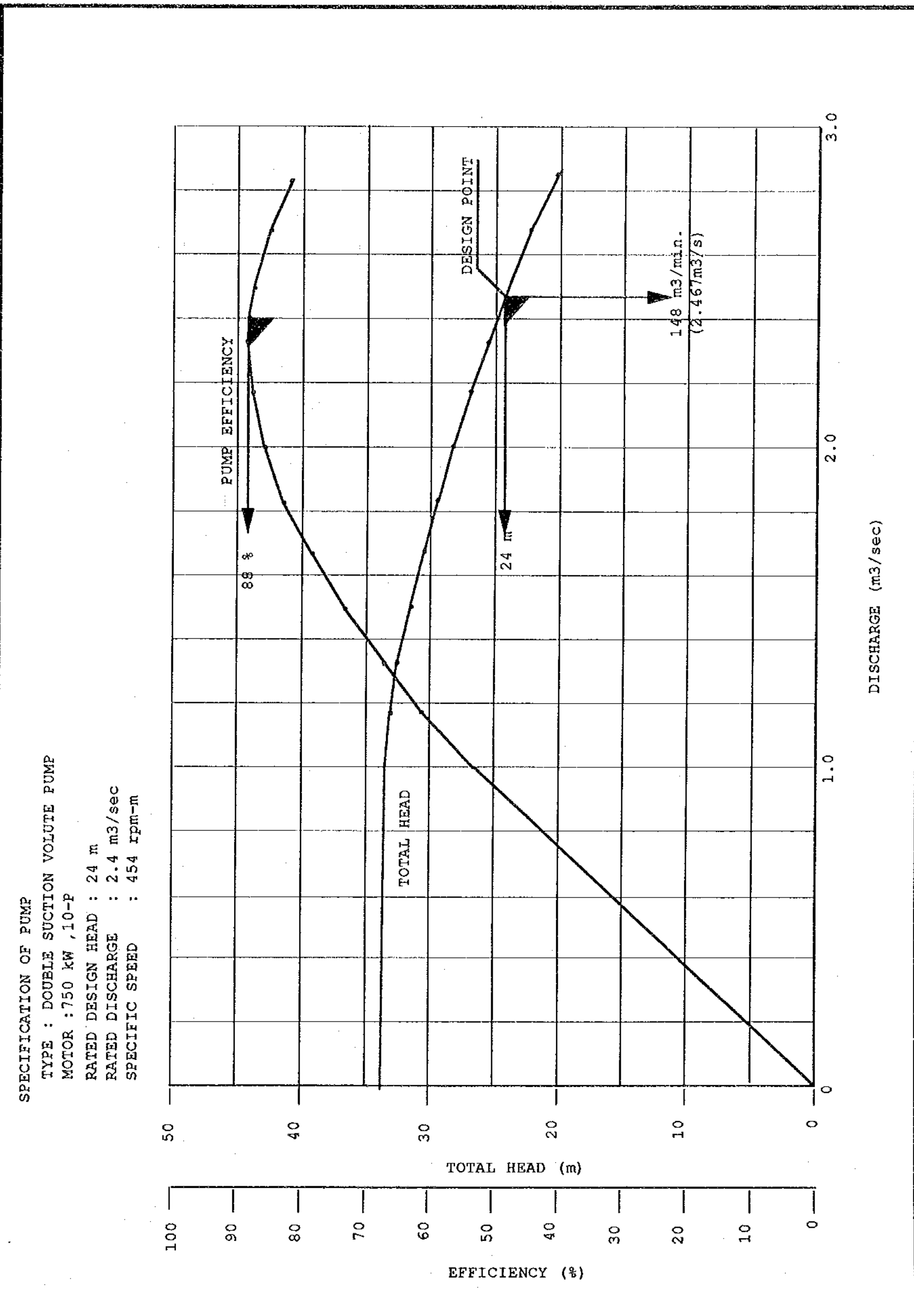
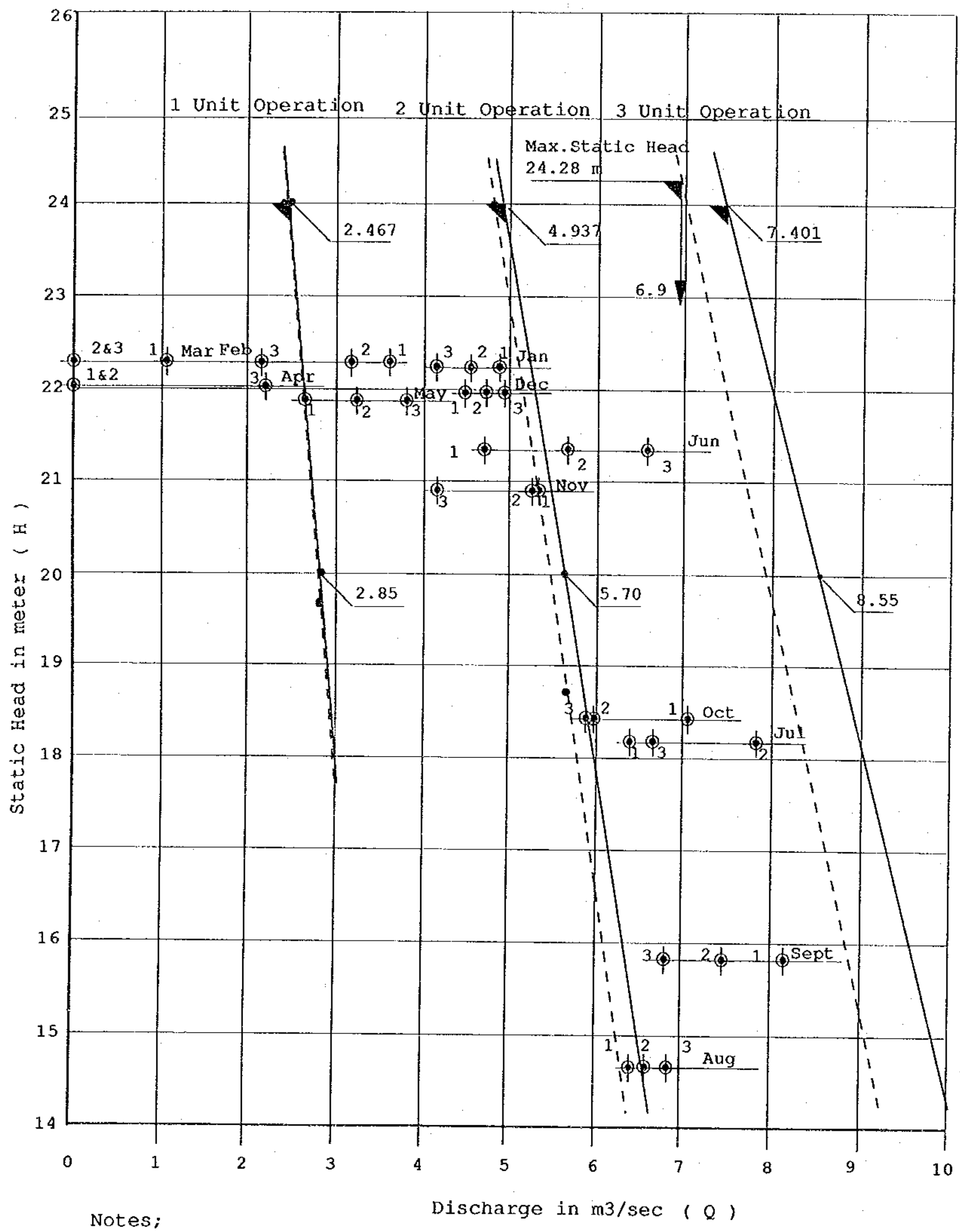


Fig.3.4 CHARACTERISTIC CURVE OF PUMP



Notes;

