When 4 generating units (including the existing one unit) are operated after completion of this project, the fuel consumption will be from 1,180 to 1,380 kl/month assuming load factor of 60 to 70%. That is, this fuel storage facility can store fuel for approximately 1 week use.

According to GEC, the fuel is being procured by a governmental corporation named Guyana National Energy Authority (GNEA) from Venezuela. Delivery to the site takes 11 to 12 days after an order is placed. Considering this situation, in the implementation of the project, study should be made to either install an additional storage tank or to transport fuel by tank lorry from a nearby power station in case of emergency.

4) Repair shop and warehouse (approximately 110 m^2)

The existing warehouse is of a temporary building. A new warehouse is needed for proper storage of parts.

5) Office rooms (approximately 35 m^2)

8.3.3 Outline of project

(1) Place of installation

The generating units of this program are to be installed in Onverwagt Power Station. For this purpose, the existing inoperable generating units (1 MW x 4) will be dismantled, and their foundation structures will be utilized because this program is very urgent and must be implemented in a short period.

(2) Study of existing foundation

1) Visual inspection conducted during the site survey by the Study Mission did not indicate any abnormal condition of the foundation structures, and there is no record that abnormal vibration and other problems have been encountered in the past.

2) The concrete foundations in question are independent from building structure, and the estimated weight of a foundation is around 80 tons.

3) The weight of existing diesel engines, which had been manufactured by Ruston-GEC, is not indicated in nameplate or drawing, but it

would be around 20 tons considering its output (1,400 PS), speed (720 RPM) and date of manufacture (1972).

4) Conclusion of study

In installing new engines, the existing foundations must be examined in detail to review the foundation weight vs. equipment weight.

(3) Engine rated speed and fuel type

Considering the constraint to be placed by the existing foundations, the new engines will be 900 RPM high speed diesel engines operating on diesel oil only.

(4) Generator voltage

The existing step-up transformer (13.8/4.16 kV) will not be used, and the generator voltage will be the rated voltage of the existing 13.8 kV bus.

(5) Utilization of existing facilities

The following existing facilities will be utilized considering the urgency of project and in order to attain higher economy.

1) Existing Foundation: 3
2) Existing Fuel Storage Tank: 5
3) Interconnection Transformer (69/13.8 kV, 16.7 MVA): 1

8.3.4 Basic design

(1) Engine output and generator capacity

The rated output of generators has been set at 2,600 kW, and the corresponding engine and generator capacities have been selected.

1) Engine output

The engine output (in French horsepower; PS) can be obtained by the following equation.

Engine output $Pe \geq P/(0.736 \times \mu g)$ (PS)

where:

generator output: $P = 2{,}600$ kW

$1 \text{ PS} = 0.736$ (kW)

generator efficiency: $\mu g = 96\%$

$$Pe \geq 2{,}600/(0.736 \times 0.96) = 3{,}680 \text{ (PS)}$$

2) Generator rated capacity

Generator output: $Pg = P/Pf$

where:

generator power factor: $Pf = 0.8$

$$Pg = 2{,}600/0.8 = 3{,}250 \text{ kVA}$$

(2) Station service transformer

In this program, a new station service transformer for supplying power to diesel generator auxiliary equipments and other ancillary equipments will be installed. The capacity of this transformer will be 3 to 4% of the main unit, or 250 kVA.

(3) Switch board (Monitoring and Control Board)

The following switch boards and monitoring and control boards are required to operate, control and monitor the diesel generators of this project.

1) Main monitoring and control board
2) Generating unit control board
3) Generator neutral grounding resistor (NGR) board
4) Station service power board
5) DC control power board

(4) Circuit breaker

Circuit breakers are required in order to connect the diesel generators of this project to the existing 13.8 kV bus and switch on and off generator output.

Vacuum circuit breakers, which have high reliability and low cost, will be adopted.

The circuit breakers protect electrical equipments by cutting off fault current in case of circuit failure. The circuit breakers are normally closed when generators are being operated, and opened when generators are shut down.

(5) Power cable

The circuit between generators and vacuum circuit breakers, and between station service transformers and line switches will be composed of 15 kV power cables.

8.3.5 Equipment/Material schedule

(1) Equipments and materials of project

Outline specifications of equipments and materials for this project are presented in the table below.

Equipment	Specification	
Diesel Engine	Number:	3
	Type: 4-cycle, stationary, power generation duty	
	Output:	3,680 PS continuous duty
	Speed:	900 RPM
	Cooling system:	Circulating water with cooling tower
	Fuel:	Diesel oil
Generator	Number:	3
	Type: 3-phase, AC, horizontal shaft, synchronous generator	
	Rated output:	2,600 kW
	Rated capacity:	3,250 kVA
	Voltage:	13.8 kV
	Current:	136 A
	Power factor:	0.8 (lag)
	Frequency:	60 Hz
	Number of poles:	8
	Insulation class:	Class F
	Excitation system:	Brushless system
	Cooling system:	Open type, air cooled
Station Service Transformer	Number:	1
	Type: Outdoor, 3-phase, oil filled, self cooled	
	Rated capacity:	250 kVA
	Voltage:	1ry: 13.8 kV, 2ry: 480 V
	Frequency:	60 Hz
	Connection:	1ry: delta, 2ry: star
	Neutral:	Directly grounded

Switch Boards (Monitoring, Control, Protection, and Station Service Boards)	Type: Indoor, enclosed, self-standing type	
	Function:	Control and protection
	(a) Main monitoring and control board;	1 set
	(b) Generating unit control board;	1 set
	(c) Neutral grounding resistor board;	1 set
	(d) Station service power board;	1 set
	(e) DC control power board;	1 set
	(Battery charger, alkaline battery, DC control)	
Circuit Breaker Board	Number:	4 boards
	Type: Indoor, enclosed, self-standing type	
	Circuit breaker:	
	Type:	Vacuum circuit breaker
	Rated voltage:	15 kV
	Rated current:	600 A
Power Cable	Type: Cross linked polyethylene insulated power cable	
	Voltage:	15 kV
	Conductor size:	60 mm^2,

8.3.6 Approximate construction cost and implementation schedule

(1) Approximate construction cost

6,150 x 103 US$

(2) Implementation schedule

Delivery of a generating unit shall take 15 months after conclusion of contract.

8.4 CONSTRUCTION OF NEW KINGSTON POWER STATION

8.4.1 Objective of project

New Kingston Power Station will be constructed as a new major base load power station in Demerara Power System. The new power station will be constructed at the site of old Kingston "A" Power Station and replace Kingston "B" Power Station (a steam power station with three 8.5 MW units) which will have to be decommissioned soon.

Low speed diesel engines operating on only fuel oil and 60 Hz rating generators will be employed in New Kingston Power Station. Two 13 MW units will be installed in 1993 and other two 13 MW units in 1995 according to Chapter 6, Power Supply Enhancement Plan.

As the new power station will supply 60 Hz power to Georgetown Districts, the commercial frequency of Georgetown will have to be unified to 60 Hz by the time the new power station is commissioned.

8.4.2 Outline of project

(1) Selection of power station site

Existing Kingston "B" Power Station is not far from load center. Heavy plant equipment have been transported to the power station site in the past, and there will be no serious problem concerning noise, exhaust gas and other pollution during construction and operation of new facilities. The foundation improvement works performed in the past for old power plants can be effectively utilized for construction of a new power station. Considering these factors as well as convenience of maintenance and repair work that will be required in future, the site of old Kingston "A" Power Station has been selected for the new power station.

A detailed geological survey must be conducted, however, before realizing this plan.

(2) Power station capacity, timing of construction, and unit capacity

1) Power station capacity and timing of construction

In the Economic Evaluation (Optimum Power Development Program) of Chapter 12, it is indicated that the optimum scale of electric power development for economical operation of power system is from 55 to 57 MW. Based on this conclusion and the supply/demand balance study in Chapter 6, Power Supply Enhancement Plan, it has been decided to install four, 13 MW generating units, with a total power station capacity of 52 MW.

The timing of construction has been decided based on the study in Chapter 6, with two 13 MW units commissioned in 1993 and other two 13 MW units in 1995.

2) Study of unit capacity

The construction cost will be reduced by the adoption of larger unit capacity. Therefore, larger unit capacity is preferable when only economy of power generation is considered.

However, the suitable unit capacity must be selected by considering the reduction of system's supply capability when a unit is shut down for periodical inspection or due to fault, as well as drop of power system frequency when a unit is lost from power system due to a sudden failure. Specifically, the following studies have been done to examine these aspects.

<1> Supply/Demand Balance with One 13 MW Unit Shut Down

As given in Table 6-3(2), the supply/demand balance of the power system can be maintained after New Kingston Power Station is commissioned even when one 13 MW unit is shut down if a maximum of 5.1 MW power can be transferred from Berbice System.