:Water requirement in Static Head & Discharge

:H-Q Curve including Head Losses

:H-Q Curve excluding Head Losses

Fig.3.5 SYSTEM CURVE OF PUMP

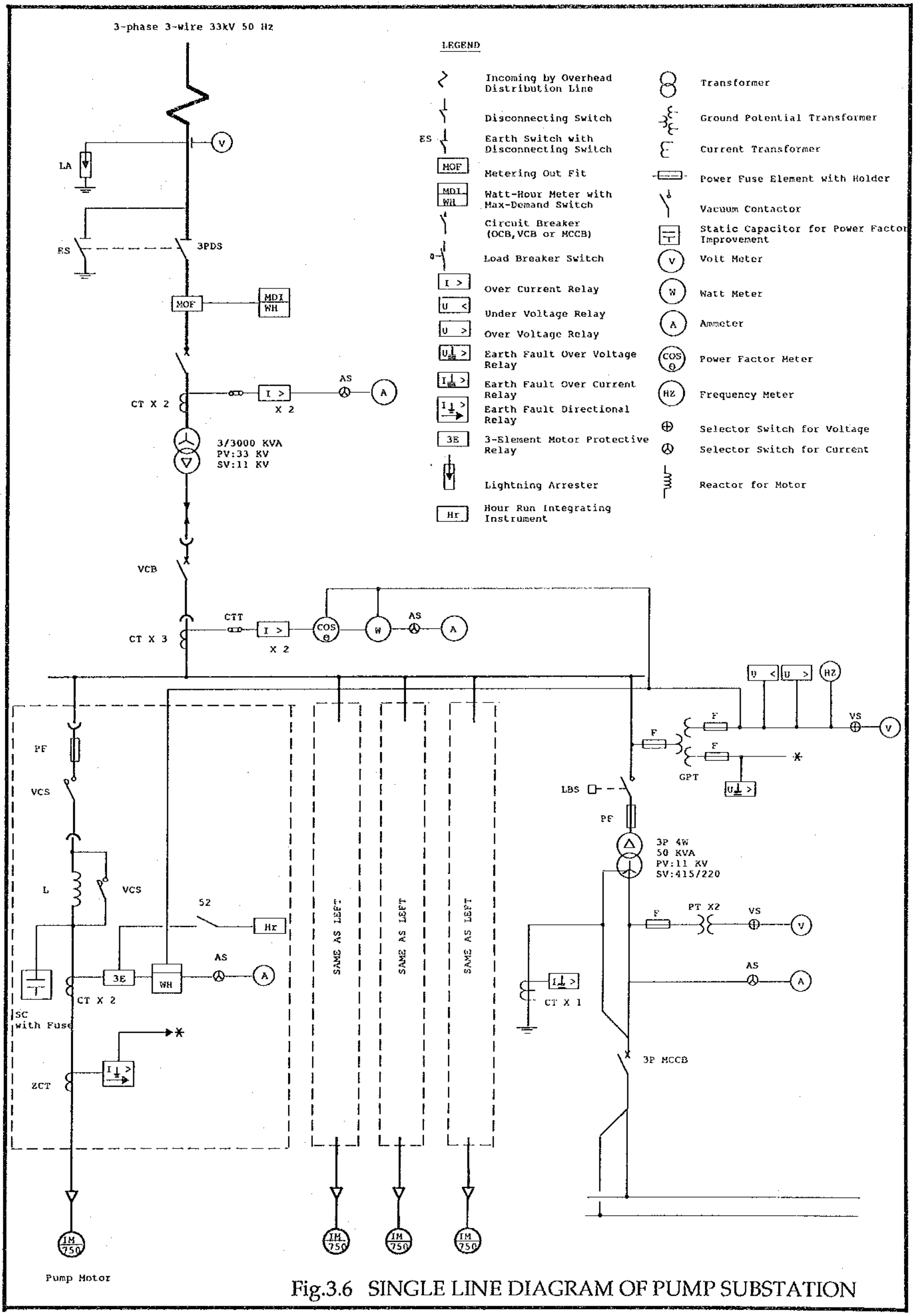


Fig.3.6 SINGLE LINE DIAGRAM OF PUMP SUBSTATION

APPENDIX

APPENDIX-I

NON-DESTRUCTIVE TEST

Results of Measurement of Schmidt Test Hammer (No. 1)

Date	Structure of Object	Measurement No.	Direction	Rebound Number	Presumption of Initial Strength	Revise Coefficient	Presumption of Compressive Strength
Nov. 20	Footing of	1	0°	39.9	350	0.63	221
Nov. 20	superstructure	5	0°	35.8	288	0.63	181
Nov. 20		10	0°	33.3	251	0.63	158
Nov. 20		11	0°	43.6	409	0.63	258
Nov. 20		12	0°	34.9	275	0.63	173
Nov. 20		13	0°	33.2	250	0.63	158
Nov. 20		23	0°	47.9	479	0.63	302
Nov. 20		24	0°	46.0	447	0.63	282
Nov. 20		25	0°	41.4	373	0.63	235
Nov. 20		22	0°	35.1	278	0.63	175
Nov. 20		27	0°	39.6	344	0.63	217
	Total						2,360
	Average						215
	Max.						302
	Min.						158
Nov. 20	Pump House	14	+90°	41.4	316	0.63	199
Nov. 20	Slub	26	+90°	47.3	416	0.63	262
	Total						461
	Average						231
	Max.						262
	Min.						199
Nov.21	Foot of	2	0°	41.0	367	0.63	231
Nov.21	Column	3	0°	39.1	337	0.63	212
Nov.21		4	0°	44.1	417	0.63	263
Nov.21		6	0°	48.4	487	0.63	307
Nov.21		7	0°	43.4	406	0.63	256
Nov.21		8	0°	47.4	471	0.63	297
	Total						1,566
	Average						261
	Max.						307
	Min.						212
Nov.21	Gear Floor	28	-90°	29.0	235	0.63	148
Nov.21		29	-90°	28.0	220	0.63	139
Nov.21		30	-90°	26.3	199	0.63	125
Nov.21		31	-90°	29.4	240	0.63	151
	Toal						563
	Average						141
	Max.						151
	Min.						125
Nov.20	Suction chamber	18	0°	36.4	297	0.63	187
Nov.21		32	0°				
Jan. 9		33	0°	35.4	283	0.63	178
Jan. 9		34	0°	36.9	304	0.63	192
Jan. 9		35	0°	24.2	130	0.63	82
	Total						639
	Average						160
	Max.						192
	Min.						82

Results of Measurement of Schmidt Test Hammer (No. 2)

Date	Structure of Object	Measurement No.	Direction	Rebound Number	Presumption of Initial Strength	Revise Coefficient	Presumption of Compressive Strength
Nov.20	Intake wall	15	0°	40.2	353	0.63	222
Nov.20		16	0°	33.0	247	0.63	156
Nov.20		17	0°	32.7	243	0.63	153
Nov.20		19	0°	36.7	301	0.63	190
Nov.20		20	0°	33.8	258	0.63	163
Nov.20		21	0°	34.9	275	0.63	173
	Total						1057
	Average						176
	Max.						222
	Min.						153

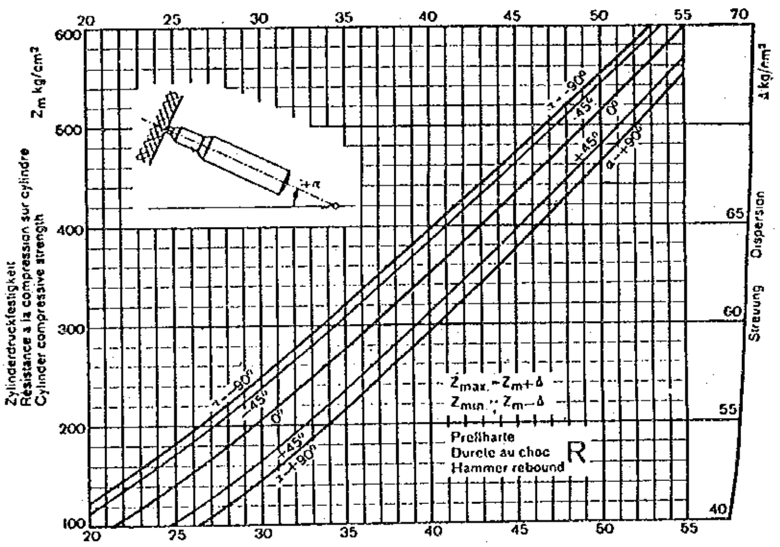
1) Measuring Instrument - Schmidt Test Hammer
Manufactured by Switzerland Proceq S.A.
Type - N Type
Applicable Concrete - Ordinary Concrete
Impact Energy - 0.225 kgf/cm²
Strength Measuring Scope - 150-600 kgf/cm²

2) Number of Stations - Judging from the Concrete's present condition, there are 20 stations in one measuring location, exceeding the norm by 10 points.

3) The abnormal values caused by extreme echos during a percussion, and the percussion direction value of +90° were excluded from the Estimated Compressive Strength of Concrete.

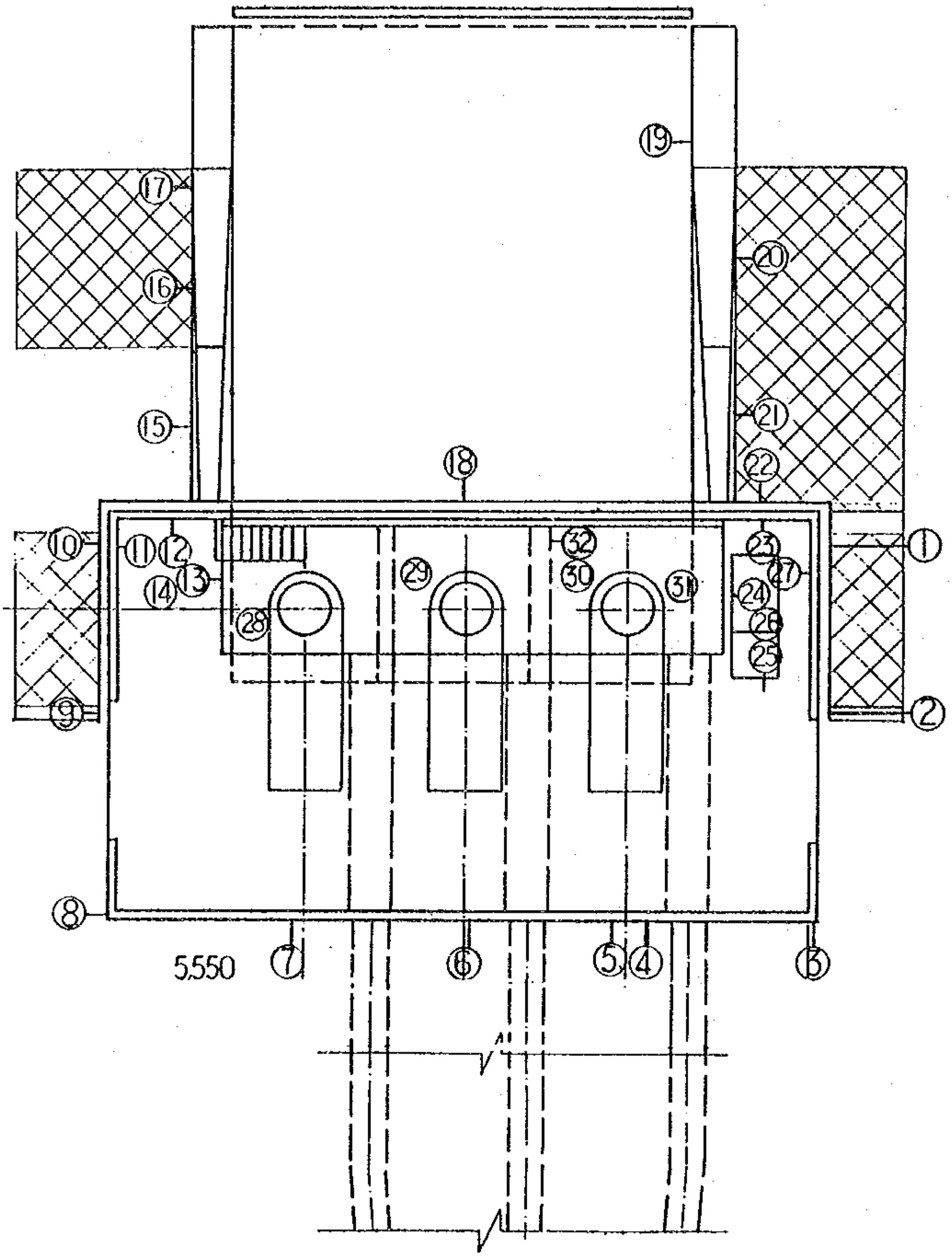
4) Presumption of Compressive Strength - The Presumption of Compressive Strength was calculated from the Rebound Number - Strength Curve Line Graph below drawn by the Federal Material Testing Center of Zurich, Switzerland.

Rebound Number - Strength Curve Line



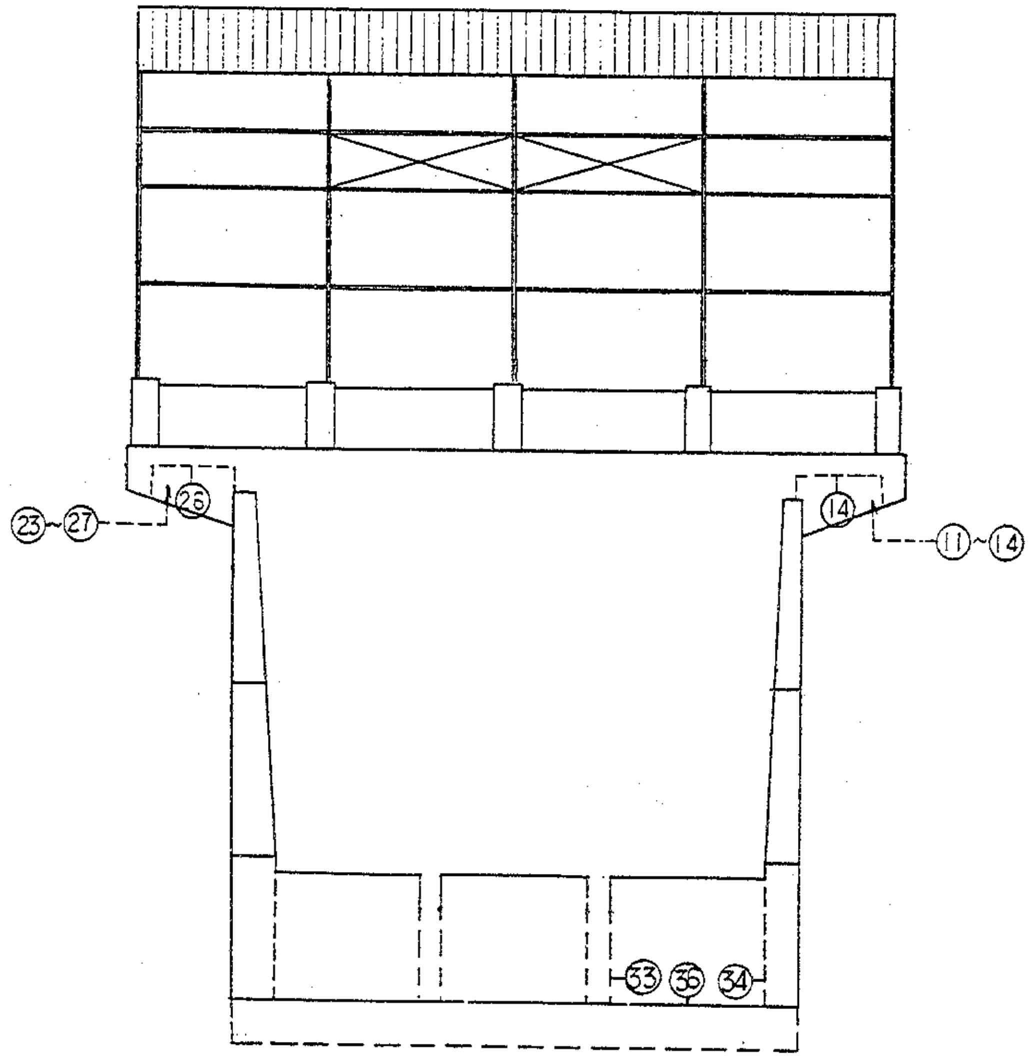
5) Revision - The Revision of the values shown in the graph was conducted by using the Internationally adopted DIN 4240 (Deutsche Industri Normen) table below.

Age (No.of days)	10	20	28	50	100	150	200	300	500	1,000	3,000
αn	1.55	1.15	1.00	0.87	0.78	0.74	0.72	0.70	0.67	0.65	0.63