<2> Effect on Power System Frequency When One 13 MW Unit is Lost

When a 13 MW unit is suddenly lost, the instantaneous frequency drop of the power system will be as given below. Although the magnitudes of frequency drop are substantial, these are within the range that can be dealt with by temporary load shedding to be actuated by frequency relays.

Year	Peak Load (MW)	Frequency Drop (Hz)
1993	59.8	-2.17
1995	63.8	-2.04
1998	70.0	-1.86
2000	74.6	-1.74

It can be concluded from the above studies that installation of four 13 MW units is the optimum choice.

(3) Study of generating systems

New Kingston Power Station is the major power source of the system for supply of peak load. For this function, there can be three options of generating system.

1) Low speed diesel generating unit operating on fuel oil (Bunker C) only.
2) Steam power plant operating on fuel oil (Bunker C) only.
3) Medium speed diesel generating unit.

Option 3) has been rejected from the study due to the following problems.

<1> A unit capacity of 13 MW is near the limit of medium speed engine.

<2> Past experience in Guyana using fuel oil (Bunker C) have resulted in operation difficulties. For this reason selection of medium speed diesels operating on fuel oil is not recommended for a base load station.

<3> Use of diesel oil in a base load station such as this is extremely uneconomical.

Therefore, only options 1) and 2) have been compared. The study indicated, as presented in Table 8.4.1, that low speed diesel units are more economical and suitable for a base load station.

(4) Type of fuel

The heavy oil produced in Venezuela, which is the kind currently used in Kingston "B" Power Station, will be employed.

The major characteristics of this fuel oil are as below.

Specific gravity:	0.9895 at 15°C
Viscosity:	132 mm^2/sec at 50°C
Flash point:	80°C
Sulfur content:	2.6%M
Moisture content:	0.05%V or less
Sediments:	0.25%V or less
Ash:	0.07%M
Vanadium content:	315 MG/KG
Sodium content:	29 MG/KG

(5) Selection of 60 Hz generator and frequency unification

In accordance with the law of Guyana which has been enforced in 1971, the new generators will be 60 Hz machines. A new 69 kV transmission line will be constructed, and all the power generated by this power station will be transmitted to the power system at 60 Hz. At the same time, 60 Hz power will be transmitted directly from the 13.8 kV generator bus to loads in

Georgetown District through distribution lines. Consequently, the customer loads in Georgetown District must be converted from 50 Hz to 60 Hz when this power station is completed.

(6) Power station building and fuel storage tank

Power Station Building: Steel structure with corrugated metal roofing, 2400 m^2.

Fuel Storage Tanks:

Existing two fuel storage tanks (with total storage capacity of 5,600 kl) will be utilized. When this project is completed and 4 generating units are operated, the fuel consumption will be 6,900 kl per month, assuming a plant load factor of 90%. Therefore, the storage tanks will have a capacity of about 24 days use.

According to GEC, the fuel is being procured by a governmental corporation named Guyana National Energy Authority (GNEA) from Venezuela, which can be delivered within 11 to 12 days after an order is placed. Considering this situation, there seems to be no need for additional fuel storage tank.

(7) Outline specifications

Outline specifications of equipments and materials for this project are presented in the table below.

1) Indoor equipment

Equipment	Specification	
Diesel Engine	Number:	4
	Type:	2-cycle, stationary, power generation duty
	Output:	18,400 PS continuous duty
	Speed:	129 RPM
	Cooling system:	Circulating water with cooling tower
	Fuel:	Bunker C oil
Generator	Number:	4
	Type:	3-phase, AC, horizontal shaft, synchronous generator
	Rated output:	13,000 kW
	Rated capacity:	16,250 kVA
	Voltage:	13.8 kV
	Current:	680 A
	Power factor:	0.8 (lag)
	Frequency:	60 Hz

Equipment	Specification
	Number of poles: 56 Insulation class: Class F Excitation system: Brushless system Cooling system: Open type, air cooled
Station Service Transformer	Number: 2 Type: Outdoor, 3-phase, oil filled, self cooled Rated capacity: 1,500 kVA Voltage: 1ry: 13.8 kV, 2ry: 480 V Frequency: 60 Hz Connection: 1ry: delta, 2ry: star Neutral: Directly grounded
Switch Boards (Monitoring, Control, Protection, and Station Service Boards)	Type: Indoor, enclosed, self-standing type Function: Control and protection (a) Main monitoring and control board; 1 set (b) Generating unit control board; 1 set (c) Neutral grounding resistor board; 1 set (d) Station service power board; 1 set (e) DC control power board; 1 set (Battery charger, alkaline battery, DC control)
Circuit Breaker Board	Number: 13 boards Type: Indoor, enclosed, self-standing type Circuit breaker: Type: Vacuum circuit breaker Rated voltage: 15 kV Rated current: 600 A
Power Cable	Type: Cross linked polyethylene insulated power cable Voltage: 15 kV Conductor size: 400 mm^2, 60 mm^2

When these facilities are operated at 50 Hz, the engine output will be 15,300 PS (approximate), generator output 11,000 kW (approximate), and speed 107 RPM.

2) Outdoor equipments

Considering the available space in the power station site, the gas insulated switchgears that occupy small area will be used.

Equipment	Specification
Interconnection Transformer	Number: 2 Type: Outdoor, 3-phase, oil filled, self cooled Rated capacity: 16,700 kVA Voltage: 1ry: 13.8 kV, 2ry: 69 kV Frequency: 60 Hz Connection: 1ry: delta, 2ry: star Neutral: Directly grounded

Circuit Breaker	Number:	1
	Type:	Outdoor
	Circuit breaker:	
	Type:	SF6 gas circuit breaker
	Rated voltage:	72 kV
	Rated current:	800 A
Power Cable	Type:	Cross linked polyethylene insulated power cable
	Voltage:	69 kV
	Conductor size:	300 mm^2

The layout of New Kingston Power Station is presented in Figure 8.4.1 and Figure 8.4.2, and its Main one-line diagram in Figure 8.4.3.

(8) Approximate construction cost

Item	Price (10^3US$)
Equipments	46,100
Marine transportation	2,800
Building and civil works	4,800
Installation cost	3,700
Miscellaneous	4,100
Total	61,500

The cost of 69 kV outdoor substation and the cost of removal of existing facilities are not included in the above cost.

(9) Implementation schedule

The implementation schedule is presented in Table 8.4.2.

8.5 REFURBISHMENT OF EXISTING POWER STATIONS

8.5.1 Objective of projects

The generating units in existing power stations shall be retired one by one as their serviceable life approach, and they shall be replaced by generating units of same capacity according to Power Supply Enhancement Plan of Chapter 6.

8.5.2 Basic principles of refurbishment plan

(1) Effective utilization of existing facilities

Existing power stations are located near load centers, and they are located in preferable sites because heavy equipments have been transported to the stations in the past, and there will be no problem concerning noise, exhaust gas and other pollution during refurbishment work or after commissioning of new facilities. Therefore, considering the convenience for future maintenance, repair and replacement, the existing facilities will be utilized as much as possible.

(2) Scope of refurbishment of existing facilities

1) The scope of refurbishment of each power station is as described below.

Diesel engines and their auxiliary equipments (lubrication oil system, fuel oil system, cooling water system, compressed air system, suction system, and exhaust system). AC generators and their auxiliary equipments (excitation system and neutral grounding resistor). Switch boards (generating unit control board, engine/generator start-up board, station service board, DC power board, etc.). Circuit breaker cubicle (for generator main circuits and station service power supply). Miscellaneous items such as wiring, piping, spare parts, etc.

2) Major facilities of existing power stations to be utilized in refurbishment plan

Power station building and existing foundation structures.
Overhead traveling crane.
Fuel storage tanks.
Cooling water.

(3) Power generation system

Medium speed diesel generators will be employed. Although heavy fuel oil is generally used for medium speed diesel engines, performance of diesel generators in Guyana running on heavy fuel oil only was poor in the past. Therefore, diesel oil will be used instead of heavy fuel oil.

(4) Unit capacity

1) As the foundation structures will be utilized for new units after the existing units are decommissioned, the unit capacity of new units will be the same as the old units.

2) Standardization of unit capacity

For Canefield Power Station, the same unit capacity as at Garden of Eden Power Station, that is 5.7 MW, will be used (existing units 5.8 MW) in order to enable interchangability of spare parts between these two stations in the future.

(5) Adoption of 60 Hz machine and frequency unification

Although the power system around Anna Regina Power Station is currently operated at 50 Hz, the refurbished units for this power station will be 60 Hz. Therefore, the power system frequency will have to be converted to 60 Hz at the time of refurbishment.

8.5.3 Main equipment specification of each power station and commissioning year

(1) Garden of Eden Power Station

1) Installed capacity and commissioning year

Installed Capacity (MW x No. of Units)	Type	Commissioning Year	Remarks
5.7 x 1	Diesel	1990	Refer to Chapter 7
5.7 x 1	Diesel	1997	

2) *Specification of main unit*

Diesel Engine

Type: single stroke, 4 cycle, water cooled, turbo-charged type.