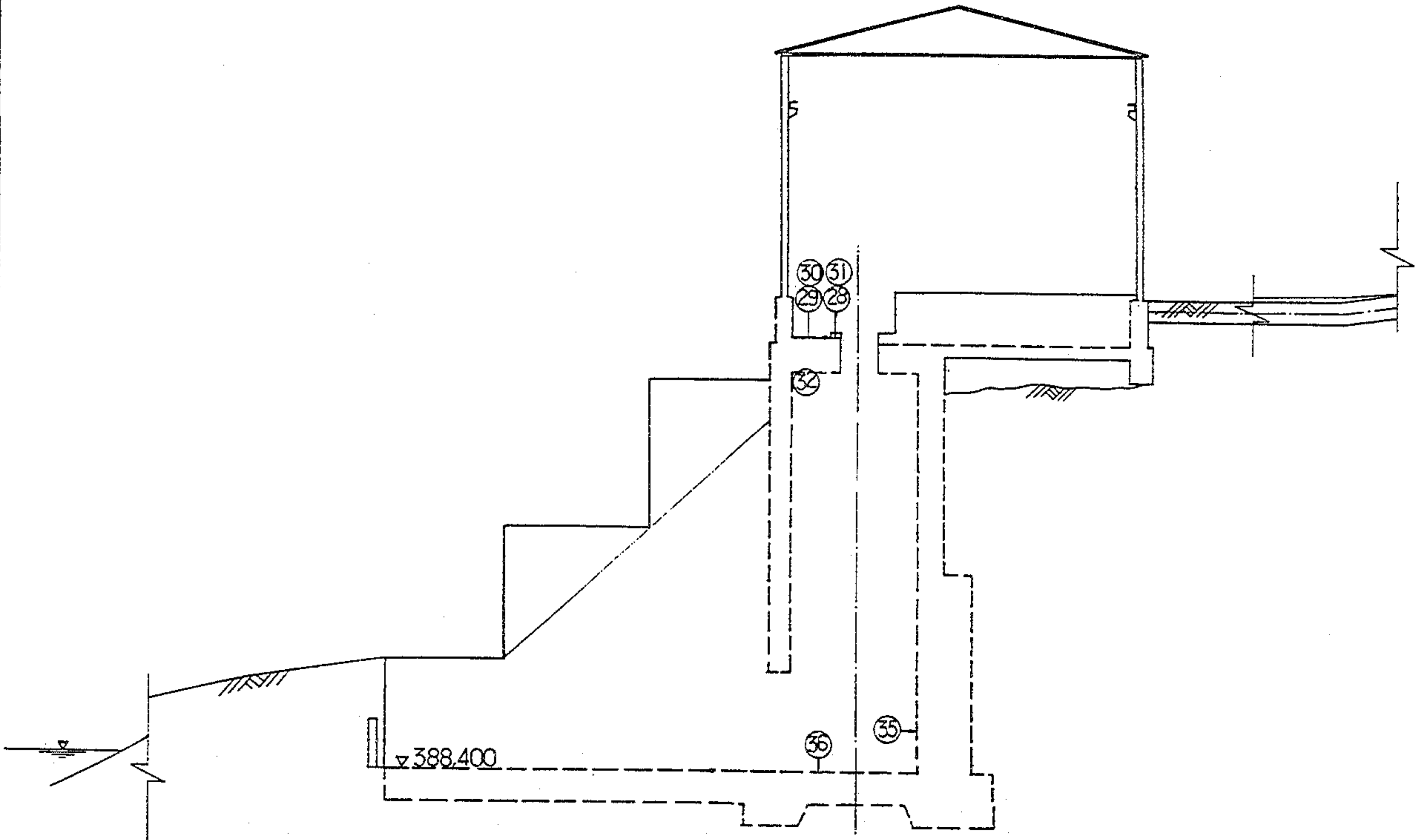
HURGA PUMP STATION (GROUND VIEW)

MEASUREMENT POINT OF SCHMIDT HAMMER TEST (1/3)



HURGA PUMP STATION (FRONT VIEW)

MEASUREMENT POINT OF SCHMIDT HAMMER TEST (2/3)



HURGA PUMP STATION (CROSS SECTION)

MEASUREMENT POINT OF SCHMIDT HAMMER TEST (3/3)

ANNEX-F

IRRIGATION AND DRAINAGE

FINAL REPORT

FOR

THE FEASIBILITY STUDY

ON

THE HURGA AND NUR EL DIN PUMP SCHEME REHABILITATION PROJECT

ANNEX F : IRRIGATION AND DRAINAGE

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1. PRESENT CONDITIONS

1.1 Historical Background

The Project area covers the existing Hurga and the Nur El Din Pump schemes.

The Hurga and Nur El Din Pump schemes were established in 1950s as private cotton growing schemes with a net irrigation area of 10,400 feddan (Ref.No.IR-101) and 8,400 feddan (Ref.No.IR-102). In the early part of 1970s, both schemes were nationalized along with all pump irrigation schemes having pumps larger than six inches in diameter on the White Nile and the Blue Nile, and came under the direct administration of the Agrarian Reform Corporation. They were further transferred to Blue Nile Agricultural Corporation (BNAC). In 1976, the management for agricultural production of these schemes were taken over by the Sudan Gezira Board (SGB). At the same time, the pumping stations and other irrigation facilities of these schemes were turned over to the Ministry of Irrigation (MOI) for their operation and maintenance.

Agricultural production was originally based on a three-course rotation of cotton-sorghum/groundnut-fallow to a 15 feddan tenancy. SGB also followed the three-course rotation and provided tenants with extension services and agricultural supporting services for growing cotton. From 1981 onward, however, SGB has actually limited his services for the schemes to water control at minor canal and Abu XX level since unstable water supply caused mainly by deterioration of pumps hindered growing cotton. MOI continued his services but pump operation has been shortened to about three to four months between July and October for supplementary irrigation for Sorghum (dura) since then.

1.2 Irrigation and Drainage System

1.2.1 General

Although both schemes were originally established as private schemes, the canal systems including pumping stations were designed and constructed in compliance with requirement of Part II of the Second Schedule of the Nile Pumps Control Regulation 1951. These canal systems fulfill the design standard currently employed by MOI.

1.2.2 Pumping Stations

Hurga and Nur El Din pumping stations are closely located on the east bank of the Blue Nile between the confluence of the Dinder and Rahad rivers, and the former one is situated about 2 km downstream of the latter pumping station.

(1) Hurga Pumping Station

The pumping station is of three reinforced concrete suction pits built into the river bank with a building made of steel framed brick masonry walls and corrugated slate roof. Three vertical mixed flow type pumps driven by diesel engines through right angled gear boxes were installed in 1958. The rated capacity of each pump is 1.5 m^3/s against a head of 20.5 m. At present two pumps and two engines as well are operational, but appear to be in a very poor state of repair and maintenance. According to the pumping test conducted by Mechanical and Electrical Under-secretariat, MOI in collaboration with the Hydraulic Research Station (HRS), MOI in September 1990, pumping capacity has decreased to some 70 % of the nominal one (Actual pumping efficiency at the time of the test is not known).

It is said that the river has fallen below the originally designed suction level during a low water period and that pumping during the same became impossible recently. According to observations conducted during November to December 1990 by the JICA Study Team, the river was going down day by day and became about 0.5 m above the floor elevation of the inlet channel. This is indicative of the above information.

(2) Nur El Din Pumping Station

The pumping station consists of a gravity type brick masonry dry well built into the river bank with a building made of a steel framed brick masonry walls and corrugated slate roof. Three mixed flow volute type pumps driven by diesel engines through flat belts were established in 1958. The rated capacity of each pump is 1.0 m^3/s against a head of 20.0 m. Out of three, two pumps are operational at present, but in so poor condition that the pumping capacity of these pumps has decreased to about 40% of the nominal one according to the pumping tests conducted along with the Hurga pumps in 1990.

Similar to the Hurga pumping station, difficulty in pumping during the low water period is reported.

1.2.3 Canal Network

(1) Hurga Scheme

The canal network is composed of a main canal, a major canal branching off from the main canal, 10 minor canals and a large number of field channels. Length and nominal commanding area of respective canals are given in Table 1.1, and breakdown of the commanding area for each of canals are shown in Table 1.2.

The field channels consists of Double Abu XXs (Abu Ishreen; water-course), Abu XXs and Abu VIs (Abu Sitta; secondary watercourse). The Double Abu XX serves a few to several on-farm blocks, locally called "Numbers", while Abu XX commands one "Number". The Number in the scheme varies from 100 feddan to some 20 feddan depending on the topographic limit. It is divided into a 5 feddan farm plot locally known as "Hawasha" by a series of Abu VI taking off at right angle from Abu XX. All the canals are of earth canals with trapezoidal to semicircular cross sections. The nominal capacity of Abu XX and Abu VI is 115 l/sec and 50 l/sec, respectively, but the actual ones seem to become much smaller by siltation as a whole except for some canals well maintained by tenants. General layout of the canal network is presented in Figs. 1.1 and 1.2.

These canals are properly aligned in general but its elevation is reportedly not high enough in some reaches. As mentioned in Sub-section 1.2 "Maintenance of Irrigation Facilities", desilting was carried out for most of these canals in this year but the silt excavated are dumped and left on the canal banks without any compaction nor dressing. Field channels exist in the most part of the service area.

Well-head regulators are generally installed at the head of the major and the minor canal. Pipe regulators are situated at the head of Double Abu XX. Both well-head and pipe regulators are constructed also in these canals as cross regulators to maintain water level at full supply level (FSL). Well-head regulators consist of an upstream brick masonry well, steel pipe(s) and steel gate(s) installed on the upstream face of the well. The pipe regulators comprise of one or more steel pipes laid under a road crossing of the canal, steel gates installed upstream side and brick masonry retaining walls at both upstream and downstream sides. The structures are either in need of repair or total replacement.

A field outlet pipe (FOP) with outlet valve chopper gate was supposed to be installed at the head of each Abu XX to regulate flow from the minor canal. At present, most of precast unreinforced FOPs have been seriously damaged or even removed. Neither measuring devices nor staff gauge are installed.

(2) Nur El Din Scheme

The canal network of the Nur El Din scheme consists of a main canal, five minor canals branching off from the main canal, and a lot of field channels. Length and nominal commanding area of respective canals are given in Table 1.1, and breakdown of the commanding area for each of canals are shown in Table 1.3. The field channels consists of Double Abu XXs, Abu XXs and Abu VIs. All the canals are of earth canal with trapezoidal or semicircular cross sections. General layout of the canal network is presented in Figs. 1.1 and 1.3.

The canal alignment is adequate as a whole, but upper reach of the main canal is not high enough for irrigating southeast corner of the scheme where the land is the highest in the area. Watercourses in more than 60 % of the service area have been silted up and total restoration of them is prerequisite.

Conditions of the regulators in the cultivated area are more or less the same with those for the Hurga scheme. Those in other area have been seriously damaged and in need of total replacement.

1.2.4 Drainage Canals

Layout of drainage canals indicated in the original layout map are well aligned but most of them have been decayed seriously. Total re-construction is needed.

1.3 Irrigated Area

Record of actual irrigation areas between 1976/77 and 1980/81 cropping seasons is shown in Table 1.4. Those from 1981/82 onward were also collected but not incorporated in this report because of involvement of suspicions.

Field reconnaissance survey conducted during the current study period by the JICA Study Team revealed that cultivated areas in 1990 were 2,260 feddan (16%) out of a net irrigable area of 13,903 feddan for the Hurga and 1,260 feddan (14%) out of 8,719 feddan for the Nur El Din schemes and that most of these areas were irrigated one to four times.

As shown in Fig. 2.1 of ANNEX D; AGRICULTURE AND AGRO-ECONOMY, the cultivated areas in the Hurga scheme are generally concentrated to Hawashas along upper reach of Abu XX due perhaps to convenience for receiving irrigation water. This implies shortage of water allowing only those limited areas to consume the water distributed through FOPs. In the Nur El Din scheme, those are confined to the commanding area of Minor canal No.1 and of uppermost reach of the Minor canal No.2. This is reportedly attributed to insufficiency of water and difficulty in water supply to remote areas due to topographic reason.

1.4 Water Supplied

1.4.1 Pump Operation

According to pump operation record obtained from Diesel Pump Station Division of Mechanical and Electrical Under-secretariat, MOI, two units each of pumps at Hurga and Nur El Din pumping stations were operated during July-October and August-October, respectively. Monthly operating hours for respective pumping stations are:

(Unit; hrs/month)

Month	Hurga	Nur El Din
July	107	-
August	464	225
September	538	494
October	322	474

Regarding the daily operation hours, it is reported that pumps used to be operated between 6:00 and 14:00, and that the operating hours was extended to 16:00 when more water was needed. Although daily operation record is not available, above two information implies the actual operation period that:

i) For the Hurga scheme, the pumps were operated daily for eight to ten hours in August and September, and six to seven days in June and 16 days in October;

ii) For the Nur El Din scheme, 8 hrs/day operation was practiced for 15 days in August and 30/31 days in September and October.

1.4.2 Water Supplied

Irrigation water supplied for Sorghum grown in both schemes in 1990 is roughly estimated by the JICA Study Team based on pump operation record and results of pumping tests conducted in September 1990 by HRS. In this estimation, water losses between discharge chamber of the pumps and FOP is assumed to be 10% of discharged volume by pumping. Then, available water for the crop is finally estimated by adding rainfall during its growth period as shown in Table 1.5, which is summarized as follows:

Available Water and CWR

(Unit: mm/day)

Month	Hurga	Nur El Din	CWR by Eo*
July	4.0	-	3.0
August	5.4	1.8	7.3
September	7.3	5.0	7.8
October	5.2	5.2	5.4

* ; See Table 1.6

As a whole, available water for Sorghum, thus estimated, for the Hurga scheme seems to fulfill crop water requirements (CWR), which is computed by a predictive method of Penman Eo x crop factor. It should be noted that sufficiency/insufficiency of water at each Number or Hawasha could not be examined due to lack of data, although it is practically much more important. In case of the Nur El Din scheme, water pumped up is considerably short with an exception in October.

1.5 Water Management

1.5.1 General

When data collection and analysis (Work-I) for current Study started at the beginning of November 1990, irrigation for the planting area of Sorghum had terminated, and hence most of the information discussed in this chapter is obtained by interviewing.

1.5.2 Irrigation Plan

For the Gezira Scheme, water requirement for the forthcoming cropping season is forecasted annually for the expected cultivation area before starting the cropping season by SGB in consultation with MOI. The pre-season forecast is reviewed and revised before starting the cropping season for wheat. (to be confirmed if this is true)

In case of the Hurga and Nur El Din, however, annual irrigation plan is virtually not prepared. Prior to the start of the forthcoming cropping season for sorghum, Block Inspectors for the Hurga and Nur El Din Blocks (Block No.106 and No.107) consult with Gezira Operation division, MOI and Mechanical and Electrical division, MOI about expected planting area for Sorghum. Then, Mechanical and Electrical division informs the Block Inspectors of conditions and discharge capacity of the pumps. Taking the said information into account, the tenants in the schemes decide planting area in relatively lower-situated fields for Sorghum relying on their experiences.

1.5.3 Water Requirement and Indenting

Normally, the indent (a request for irrigation water at field level) in the Gezira Scheme is rendered at intervals by the Block Inspector of SGB to the Assistant Divisional Engineer of Gezira Operation, MOI. The traditional method of determining indent is prevailing at field level. The basic indent for all crops is empirically estimated to be 30 m^3/fd/day (7.1 mm/day). This corresponds to 420 m3/fd (100 mm in depth) per fortnight.

In case of the schemes, however, distributing water tapped by pumps is only the thing that the Block Inspectors deal with because the indent is always beyond pumping capacity for both schemes.

1.5.4 Water Distribution

As discussed previously, irrigation water for the schemes was limitedly available. In such situation, strict and equitable water distribution is essential to utilize it to the maximum extent. Nevertheless, flow in the main and/or major canals was diverted to the major or minor canals through the well-head regulator relying on feeling and experience. This probably facilitated water shortage in some cultivated areas in the schemes and resulted in disorder of irrigation times at the Hawasha level as discussed in the succeeding sub-chapter.

1.5.5 Field Water Application

After the minor canals reaches full supply level (FSL), water is reportedly delivered to Abu XX by opening FOPs or cutting the bank of the minor canal where FOPs are damaged or removed. Irrigation water entering into the Abu XX is distributed to Hawashas in a Number through Abu VI, fields in which is watered from a Rabat to another until the soil is well saturated and standing water appears.

According to the result of an interview survey to 50 tenants each for Hurga and Nur El Din schemes and 50 tenants in the Gezira Scheme conducted during current Study period by JICA Study Team in collaboration with Planing and Socio-Economic Research Unit of SGB, some 60% of tenants in the Hurga scheme received water with two times irrigation on an average ranging from 1 to 4 times during July to October, 20% in the Nur El Din scheme with an average of two times irrigation with a variation of 1 to 3 times between August and October. While in the Gezira

Scheme, about 90% of interviewed tenants enjoyed five times irrigation on an average for Sorghum during July through December, and frequency of irrigation is mostly between 3 to 6 times.

1.6 Maintenance of Irrigation Facilities

1.6.1 Maintenance Works

MOI is responsible for maintenance of the irrigation facilities between main and minor canals including structures related to them, while SGB is responsible for the maintenance of the field channels. The maintenance works by MOI include the following:

i) Annual/seasonal maintenance works for the canals and structures, including FOPs and valves thereof;

ii) On the spot maintenance/repairs; and

iii) Continuous maintenance works

The items (i) & (ii) above are usually carried out by Gezira Operation, MOI on the force account basis, The item (iii) covers removal of silts and weeds in the canals. It is conducted continuously from a canal to another in accordance with priority set by the Assistant Divisional Engineer of Gezira Operation. These works are contracted to Earth Moving Corporation (EMC) for implementation.