Output: 8,070 PS

Speed: 720 RPM

Fuel: diesel oil

Generator

Type: AC 3-phase synchronous generator.

Capacity: 7,125 kVA (output; 5,700 kW)

Frequency: 60 Hz.

Voltage: 13.8 kV.

(2) Canefield Power Station

1) Installed capacity and commissioning year

Installed Capacity (MW x No. of Units)	Type	Commissioning Year
5.7 x 2	Diesel	1998

2) Specification of Main Unit

Diesel Engine

Type: single stroke, 4 cycle, water cooled, turbo-charged type

Output: 8,070 PS

Speed: 720 RPM

Fuel: diesel oil

Generator

Type: AC 3-phase synchronous generator

Capacity: 7,125 kVA (output; 5,700 kW)

Frequency: 60 Hz

Voltage: 13.8 kV

(3) Anna Regina Power Station

1) Installed capacity and commissioning year

Installed Capacity (MW x No. of Units)	Type	Commissioning Year
2.0 x 1	Diesel	1991
1.0 x 1	Diesel	1992

2) Specification of main unit

Diesel Engine

Type:	single stroke, 4 cycle, water cooled, turbo-charged type	
Output:	2,840 PS	1,420 PS
Speed:	900 RPM	900 RPM
Fuel:	diesel oil	diesel oil

Generator

Type:	AC 3-phase synchronous generator	
Capacity:	2,200 kVA (output; 2,000 kW)	1,250 kVA (1,000 kW)
Frequency:	60 Hz	60 Hz
Voltage:	13.8 kV	13.8 kV

When this unit is operated at 50 Hz, the engine output is 2,300 PS and 1,150 PS respectively (approximate), generator output 1,600 kW and 800 kW respectively (approximate), and speed 750 RPM.

(4) Wakenaam Power Station

1) Installed capacity and commissioning year

Installed Capacity (MW x No. of Units)	Type	Commissioning Year
0.5 x 1	Diesel	1993

2) Specification of main unit

Diesel Engine

Type: single stroke, 4 cycle, water cooled, turbo-charged type
Output: 720 PS
Speed: 900 RPM
Fuel: diesel oil

Generator

Type: AC 3-phase synchronous generator
Capacity: 625 kVA (output; 500 kW)
Frequency: 60 Hz
Voltage: 4.16 kV

(5) Bartica Power Station

For the new generating unit to be installed in 1991, the generator room will be expanded to provide space for one more unit (by utilizing the space currently used as repair shop and warehouse), and a new foundation structure will be constructed. For the generating unit to be installed in 1998, existing old unit will be removed and its foundation will be utilized.

1) Installed capacity and commissioning year

Installed Capacity (MW x No. of Units)	Type	Commissioning Year	Remarks
0.4 x 1	Diesel	1991	Extension of existing building.
0.4 x 1	Diesel	1998	

2) Specification of main unit

Diesel Engine

Type: single stroke, 4 cycle, water cooled, turbo-charged type

Output: 570 PS

Speed: 900 RPM

Fuel: diesel oil

Generator

Type: AC 3-phase synchronous generator

Capacity: 500 kVA (output; 400 kW)

Frequency: 60 Hz

Voltage: 4.16 kV

8.5.4 Approximate construction cost and implementation schedule

(1) Approximate construction cost

Refer to the approximate construction cost of Master Plan presented in Chapter 11.

(2) Implementation schedule

Delivery of a generating unit shall take 15 months after conclusion of contract.

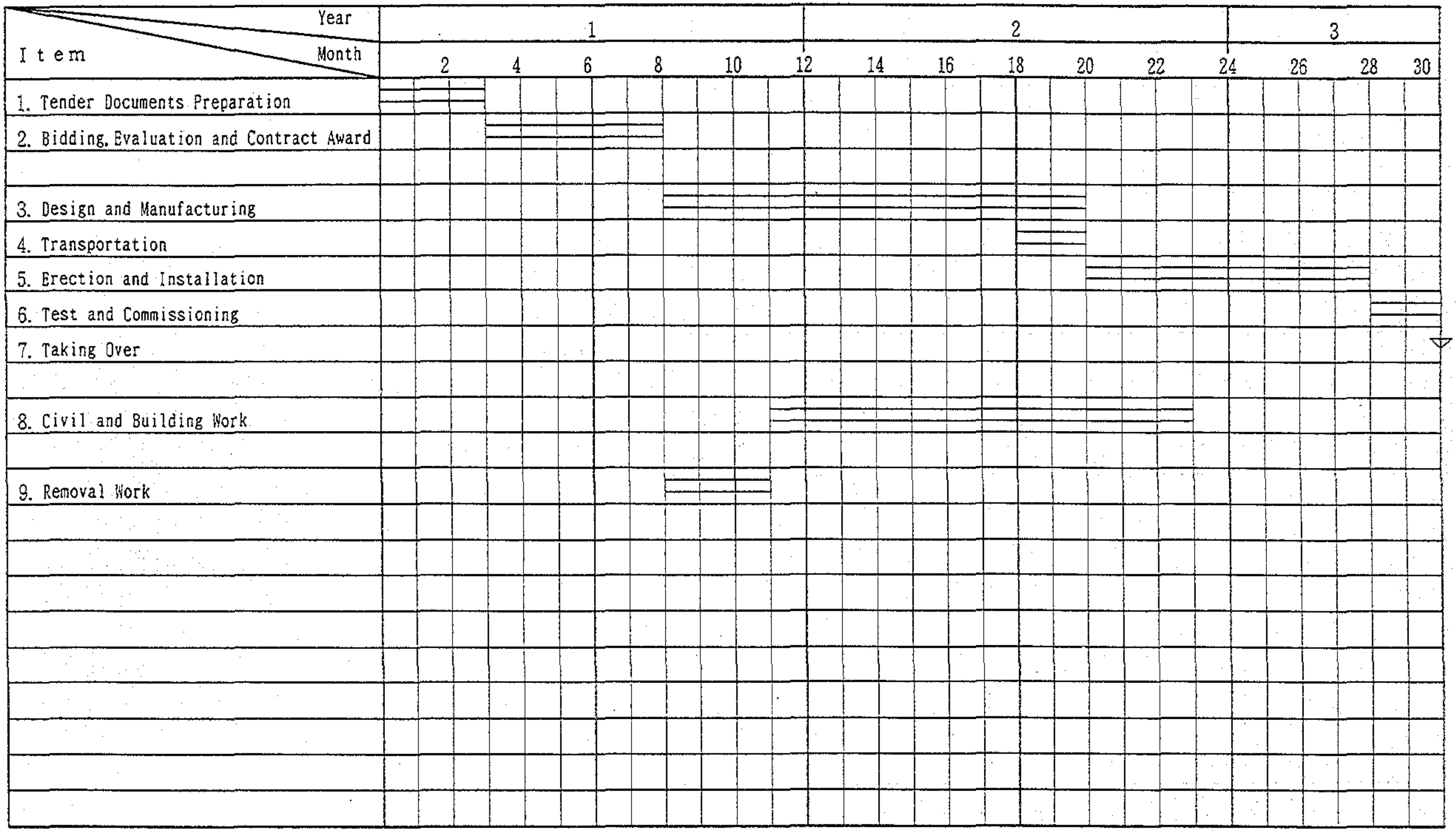
Table 8.4.1 Comparison between Low Speed Diesel Set and Steam Turbine Set

Kingston Power Plant
(at 100% load)

	Item	Unit	Low speed D/G (129 rpm)	S T/G	Remarks
1	Unit installed capacity	kW	13,000	13,000	
2	Station power consumption	%	3.0	6.0	
3	Total delivered power	kW	12,610	12,220	(1)x(1-(2))
4	Annual operating hours	hrs/year	7,884	7,884	24x365x0.9
5	Annual delivered power	GWh/year	99.4	96.3	(3)x(4)
6	Total Construction cost	Million yen	2,000	1,950	
7	Construction Cost per kW	Yen	153,850	150,000	(6)/(1)
8	Depreciation and Interest	Million yen	188.78	167.33	(6)x0.09439 L.S D/G (6)x0.08581 S T/G Service life (years) L.S D/G: 20 S T/G : 25 Rate of Interest:7%
9	Number of employees	Person	15	15	
10	Salaries per head	Yen/year	343,200	343,200	1G$=13.0Yen 2200G$/monthx12x13.0
11	Total salaries	Million yen	5.15	5.15	(9)x(10)
12	Total fixed cost	Million yen	193.93	172.48	(8)+(11)
13	Total fixed cost per kWh	Yen/kWh	1.95	1.79	(12)/(5)
14	Fuel price per liter	G$/liter	0.82	0.82	
15	Fuel price per liter	Yen/liter	10.66	10.66	1G$=13.0Yen
16	Specific gravity of fuel		0.955	0.955	
17	Fuel price per kg	Yen/kg	11.16	11.16	(15)/(16)
18	Thermal efficiency	%	45.0	32.0	
19	Specific heat consumption	kcal/kWh	1,910	2,690	860/(18)
20	Calorific value of fuel	kcal/kg	10,200	10,200	

	Item	Unit	Low speed D/G (129 rpm)	S T/G	Remarks
21	Specific fuel consumption	kg/kWh	0.187	0.264	(19)/(20)
22	Fuel cost per kWh	Yen/kWh	2.09	2.95	(17)x(21)
23	Lub oil price per liter	G$/liter	18.4	0	
24	Lub oil price per liter	Yen/liter	239	0	1G$=13 Yen
25	Specific gravity of lub oil		0.9	0	
26	Lub oil price per kg	Yen/kg	266	0	(24)/(25)
27	Specific lub oil consumption per kWh	g/kWh	1.20	0	
28	Lub oil cost per kWh	Yen/kWh	0.32	0	(26)x(27)x10^{-3}
29	Variable maintenance cost	Yen/kWh	0.5	0.3	
30	Total operation cost per kWh	Yen/kWh	2.91	3.25	(22)+(28)+(29)
31	Unit cost per kWh	Yen/kWh	4.86	5.04	(13)+(30)
32	Unit cost per kWh	G$/kWh	0.374	0.388	(31)/13

Table8.4.2 IMPLEMENTATION SCHEDULE



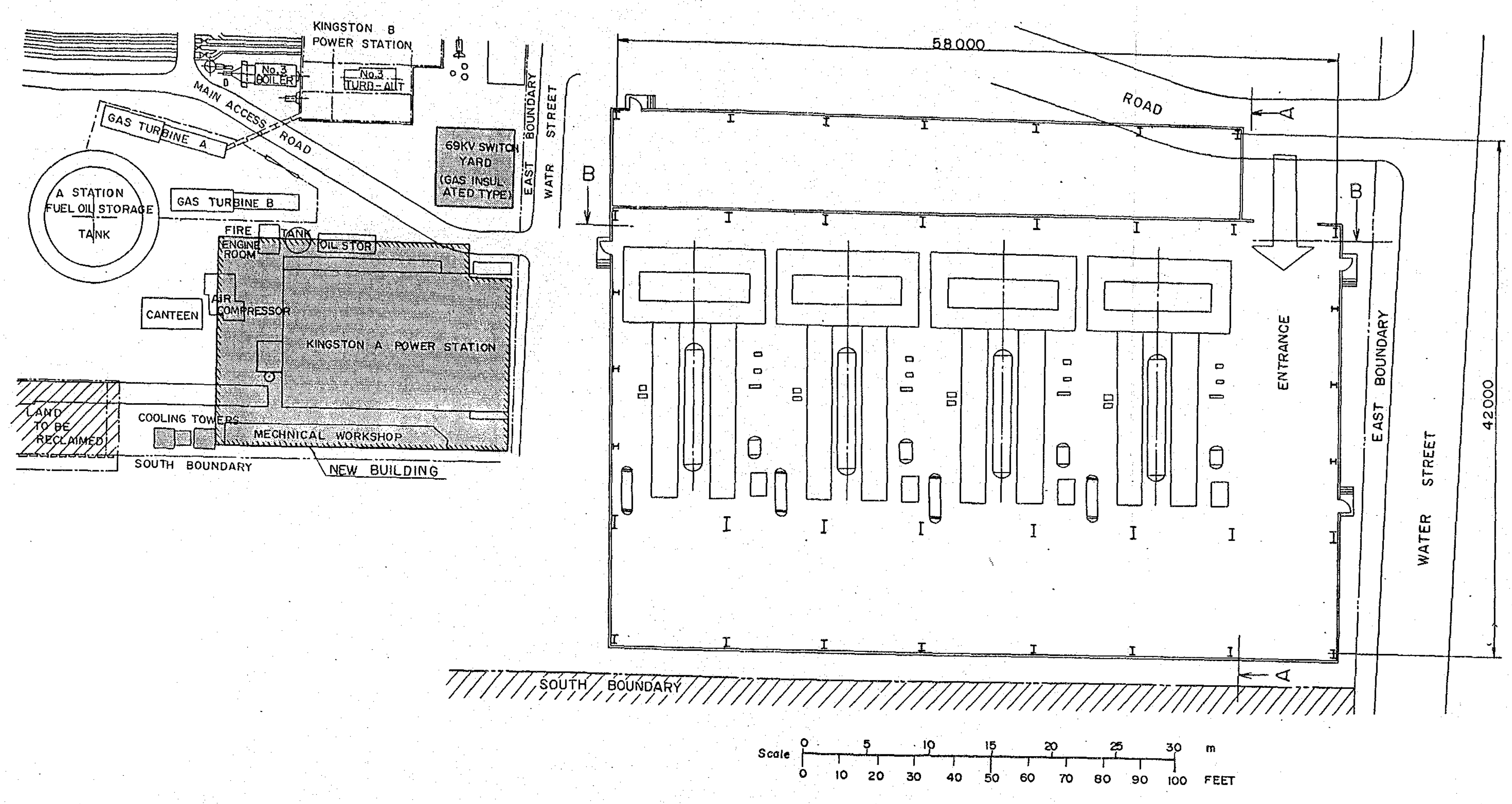
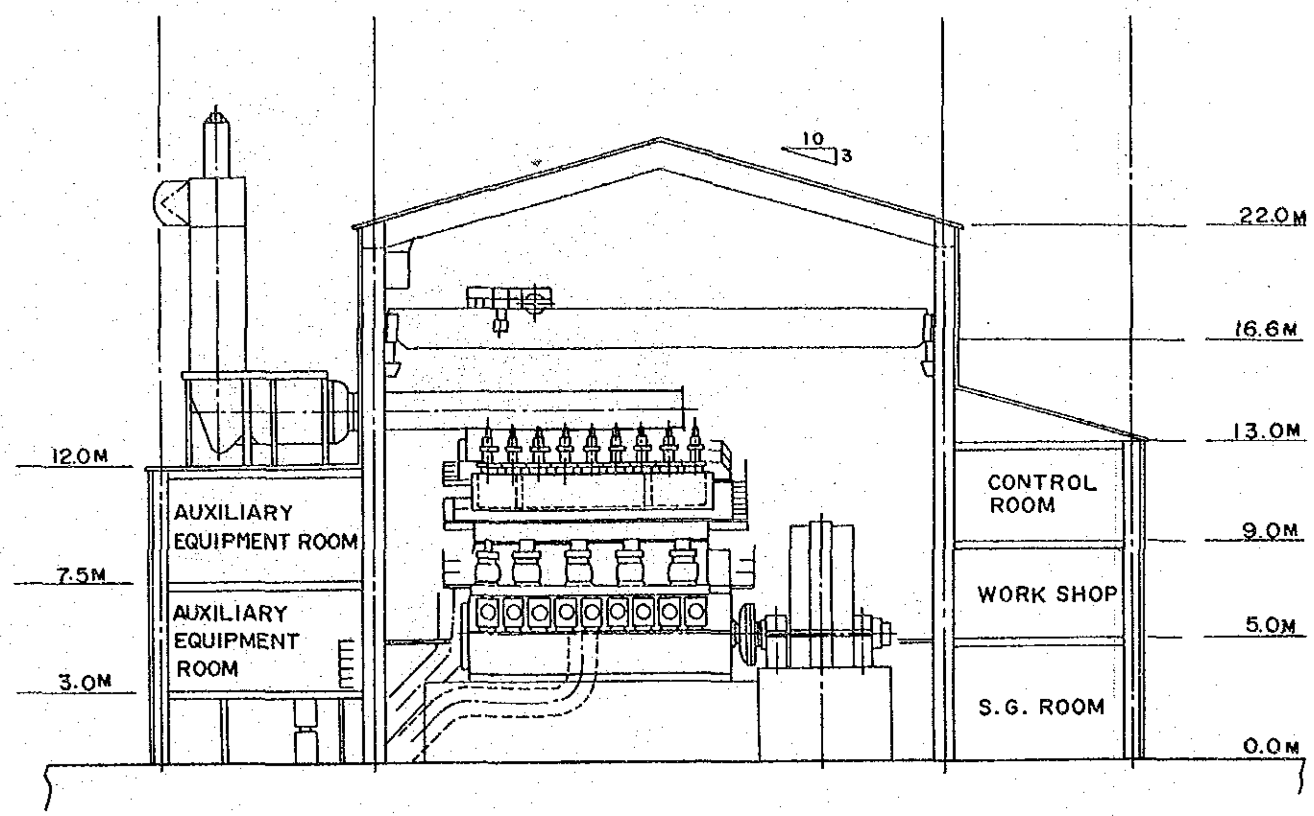
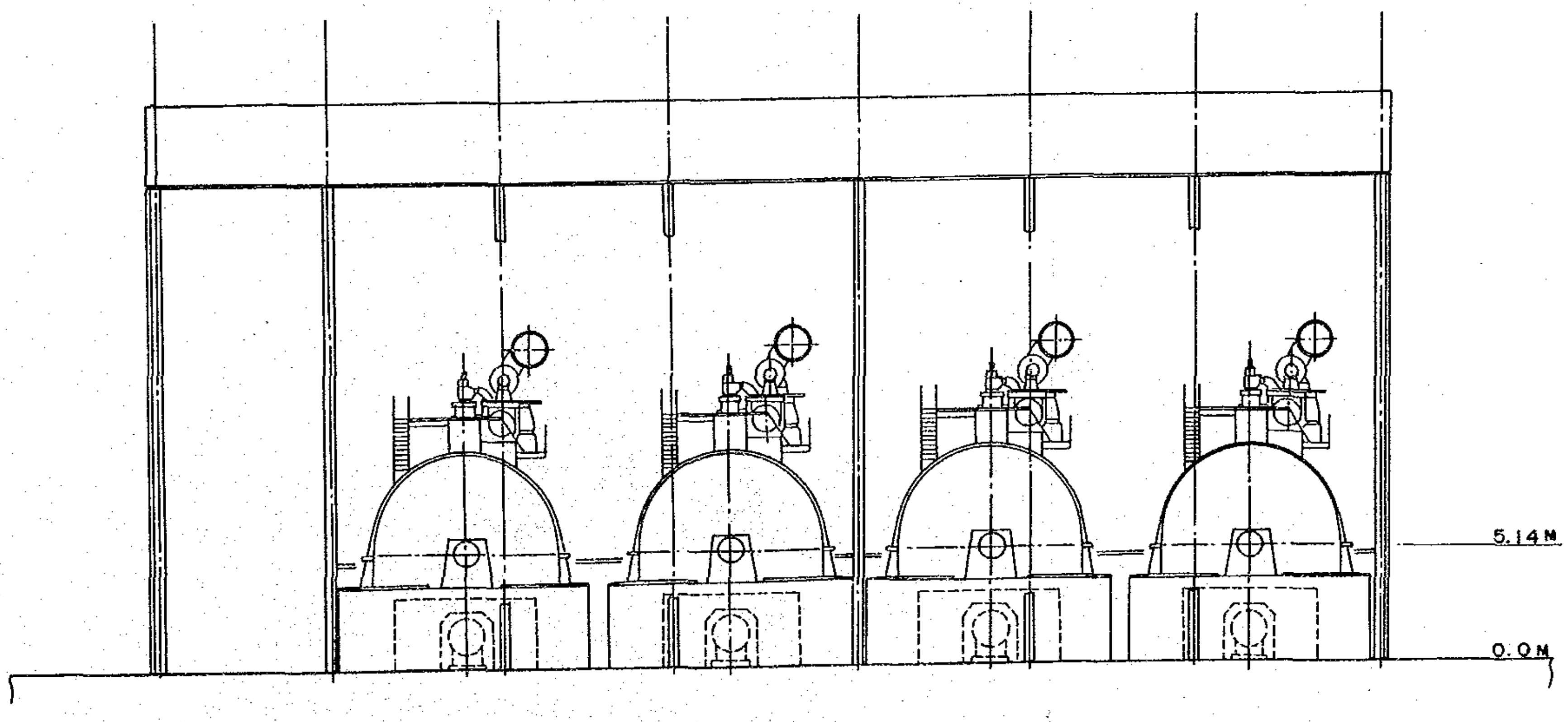