1.6.2 Procedure of the Maintenance Works

The maintenance works under responsibility of MOI are carried out in the following way:

i) Assistant Divisional Engineer prepares and submits, in December of a year, a programme of maintenance work for the following year. The programme covers the annual maintenance works and the continuous maintenance works. Work quantities for the programme is roughly estimated without field survey.

ii) Cross section survey is carried out to estimate sediment volume in the canals by Assistant Divisional Engineer or if necessary by Survey Department of Project Division, MOI upon request from Gezira Operation, MOI.

iii) Detailed work quantities for the annual and continuous maintenance works are prepared and submitted to Divisional Engineer for his check and taking action.

iv) After checking and submission by Gezira Operation, budget arrangement for the programme is made by MOI headquarter.

v) Irrigation, Gezira and Managil Under-secretariat gives an instruction to EMC for arranging equipment necessary for removing silt and weeds in the canals.

vi) Silt clearance work is contracted to EMC in early part of the following fiscal year, while annual maintenance works are carried out by the staff of Sub-Division excepting the case contracted to IWC before irrigation cut-off period.

1.6.3 Desilting Work in 1990

Silt clearance was carried out for both Hurga and Nur El Din schemes in this year by EMC. The canals desilted are:

i) Hurga scheme
- Main canal
- Major canal
- Gannabia No.1, No.2 and No.3
- Canal No.1, No.2(only a part), No.3, No.4(about half of the canal), No.5 and No.6

ii) Nur El Din
- Main canal
- Canal No.1 and No.2

The silt removed from the canals are heaped up on the canal banks without shaping. Unless some treatment is made for the heaps of silt on the canal banks before rainy season, considerable part of the silt would be eroded by and flow into the canals together with rainwater.

1.7 Organization for Operation and Maintenance

Hurga and Nur El Din Pump Schemes have been jointly managed by MOI and SGB since 1976.

Mechanical and Electrical Under-secretariat of MOI has been responsible for operation and maintenance of the pumps and appurtenant facilities and metal works of the canal structures. Irrigation for Gezira and Managil Under-secretariat of MOI has undertaken operation and maintenance of canals and their related structures between the head of the main canal and the end of the major canal and maintenance of the minor canals. While, Agricultural Production Department of SGB had been managing the rest of these schemes and responsible for crop production from them since then. However, it has virtually suspended services for the schemes since 1981 because cotton growing were discontinued due to shortage of water resulted from deterioration of the pumps and other reasons.

Organization structure of Mechanical and Electrical Under-secretariat of MOI is shown in Fig. 1.4. One Mechanical Engineer is assigned for and engaged in operation and maintenance of respective Hurga and Nur El Din pump stations under supervision of a Chief Mechanical Engineer at Wad Medani.

Organization structure of Irrigation, Gezira and Managil Under-secretariat is shown in Fig. 1.5. One Assistant Divisional Engineer is assigned for the operation and maintenance the irrigation facilities of the schemes under Wad Medani Division.

Organization structure for SGB is shown in Fig. 1.6. The Gezira Scheme is divided into 107 number of blocks for management purpose, and the Hurga and Nur El Din schemes correspond to Block No.106 and 107, respectively. Three Field Inspectors consisting of one Block Inspector, one Second Field Inspector and one Third Field Inspector are supposed to be assigned for the Block No.106, and two Field Inspectors for Block No.107. Actually, however, a Block Inspector working for another Block are temporarily appointed as acting Block Inspector for the Hurga and the same way is adopted for the Nur El Din scheme. Nine and seven Ghaffirs (gate keeper for FOP) are also supposed to be assigned for respective schemes, but six Ghaffirs for the Hurga and 6 for the Nur El Din are actually employed at present.

2. PROBLEMS AND CONSTRAINTS OF PRESENT IRRIGATION AND DRAINAGE

2.1 General

Severe deterioration of the existing pumping stations has resulted in shrinkage of actual irrigation area for recent decade. This indispensably induced to remain less or no maintenance on uncultivated areas and thus facilitated deterioration of the facilities in those areas. Since irrigation and farm management activities were very limited, present problems and constraints on water management, institution,etc. could not be clearly identified during the current study period. Thus, the findings on the problems and constraints are one-sided to physical aspects.

2.2 Physical Aspects

(1) Deterioration of Pumping Equipment

Out of three, one unit pump have been totally damaged for respective pumping stations. Discharge capacity of remaining pump units have dropped to 64% of the rated capacity for the Hurga pumping station and 36% of the same for the Nur El Din pumping station. Furthermore, those operational pumps are obliged to cease operation during the low water stage of the Blue Nile due mainly to the recent degradation of the Blue Nile. Total rehabilitation or renovation of the existing pumping stations is primarily needed.

(2) Deterioration of Irrigation Facilities

Especially gates of regulating structures in the distribution system and all FOPs and their gates are deteriorated or even removed. Rehabilitation, improvement or replacement of these gates are essential for proper water distribution.

Operation and maintenance roads along the distribution canals are cut in many places by Abu XX where FOP has been collapsed or taken away, and remain impassable consequently.

Silts removed from the canals are dumped on the canal banks without any compaction nor dressing. This would facilitate influx of the silts on the banks into the canal by water erosion and/or wind erosion.

(3) No Provision of Measuring Devices

Neither measuring devices nor staff gauges at regulating structures are installed. To keep irrigation efficiency, equitable water distribution, and reliability, discharge measurement at strategic points are essential.

(4) Insufficient Height of Canals

Distribution canals are adequately aligned, but not high enough in some parts for commanding its service area. Especially, some 80 cm of heightening design water level is needed in upper reaches of the main canal for the Nur El Din area. Either heightening canal or provision of booster pumps will be the solution.

(5) No All-weather Type Feeder Road

There exist feeder roads connecting the Hurga and Nur El Din areas and Wad Medani-Gedaref highway. All roads are unpaved dirt roads and almost impassable when wet. To secure delivery of farm input and farm machinery at proper time, construction of the all-weather type roads is desirable.

(6) Discontinuous Pump Operation

Daytime pump operation causes time lag in water supply between the head and tail of the canal, resulting in uneven water distribution unless regulating ponds functioning as a buffer is provided. To cope with this, provision of the regulating pond or equivalent is needed if discontinuous pump operation is applied for the Project.

3. REHABILITATION AND IMPROVEMENT PLAN

3.1 Irrigation Water Requirement

3.1.1 General

The method used for calculating the irrigation water requirements for the Project is basically the same with the one employed for the Gezira Scheme by MOI. The methodology and procedure of the calculation employed for the Project are summarized as follows:

$$CWR = Eo \times Kc$$
$$IWRf = (CWR - Re)$$
$$IWRp = IWRf \times (1+Ei/100)$$

where,
- Eo ; Evaporation computed by Penman method (mm/day)
- Kc ; Crop coefficient (Crop factor)
- CWR ; Crop water requirement (mm/day)
- Re ; Effective rainfall (mm/day)
- IWRf ; Irrigation water requirement at the on-farm level
- IWRp ; Irrigation water requirement at the pumping site
- Ei ; Irrigation losses (%)

3.1.2 Evaporation

The crop water requirements (CWR), consumptive use of water by crop, vary seasonally correlating with the growth stages of the crops and climatic factors. They are obtained by multiplying an evaporation rate by a crop factor. The evaporation (Eo) rate employed for the Project is based on the original Penman method, and are calculated by the Sudan Meteorological Department from the basic meteorological data observed at Wad Medani between 1980 and 1989. Monthly mean daily evaporations (Eo) during the same are as shown below:

(Unit: mm/day)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
6.4	6.8	8.4	8.8	9.1	10.0	8.5	8.1	7.4	7.1	6.5	6.2

3.1.3 Crop Factor

The crop factor (Kc), which covers the effect of crop characteristics, presents the relationship between Eo and CWR. Kc values vary with crop, its growth stage, growing season and the prevailing weather conditions. Kcs employed for the Project are given in Table 3.1, which were worked out by Gezira Research Station (GRS) through field measurements. It is noteworthy that since the total discharges measured at the FOP were regarded as CWR and Kcs were derived from CWR/Eo, the Kc involves all losses at the on-farm level (field application losses).

3.1.4 Effective Rainfall

The effective rainfall (Re) is the part of rainfall which contributes to crop water requirement. Re for the crops is estimated using the method developed by U.S.Department of Agriculture's Soil Conservation Service (Ref.No.IR-325), and is shown in Table 3.2. To estimate Re, a probable annual rainfall with a 5-year return period of 192 mm is employed. The probable annual rainfall is distributed to respective months in proportion to the monthly distribution pattern of the average monthly rainfall between 1980 and 1990 as shown below:

(mm/month)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Avg*	0.0	0.0	0.0	0.2	17.4	25.7	65.3	92.9	49.3	11.1	2.9	0.0
5-yr**	0.0	0.0	0.0	0.2	12.6	18.6	47.3	67.4	35.7	8.1	2.1	0.0

*; Average monthly rainfall between 1980 and 1990 (Table 2.1 ANNEX B).
**; Probable rainfall with a 5-year return period.