Fig 8.4.1 GENERAL LAYOUT OF KINGSTON POWER STATION



A – A



B – B

Fig 8.4.2 CROSS SECTION OF NEW KINGSTON POWER STATION

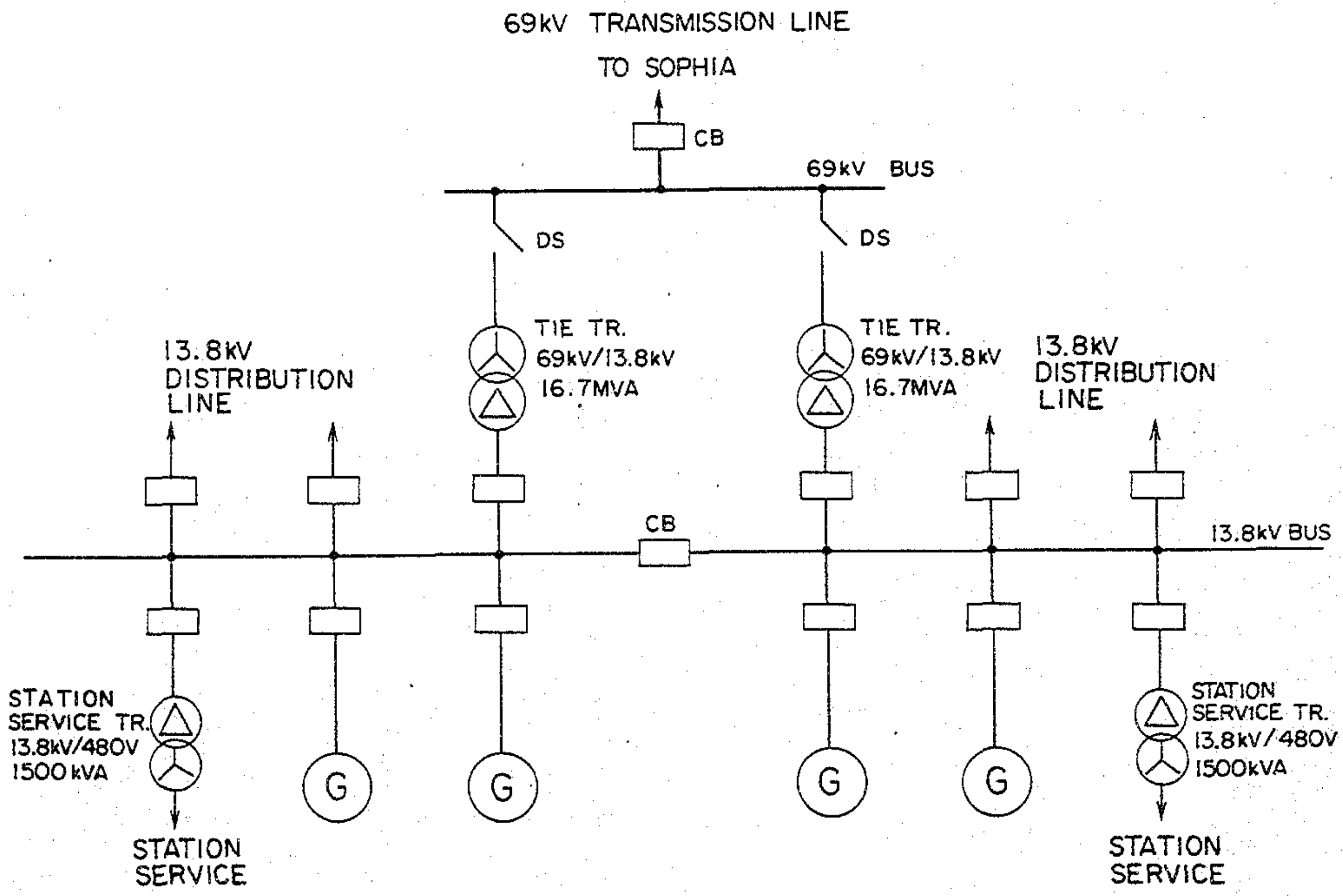
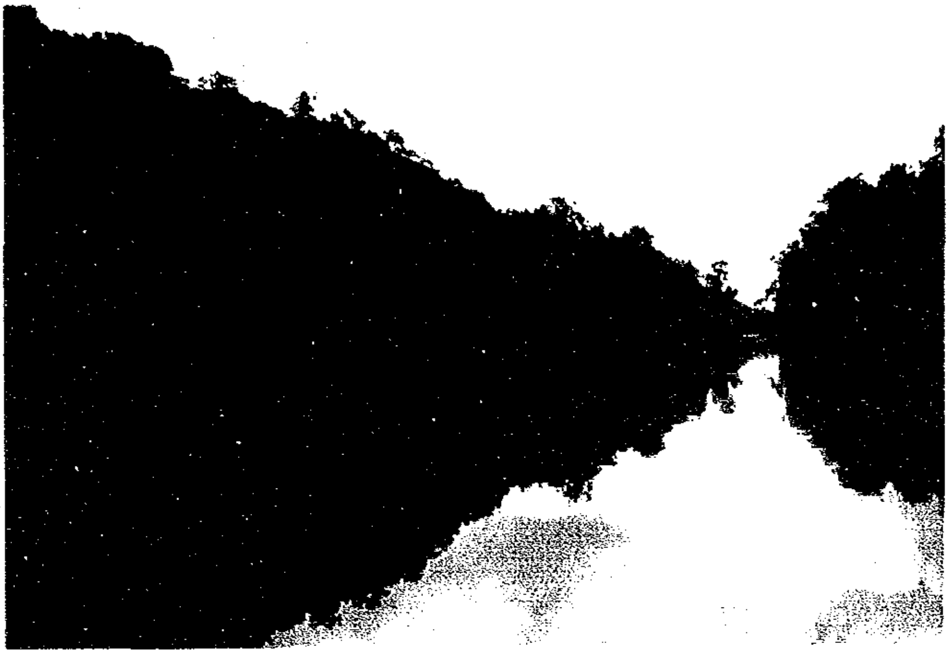


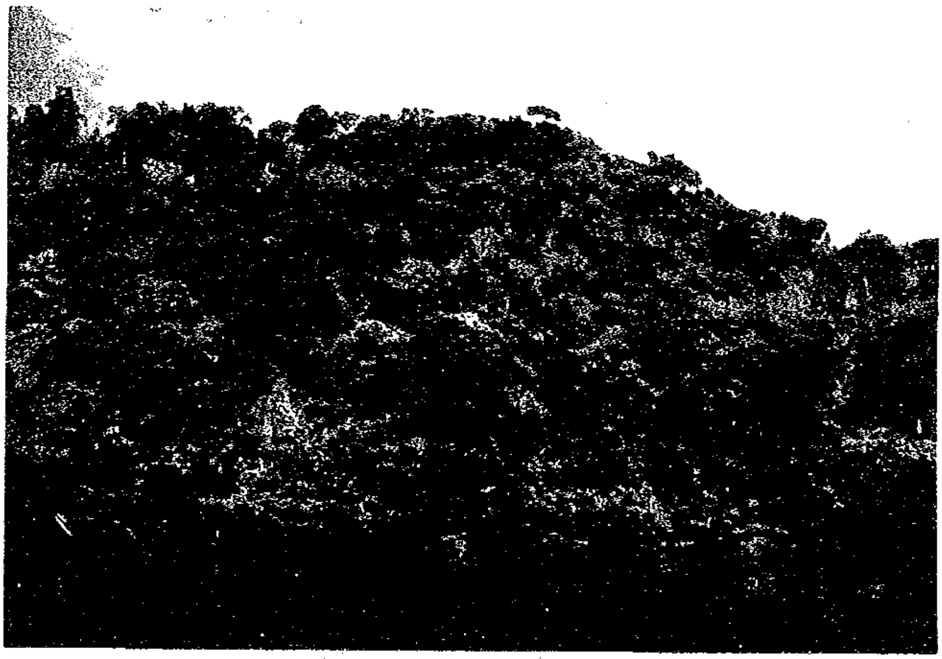
Fig. 8.4.3 MAIN ONE LINE DIAGRAM OF NEW KINGSTON PS.

CHAPTER 9

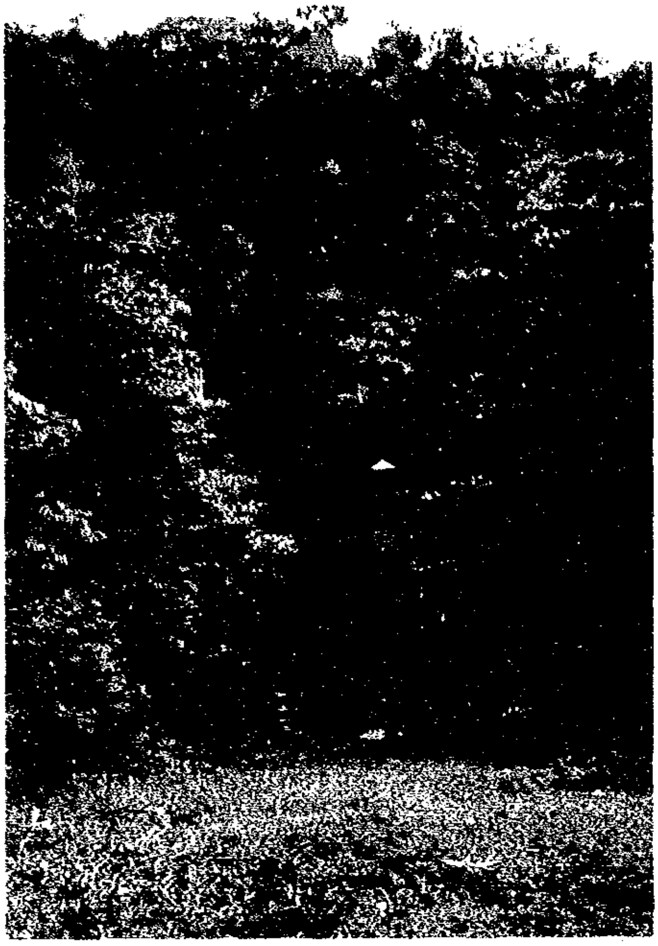
HYDROELECTRIC POWER DEVELOPMENT SCHEME



Tiger Hill Damsite



Left Bank of Tiger Hill Damsite



Great Falls
Gauging Station

Great Falls Meteorological Observatory

CHAPTER 9 HYDROELECTRIC POWER DEVELOPMENT SCHEME

9.1 INTRODUCTION

Surveys for hydroelectric power development in Guyana have been carried out since the beginning of the twentieth century by various foreign consultants and experts, and 59 potential sites have been investigated up to the present. However, most of these sites are located remote from the load consuming centre on the Coastal Area, where 85% of population is concentrated. The Tiger Hill site which was investigated by the Team is located in the Demerara River Basin approximately 60 km upstream of Linden. This site is close to the center of demand for electric power and is a site advantageous for hydroelectric power development.

The bauxite mining company GUYMINE located at Linden has its own power generating facilities and is also interconnected with the Coastal Area by a 69 kV transmission line.

9.1.1 Necessity for hydro power development

At present supply of electric power in Guyana relies on thermal power generation by diesel and steam using fossil fuels. The installed generating capacity in Guyana as of September 1988 amounted to 154 MW including the facilities owned by GUYMINE. However, almost all of these facilities are obsolete because of equipment breakdown and lack of spare parts, and dependable capacity is only about 81 MW.

Guyana is endowed with abundant water resources, and supply of electric power in this country should be by hydroelectric power generation utilizing these abundant resources.

The Tiger Hill hydro power development site which was investigated by the Team is located close to the load centers of the Coastal Area, and is an excellent site from the points of view of topography and geology, no specific engineering problems are foreseen, and it may be said to be the most favorable site for hydro power development in the Demerara River Basin.

The reason development of hydroelectric power generation had not been realized in spite of the fact that various hydro power development schemes had been studied since the turn of the century and the superiority of hydroelectric power generation had been ascertained was probably because of the large initial investment that would have been required and the long construction period compared with thermal power plants.

For the sake of stable supply of electric power, it is necessary to establish a policy on a long-range to utilize indigenous energy instead of relying only on thermal power generation using fossil fuels which require yearly expenditures of large amount of foreign exchange.

The outline of the Tiger Hill Hydroelectric Power Development Project and the results of economic analyses are given below.

Installed capacity	56,000 kW (28,000 kW x 2 units)
Annual energy production	265 GWh
Total construction cost	US$174.5 x 10^6
Generating cost per kWh	US$0.056/kWh
Economic comparison with thermal P/S	
B/C ratio	1.125
B - C	US$1.86 x 10^6

As indicated above, the Tiger Hill Hydroelectric Power Development Project is economical compared with thermal power generation, and it is desirable to implement the development of the project at the earliest in order to save on fuel costs.

The work required hereafter for implementation of the Tiger Hill Hydroelectric Power Development Project will be as follows:

- Feasibility study and geological investigation 1.5 yr
- Basic design, preparation of bid documents 1.5 yr
- Tender evaluation, contract awarding procedure, and contract awarding 1.0 yr
- Detailed design and construction work 4.0 yr

That is, a period of at least 8 years from start of Feasibility Study until start of power generation is required, and the following are proposed for early commencement of the Project.

- That the Guyanese Government adopts a policy for promotion of development of the Project.

- That the various preparations (approaching foreign organizations, procurement of funds for financing investigations) required for carrying out the investigations be started.

- That the additional investigation work proposed in this Report and a feasibility study be made.

- That preparations for financing to implement the Project be made.

9.1.2 Past studies

In 1956, Demerara Bauxite Company Limited considered hydroelectric power generating plant to replace existing diesel facilities and commissioned Aluminium Laboratories Limited of Canada to make a feasibility study of hydroelectric power development in the Demerara River Basin. The Tiger Hill site, Malali site, Great Falls site, and diversion from the Essequibo River to the Demerara River were examined in the study, and topographical surveying, hydrological investigations, and geological investigations by boring were carried out. The proposed development scheme of this study was 110 MW with three (3) generators at the Tiger Hill.

In 1967, Shawinigan Engineering Company Limited conducted power development surveys of the Tiboku site on the Mazaruni River and the Tiger Hill site on the Demerara River.