3.1.5 First Irrigation Water Requirement

The first irrigation water, being distinguished from the CWR, is the water to provide soil with sufficient moisture for germination of the seed, and is generally practiced just after sowing. The amount of the first irrigation requirement depends largely on the water-holding capacity of the soil and the state of moisture in the soil at the time of the first irrigation. The first irrigation requirement employed for the Project is shown below:

Crops	First Water Requirement	
	m^3/fd	mm
Groundnut	800	190
Sorghum	800	190
Fodder	800	190
Wheat	600	142
Cotton	400	95

3.1.6 Irrigation Losses

Irrigation losses generally consist of field application losses, transit losses and operation losses. The field application losses are included in the crop water requirements as discussed previously. The field losses conceivable are deep percolation, evaporation in the field channels, and operation losses.

The transit losses consist of deep percolation and seepage loss from wetted perimeter of canals, direct evaporation from water surface of the canals and losses through breakage and escape.

For estimating the transit losses from the headworks to FOP, MOI formerly used conventionally assumed values including the loss of escapage (Ref.No.IR-326) as follows:

Canals	Loss in % of the Discharges	
	January - April	July - December
Main & Major	3	5
Minors	3	3
Escapage	2	5
Total	8	13

Due to the impermeable clay, however, the seepage losses were considered to be negligibly small, and the absence of deep percolation from canal bottom was confirmed by GRS. To estimate the transit losses which consist only of evaporation loss from the canal water surface practically, GRS employs the following equation:

$$Lt = A \times Eo \times c$$

where; Lt ; Transit loss
A ; Water surface area of canals
Eo ; Evaporation computed by original Penman
c ; Correction factor

For the case of the Project, however, the transit loss for the Project is assumed to be 10% of the irrigation water requirement at the on-farm level.

Apart from the transit losses, operational losses are considered for the Project. Field investigations on water management on minor canals in the Gezira Scheme (Ref.No. IR-302) was conducted by HRS in 1988. Aiming at clarifying the performance ratios on water delivery at the minor canal level, relationships between performance indicators were examined at three different stages,i.e., indent/canal water requirement, authorized release/indent, and actual discharge/ authorized release. The result of the examinations are summarized in Table 3.3. According to the Table, an average irrigation efficiency (actual discharge/canal water requirement) of the nine minor canals is seemingly so satisfactory as indicating just 16% over-supply. And this is considered to be a result of compensatory actions taken by both the SGB and MOI officials in the effort to assure the delivery of sufficient irrigation water to the minor canals according to Ref.No.IR-302. It should be, however, recognized that inequities in supply are obvious among the minor canals showing such wide range of irrigation efficiencies as from less than 50% under-supply up to nearly 100% over-supply. Although the mean irrigation efficiency is arithmetically satisfactory level, under-supply of a minor canal could not be compensated by the over-supply of the others, thus the over-supply of a minor remains unused. This implies the necessity of accounting for the operation losses other than the transit losses in both planning and operation stages. The operation losses for the Project is tentatively assumed to be 10% of the irrigation water requirement at the on-farm level.

3.1.7 Irrigation Water Requirement

Irrigation water requirements for the proposed cropping pattern are estimated in line with the methodology discussed above. The proposed cropping pattern and calender for the Project is shown in Fig. 3.1. The irrigation water requirements thus estimated are shown in Table 3.4 .

3.2 Water Distribution and Application

3.2.1 Water Distribution Method

(1) Available Soil Moisture

It is an agreement that a depth of irrigation water to be applied is generally determined by difference of soil moisture contents between the permanent wilting point (PWP) and field capacity. Moisture content at field capacity is defined as the one a few days after irrigation or rainfall when downwards drainage by gravity has ceased.

In the case of Gezira clay, however, it has been proved through long and a large number of field researches that this standard manner of determining irrigation water depth is not applicable because the mechanism of water movement in the Gezira clay departs from that stated in textbooks. According to Farbrother (Ref.No. IR-323), movement of water into the Gezira clay is considered to involve the following mechanisms:

a) At an initial stage water on the soil surface moves downwards rapidly via well developed cracks and form the initial moisture pattern;

b) Water filled in the cracks is re-distributed from the soil surfaces of the cracks into the soil by movement in response to the gradient of tension from wet soil to dry, horizontally and vertically as well; and

c) Gravity plays no role in the distribution of water.

The quantity of water entering the cracks is dependent on the volume of the cracks, which in turn is dependent on the moisture content of the soil and thus dependent on fallow periods, intervals of irrigation, consumptive use of water by crops, rainfall, etc.

The researches on moisture status on the field soil conducted by GRS revealed moisture contents in the soil of before and after irrigation (Ref.No.IR-323). Depth of soil in which soil moisture changes cyclically by irrigation and crop consumptive use is limited to about 0.6 m and

0.4 m for cotton and groundnut, respectively, under normal irrigation practices. And soil moisture content below it remains virtually constant due to absence of downward drainage. Difference in moisture content before and after irrigation thus clarified is some 95 mm (400 m^3/feddan) for cotton and 85 mm (350 m^3/feddan) for groundnuts, which are regarded as readily available moisture for the crops.

(2) Irrigation Intensity in the Gezira Scheme

In the Gezira Scheme, the irrigation water demand at the head of the watercourse, locally known as Abu Ishreen (Abu XX), for cotton was formally recommended to be 420 m^3/fd at 14-day intervals, which was supported by data obtained through long-term field trials. The recommendation was equivalent to a crop water requirement of 30 m^3/fd per day (7.1 mm). Despite that this recommendation was originally employed for cotton, it has been employed for late introduced new food crops regardless type of crop, season or growth stage of the crop.

A field irrigation system of the Gezira Scheme is designed to serve a standard farm unit of 90 feddans locally called "Number" by a Abu XX. The "Number" is divided into 18 numbers of 5-fd plots called as "Hawasha" by a series of secondary watercourses called Abu Sitta (Abu VI), taking from Abu XX at right angle. Original capacity of Abu XX and Abu VI are 116 l/s (5,000 m^3 in 12 hrs) and 46 l/s (2,000 m^3 in 12 hrs), respectively.

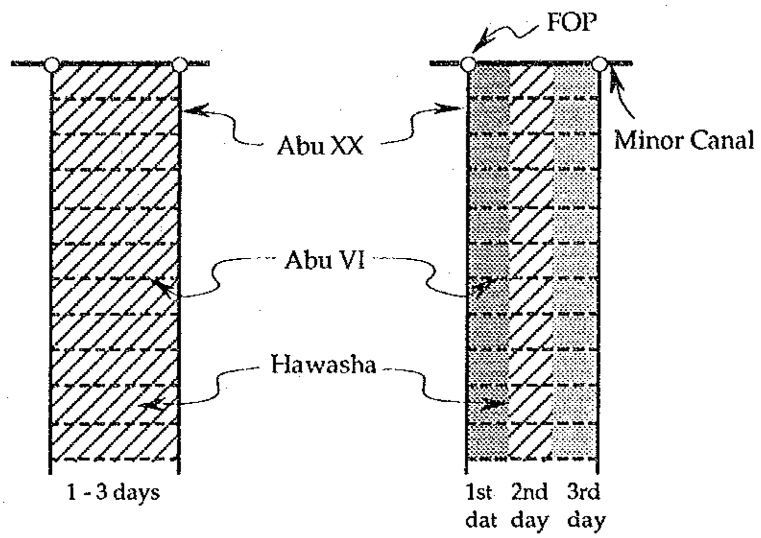
According to the original recommendation, the irrigation water diverted to Abu XX is distributed over the Number in one week. The eight Hawashas with 40 feddans in the Number are irrigated simultaneously for three days and the remaining Hawashas of 50 feddans in the same are irrigated another four days in a week. The Numbers commanded by a minor canal is divided into two groups, and each group has a 7-day application alternately. Thus, an irrigation interval of 14-day is established at the level of Hawasha. In this standard water application, a 24-hour consecutive flow is practiced for the minor canal, while a 12-hour watering is the original practices for Abu XX.

From the above standard water application method recommended originally for the Gezira Scheme, it is inferred that:

i) In case a group of Hawashas with 40 fd (or 50 fd) is watered simultaneously over a 3-day (or 4-day) irrigation period, the rate of irrigation (irrigation intensity) is estimated at 2.5 mm/hr;

$$5{,}000\ m^3 \times 3\ \text{days}/(40\ \text{fd} \times 0.42 \times 10{,}000) \times 1000 = 89\ \text{mm}$$
$$89\ \text{mm}/(3\ \text{days} \times 12\ \text{hrs}) = 2.5\ \text{mm/hr}$$

ii) In case the first one third of respective Hawashas of the group is watered in one day and the second and third ones are watered in the following days by turns, the rate of irrigation corresponds to 7.4 mm/hr (= 89 mm/12 hrs).