From 1974 to 1976, MONENCO of Canada made a survey of the hydroelectric potentials of the principal hydro power sites in Guyana, while in 1983, SWECO of Sweden carried out a power study on all of Guyana. In the study SWECO reviewed past studies, and proposed a development scheme of 62 MW for Tiger Hill (2 units of 31 MW, maximum discharge 81 m^3/sec per unit). The high water retention level of the reservoir proposed by SWECO is 46.55 m.

9.1.3 General description of development project

In formulation of the present Electric Power Master Plan for the Coastal Area, past studies mentioned in Section 9.1.2, were reviewed and the optimum plan for hydroelectric power development is proposed.

The principal facilities of the Tiger Hill Project are as follows:

- Dam and reservoir
- Spillway
- Headrace, penstock
- Powerhouse
- Substation
- Transmission line
- Access road

The layout of the dam and power station sites is shown in Dwg. 9-2.

The outline of the Tiger Hill Development Project proposed in this Report is as follows:

Maximum output	56,000 kW
Annual energy production	265 GWh
Catchment area	4,100 km^2
Reservoir	
High water level	EL. 46 m
Low water level	EL. 34 m
Available drawdown	12 m
Effective storage capacity	4,215 x 10^6 m^3
Total storage capacity	5,765 x 10^6 m^3
Reservoir area (at HWL)	534 km^2
Hydrology	
Average runoff	113.7 m^3/sec
Average annual inflow	3,588 x 10^6 m^3
Design flood discharge	960 m^3/sec
Design discharge during construction	580 m^3/sec
Dam	
Type	Fill dam
Height	62 m
Dam crest elevation	EL. 50 m
Dam crest length	365 m
Volume	1,498 x 10^3 m^3

Spillway	
Type	Surface, chute type
Overflow crest	EL. 37 m
Gate	Radial gate, 2 units
Headrace tunnel	
Type	Circular, concrete lined
length	235 m (incl. 45 m intake portion)
Inside diameter	8 m
Average velocity	3.78 m/sec
Penstock	
Type	Embedded, inside dia. 4.5 m, 3 lines
Total length	215 m
Turbine	
Type, capacity	Kaplan-type turbine, 29.3 MW x 2 units 29.3 MW x 1 unit (future)
Maximum discharge	186 m^3/sec
Normal effective head	36 m
Speed	212 rpm
Generator	
Capacity	32.3 MVA x 2 units
Frequency	60 Hz
Transmission line	
Length	135 km, 2 cct
Voltage	138 kV
Access road	15 km

The catchment area at the proposed dam site is 4,100 km^2, the reservoir area at high water level is 534 km^2, and the length of the reservoir is approximately 120 km (see Dwg. 9.1). The reservoir high water level was set approximately 0.6 m lower than that proposed by SWECO in 1983 in order to reduce the area to be submerged.

The proposed Tiger Hill Dam is a fill-type structure with a center impervious core having a height of 62 m, crest length of 365 m, and volume of 1.5×10^6 m^3 (see Dwgs. 9.2 and 9.3). Core materials would be collected from the right bank of the Demerara River between Tiger Hill and Malali, and excavated rock for the spillway is to be utilized as embankment material.

A diversion tunnel of discharge capacity 580 m^3/sec is to be constructed in the left bank. This diversion tunnel is to be a horseshoe-shape structure of inside diameter 9.5 m, length 650 m to divert the flow of the river during construction.

Water for power generation is to be drawn by an intake constructed on the left bank upstream of the dam and conducted to the powerhouse by a headrace of inside diameter 8 m and three lines of penstocks. A screen and a gate for headrace inspection is to be provided at the intake.

A powerhouse with sufficient space for installing three generators is to be constructed on the left bank downstream of the dam. Initially, the power station would be operated with two 28 MW units, but another unit would be added as demand increases. The turbines are to be vertical-shaft Kaplan turbines, with a discharge of 93 m^3/sec each, the normal effective head being 36 m. The power generated is to be sent to load consuming areas by 138 kV transmission line from a switchyard provided on the opposite bank of the powerhouse via the substations of Linden and Garden of Eden.

Access to the Tiger Hill site is to be by a new road approximately 15 km to be constructed from the Linden-Ituni road to the site. This road would serve concurrently as an inspection road for the transmission line.

The construction period for the Project would be approximately 4 years not including the construction of the access road. The proposed work schedule for the project is shown in Fig. 9-18.

The reservoir will store a large quantity of water, approximately 58 x 10^8 m^3 at high water level and 20 x 10^8 m^3 at low water level. Therefore, approximately 1 year would be needed to reach a water level which would permit power generation. In order to secure flow of water in the downstream area during impounding of water and while the power station is shut down, outlet works having a capacity of 15 m^3/sec are to be provided.

The estimated construction cost of the Tiger Hill Project is US$174.5 x 10^6 (see Table 9-16). The construction cost includes the costs of constructing an access road, transmission line, and administrative costs, but does not include interest during construction. The unit power generation cost has been calculated to be US$0.056 per kWh.

9.2 TIGER HILL HYDRO POWER DEVELOPMENT PROJECT

9.2.1 Hydrology

(1) River basin

The Demerara River rises from Mt. Makari, EL. 400 m, and flows roughly northward parallel to the Essequibo River and empties into the Atlantic Ocean at a point west of the capital city of Georgetown. The entire river basin is covered by dense forest, both of the river banks are flat, and the river gradient is very gentle except for the two points of Malali and Great Falls. The elevations of the ridges at both banks are lower than 60 m, and 50 m at the lowest point (see Fig. 9-2).

The Tiger Hill site is situated approximately 60 km up along the Demerara River from Linden where there is bauxite mine and 170 km upstream from the river mouth. The Tiger Hill site is located where the river valley is the narrowest along the course of the Demerara River, and is topographically favorable as a dam site.

The catchment area at the dam site is 4,100 km^2 and the average annual inflow is approximately 3.6×10^9 m^3.

Access to the Tiger Hill site is by the Mabura Hill road on the left bank and a foot path from the Linden-Ituni road. Access is also possible by boat from Linden.

(2) Meteorology and hydrology

Guyana is located less than 10 degrees latitude north of the equator, is affected very little by the strong hurricanes that occur in the western part of the Atlantic Ocean and the Carribean Sea, and compared with other Central and South American countries, damages from heavy rains causing landslides and debris outflow and destruction of structures by strong winds are infrequent.

The Demerara River has a catchment area of approximately 4,100 km^2 at the Tiger Hill site and the specific runoff per 100 km^2 at this site is 2.8 m^3/sec. Guyana has two rainy seasons, from May to August, and from November to January. The mean annual rainfall at the Georgetown Botanic Gardens for the 25-year period from 1962 to 1987 was 2,256 mm.

The air temperature is more or less constant throughout the year, the annual mean of maximum temperatures is 30.4°C and that of minimum temperatures is 24°C.

(3) Runoff gauging stations and meteorological observatories

There are Great Falls Runoff Gauging Station (catchment area: 2,460 km^2) and Saka Runoff Gauging Station (catchment area: 4,040 km^2, not in use from 1976) in the Demerara River Basin, and runoff data since 1950 are available.

There are the meteorological observatories of Great Falls, Ituni, and Mackenzie in the surroundings of the site where precipitation, air temperature, humidity, evaporation, etc. are being observed. However, there are occasional unrecorded data at these observatories.

At the Botanic Gardens Observatory in Georgetown there are complete observation data available from the 1880s.

(4) Runoff calculations for the project site

Calculations of catchment areas are based on a 1:50,000 aerial-photo map prepared in 1970 by the Lands Survey Department, Ministry of Agriculture of Guyana.

The runoff at the Tiger Hill site was determined from the runoff data of the 37-year period from 1950 to 1986 obtained at the Great Falls and Saka gauging stations. Flow duration curves in 1973, 1974 and 1975 for the dam site are shown in Fig. 9-6.

The catchment areas of these runoff gauging stations and the Tiger Hill site are as follows:

Tiger Hill site	4,100 km^2
Saka Gauging Station	4,040 km^2
Great Falls Gauging Station	2,460 km^2

a) Average monthly inflow

The average monthly runoff from 1950 to March 1976 was calculated by multiplying the runoff at Saka Gauging Station with the catchment area ratio, and this was taken to be the runoff at the Tiger Hill site.

$$Qt = Qs \times 4,100/4,040$$

where, Qt: runoff at Tiger Hill site

Qs: runoff at Saka Gauging Station

Calculation of runoff from April 1976 to 1986 was done in accordance with the method below based on the runoff of Great Falls Runoff Gauging Station since the gauging station at Saka was abolished in March 1976.