(3) Measuring Intake Rate

Knowing intake rate (rate of entry of water into soil under field conditions) is of fundamental importance in any of irrigation methods except sub-surface irrigation when irrigation plan is formulated. Excessive application causes standing water entailing increase in application loss by either surface runoff or evaporation.

The best method of measuring intake rate is to obtain direct measurements by observing the water applied less the water flowing out from the field. If measuring inflow and outflow is not applicable, measurement intake by cylinders is one of the recommendable methods. The results obtained by cylinder intake are experimentally proved to be indicative of the rates to be expected during the irrigation. Close correspondence could be expected when basin irrigation is practiced. The intake rate obtained by the intake cylinder method is generally referred to as an index for plan formulation of the Project.

Intake rate tests by intake cylinders and ponding methods have been conducted at three sites each in the Project area during the current Study period, details of which are given in APPENDIX-I of this sector report. Intake rate and accumulated intake obtained by the tests are given in Fig. 3.2. Although the observation of intake extended over 2.5 hrs, 5.0 hrs and 4.0 hrs for respective sites No.1, 2 and 3, it is not unreasonable to estimate accumulated intake for more than the observation period by extrapolation with limitation of moisture holding capacity of soil. Thus, accumulated depth of water to be applied for 12 hrs is estimated at a range of 80 - 60 mm.

In order to examine possible field water application method for the Project, necessary lapse of time that the water of 89 mm in depth enters into the soil, is estimated at a range of 16.5 - 36 hrs using the said equations shown in the Fig. 3.2. This implies a possibility that standing water of 10 - 30 mm in depth would gradually enters into soil for 4 - 24 hrs after 12-hour watering in case one third of respective Hawashas of the group is watered in one day as mentioned above.

(4) Proposed Irrigation Interval

Determining appropriate interval between irrigations is essentially needed for not only the design of an irrigation network but also adequate water application. The irrigation interval depends mainly on quantity of soil moisture readily available for the crop, consumptive use of water by the crop, and a pattern of extracting soil moisture by the crop.

The irrigation interval is determined by dividing the available soil moisture by the crop's daily consumptive use of water. It is evident from the above that the irrigation interval varies from month to month as well as from a crop to another. Assuming that the available soil moisture of the Project area shows similar behavior to the Gezira scheme, the minimum irrigation interval is estimated by readily available moisture discussed precedently and using the peak daily evapotranspiration shown in Table 3.5 as follows:

Cotton	;	95 mm/8.07 mm/day = 12 days
Groundnuts	;	85 mm/8.83 mm/day = 10 days

The minimum irrigation interval of 12 days for cotton would last from the last 10-day period of September to the first 10-day of January, while 10-day interval for groundnuts would be required almost throughout growth period except June if no rainfall occurs. Although the minimum irrigation intervals for sorghum and wheat could not be estimated due to absence of data, a 10-day interval seems to be safe for those crops, and therefore it is recommendable for all the crops throughout their growth periods for the convenience of operation. Discharge control in response to variation of water demand would be achieved by gate control of FOPs coupled with watering time control at the field.

(5) Proposed Rotation System

The Numbers on each minor canal is divided into two groups and the first group would be watered in five days and the second one would be watered in consecutive five days. As a rule, one group consists of five Numbers. Cotton, wheat, and fodder would be grown on respective Numbers. Dura and groundnuts would share another Number and the last Number would be left fallow.

Hawashas in each Number are also divided into two groups and would be irrigated for two and three days for each of groups.

(6) Proposed Water Distribution

Required irrigation water would be tapped at the proposed pumping station on the Blue Nile. Peak water demand would be fulfilled by three pumps with 18 hours (0:00 - 18:00) per day operation. Discharge control at the pumping station would be made by unit of operating pump and lapse of operating hours. Immediately after the pumping station, the water tapped would flow into a sand settling basin, then it would be diverted into the respective main canals for the Hurga and Nur El Din areas through a diversion structure located at the end of a link canal connecting the sand settling basin and said two main canals. At the diversion structure the water would be divided in proportion to each service area.

The water in the main and/or the major canal would be diverted to all minor canals simultaneously through movable weirs on the main/major canals between 0:00 and 18:00 in accordance with pumping hours. The water in the minor canal would be distributed to the first half Numbers on each minor canal for five days and to the second half Numbers for another five days through Abu XX. Water distribution to the Numbers would start at 6:00 and finish at 18:00. Balance of influx into and efflux from the major canal would be regulated in the minor canal.

3.2.2 Field Water Application Method

There has been argument in recent years on field water application methods, i.e., traditional "Angaya irrigation" and late introduced "long furrow irrigation". The Angaya irrigation, a sort of basin irrigation, has long been adopted for the Gezira and other schemes traditionally. While Long furrow irrigation has been introduced to the Rahad Irrigation Project after trial on Tambule Pilot Farm. Field layout for respective water application methods is illustrated in Fig. 3.3.

The Angaya irrigation is generally adopted to each Hawasha which is divided into 16 strips (Angayas) by small ditches (locally called Gadwal) and bands (locally known as Tagnet) 17.5 m apart each. Each Angaya is further divided into 4 (in case of a 5-feddan Hawasha) small rectangles called locally "Hods" by ridges (Rabat). Irrigation water fed to Abu VI through Abu XX is supplied to each Hawasha through Gadwals. Many reports recognized that this method is well fitted to the Gezira clay because of its "self regulating" capacity of the heavy clay soils which absorb water until the clay has swelled sufficiently to close the cracks which develop on drying out. However, its limitation also has been realized according to existing reports on the other hand. High rainfall on such soils leads to excessive surface runoff, especially if the rain take place immediately after watering, resulting in water logging. A further problem encountered with the Angaya system is the division of the field into small plots, which hinder the effective use of agricultural machinery.

The long furrow irrigation is the method to supply water to a series of furrows with a standard length of 280 m long in the Number, which are fed through flexible siphons of 4 - 5 cm in diameter from Abu XX. According to existing reports and interviews at SGB, the following advantage and disadvantages are identified:

a) Waterlogging in the Number could be avoided by construction of field drainage canal at the lower end of the Number;

b) Raising of water level throughout the canal system is required because sufficient head for siphon is needed in the Abu XX to distribute water into the furrows;

c) Accurate land levelling and regular slopes in the direction of the furrows are prerequisite for the proper flow of water through the furrow with a standard length of 280 m; and

d) More properly maintained field drains are needed.

Although argument on the field water application method has not arrived at conclusion, the Angaya irrigation method is proposed for the Project due to the following reasons:

a) Beneficiary tenants are aware of the Angaya irrigation method;

b) Probable daily rainfall with a 10-year and 5-year return periods are 73 mm and 65 mm, respectively. Considering these probable daily rainfalls, heavy waterlogging might not occur so frequently as causing serious damage to crops;

c) Raising of design water level of the canal systems could be minimized; and

d) Present farm plots could be used without land levelling.

3.3 Rehabilitation and Improvement Plan of Irrigation System

3.3.1 Irrigation System

The proposed irrigation system for the Project consists of a pumping station, a sand settling basin, a link canal and canal network for the Hurga and Nur El Din areas. The canal network for the Hurga area is composed of a main canal, a major canal, 12 minor canals including Gannabia canals, and a large number of on-farm canals. The Gannabia canal is a minor canal running along the main or major canal. The canal network for the Nur El Din area consists of a main canal, 5 of major canals and a large number of on-farm canals. The on-farm canals for respective areas are of watercourses (Abu XX) and secondary watercourses (Abu VI), which branch off from Abu XX at right angle at appropriate intervals so as to form a 3-feddan Hawasha. All the Abu XXs would be fed through the minor canal for the convenience of operation, and direct diversion from the main/major canal to Abu XX is not proposed.

A structure would be provided at the end of the link canal to bifurcate water into respective main canals in proportion to each of the service areas. A movable weir, which is the same type as that used presently in the Gezira scheme, would be provided at the head of the major or minor canal instead of the present well-head regulator. The movable weir would be installed so that perfect overflow condition could be maintained regardless the water level in the minor canal. Since reservoir function is expected to the minor canal and consequently the water level in the canal is expected to rise and fall in a day, the weir type regulator is more convenient for discharge control at the structure than the gate type regulator such as the well-head regulator. In the case of the well-head regulator, discharge volume would vary in accordance with the fluctuation of water level in the minor canal even if magnitude of gate opening is set constant. The well-head regulator would be provided at the head of double Abu XX. The water level in the main, major and minor canals would be maintained at full supply level by pipe regulators functioning as cross regulators. Field outlet pipe (FOP) with a slide gate would be installed at the head of Abu xx to control discharges flowing into Abu XX from the minor canal.