The correlation between the runoffs at the two gauging stations of Saka and Great Falls from 1950 to March 1976 was obtained, and the runoff at the Saka site was calculated based on this correlation, and then the runoff at the Tiger Hill site was estimated multiplying the calculated Saka runoff by the catchment area ratio. The runoff at the Tiger Hill site was calculated by dividing it into the two cases of average monthly runoff less than 1,500 cfs and more than 1,500 cfs.

$Qg < 1,500$ cfs

$$Qt = (1.4921 \times Qg + 325.6) \times 1.015$$

$Qg > 1,500$ cfs

$$Qt = (1.2325 \times Qg + 811.6) \times 1.015$$

where, Qt: runoff at Tiger Hill Site (cfs)

Qg: runoff at Great Falls Gauging Station (cfs)

The discharge conditions at the Tiger Hill site obtained from the runoff data for the 37-year period are as follows:

Max. av. monthly runoff	189.2 m^3/sec
Min. av. monthly runoff	53.7 m^3/sec
Av. runoff	113.7 m^3/sec
Max. runoff	454.0 m^3/sec
Min. runoff	12.0 m^3/sec
Max. annual inflow	5970 x 10^6 m^3
Av. annual inflow	3590 x 10^6 m^3
Min. annual inflow	1700 x 10^6 m^3

The average monthly runoffs at Great Falls and Saka Gauging Stations used for calculating runoffs and preparing mass curves are given in Table 9-1 and 9-2 respectively.

b) Maximum runoff

The yearly past maximum runoffs at the dam site obtained from the runoff data are given in Table 9-8.

(5) Precipitation

The precipitations by month at the Botanic Gardens in Georgetown are given in Table 9-3. The annual average, maximum, and minimum precipitations during the 27-year period from 1966 are as follows:

Average annual precipitation	2,256 mm
Annual maximum precipitation	2,994 mm
Annual minimum precipitation	1,728 mm

Table 9-3 Monthly average precipitation (mm)

January	184	July	265
February	87	August	200
March	103	September	101
April	145	October	112
May	303	November	179
June	323	December	256

(6) Air temperature and humidity

Data at the meteorological observatory of Botanic Gardens are given in Table 9-4.

Table 9-4 Air temperature and humidity (1966 - 1987) (Botanic Gardens) Georgetown

	Temperature (°C)		Humidity (%)	
	Max.	Min.	12:00 hrs.	18:00 hrs.
Av. annual	30.4	24.0	82.8	70.2
Max.	39.4	25.7	92.0	83.0
Min.	28.3	22.5	73.0	65.0

(7) Evaporation

The values according to the Water Budget Method obtained by SWECO in 1983 were referred to in the calculation of evaporation from the reservoir surface. The data of nearby observatories listed below from 1968 to 1975 which records were complete were used.

Precipitation	Ituni, Great Falls
Discharge	Great Falls, Saka
Evaporation	Great Falls

Evaporation from the reservoir is expressed by the equation below.

$$E_{net} = k \times E_{pan} - (P-Q)$$

where, E_{net}: evaporation loss from reservoir (mm)

E_{pan}: evaporation from evaporation pan at observatory (mm)

P: precipitation (mm)

Q: discharge (mm)

k: pan coefficient

The pan coefficients generally used for calculation of evaporation from the reservoir are 0.6 to 0.8. However, according to the research by Mr. Chander Persaud of HYDROMET (Hydrometeorological Service, Ministry of Works and Transport) of Guyana, the pan coefficient of Guyana was 1.08. This pan coefficient was used in this study also.

The monthly evaporation losses are given in Table 9-11.

Table 9-11 Evaporation from reservoir (mm)

Jan	35	Jul	0
Feb	70	Aug	60
Mar	95	Sept	80
Apr	90	Oct	80
May	-10	Nov	40
Jun	-70	Dec	10
	Annual evaporation		480 mm

The annual evaporation estimated in past studies for the various proposed reservoir sites are given below.

Table 9-12 Annual net evaporation losses from reservoir (mm)

	Shawinigan-88	SWECO-76	MONENCO-76	SWECO-83
Tiger Hill			500	480
Tumaturani			500	390
Amaila			500	310
Kaiteur			500	310
Upper Mazaruni	200	200	500	650
Tiboku			500	650

(8) Sedimentation

Measurements of suspended sediment were made at Kamarang/Latipu on the Mazaruni River during a 9-month period from April 1976. The quantity of suspended sediment measured during this period was 142,530 tons, the total runoff during the period having been 205.3×10^9 m^3. This means that 6 ppm of suspended sediment is contained in flowing water.

The topography in and around the reservoir area is gently sloped and covered by dense forest. The water does not become turbid even in the flood season, and it is considered that there is very little transport of sediment by flowing water. The color of river water is a transparent brown throughout the year. The results of analyses of water samples collected on August 22, 1988 at Tiger Hill is given in Table 9-14. The amount of suspended solids at this time was 100 ppm.

Water is sampled periodically and water quality analyses made each year at the Great Falls site and the results are given below:

Suspended solids, pH of flowing water of Demerara River

Date	Runoff (Great Falls)	Suspended solids (ppm)	pH	Remarks
22/04/73	267 cfs	48	5.8	Great Falls
20/08/73	2,940	148	4.8	-do-
02/06/75	2,260	49	6.4	-do-
10/06/77	2,860	57	4.6	-do-
06/09/77	2,510	170	4.4	-do-
22/02/78	578	55	5.2	-do-
20/07/81	7,520	75	-	-do-
12/12/86	1,600	58	6.8	-do-
22/08/88	7,170	100	4.5	Tiger Hill

Assuming that all of these suspended solids contained in the flowing water are deposited inside the reservoir, it can be estimated that the average annual sediment inflow at Tiger Hill site will be approximately 400,000 tons. If bed load is assumed to be 20 percent of the suspended sediment, the sediment deposited in the reservoir during a 100-year period would be approximately 34×10^6 m^3. This is a very small quantity and sedimentation will not be a decisive factor in determining the reservoir low water level at the Tiger Hill site.

(9) Design flood discharge

a) Annual maximum discharge

Design flood discharge at the Tiger Hill site was calculated by employing the annual maximum discharges at Saka and Great Falls Gauging Stations from 1950 to 1986.

The yearly maximum discharges at Great Falls and Saka Runoff Gauging Stations are shown in Table 9-8.

b) Probable flood discharge

The three methods below are conceivable for calculating probable flood discharge.

- Log-Peason Type III
- Peason Type III
- Gumbel Type I

The design flood discharge at the Tiger Hill site was taken to be 960 m^3/sec considering a 10-percent allowance in addition to 10,000-year return period flood discharge according to Gumbel distribution. The results of calculations of probable flood discharge are given below.

Return period (yr)	Probable flood discharge (m^3/sec)
10,000	870
5,000	820
1,000	720
500	680
250	640
200	620
100	580
50	540
20	480
10	430
5	390

The larger of past maximum flood discharge or 100-year return period flood discharge is to be used as the design flood discharge during construction work.

Past maximum flood discharge	454 m^3/sec
100-year return period flood discharge	580 m^3/sec

Based on the above results, the design flood discharge during construction was taken to be 580 m^3/sec.

The results of flood analyses made in past studies are given in Table 9-13.

Table 9-13 Design flood analyses in past studies of Tiger Hill Site (m^3/sec)

Study	Flood discharge (m^3/sec)
Aluminium Lab., 1957	
Design flood	850
Constr. flood	570
Shawinigan, 1967	
(Log normal distribution)	
Design flood (1:10,000)	2,500
Const. flood (1:100)	1,420
MONENCO, 1976 and 1981	
Design flood	1,010
1:10,000 year	980
Constr. flood (1:25)	500
SWECO, 1983	
PMF method	800
(Frequency analysis)	
1:10,000 year	1,100
1:100 year	660
1:25	550

9.2.2 Geology

(1) Geology of reservoir

a) Size of reservoir and investigation method

The size of Tiger Hill Reservoir will be as follows:

Dam crest elevation	EL. 50 m
Dam height	62 m
High water level	EL. 46 m
Catchment area	4,100 km^2
Reservoir area	534 km^2

The techniques for investigation and study to check the watertightness of the reservoir are as follows:

- Geological interpretation based on aerial photographs (1:50,000 aerial photographs)
- Analyses of summit levels (1:50,000 aerial photographs)
- River system pattern analyses (1:50,000 aerial photographs)
- Surface geological reconnaissances of accessible sites
- Chemical analyses of turbid water

These investigations and studies are recapitulated in Dwg. 9-5.

b) Topography

The Demerara River rises from Mt. Makari, elevation approximately 400 m, located to the south, and flows roughly north and drains into the Atlantic Ocean at Georgetown. Within the basin, the width of the river is narrow at the two points of Great Falls and Tiger Hill, and the river banks are comparatively steep. Except at these sites, the river banks are flat and covered by dense forest.

c) Geology

An outline of the geology of the project site is shown in Dwg. 9-5. The rocks distributed within the reservoir area are composed of greenstone, migmatite, granitoids, fluviatile sandstone and conglomerate belonging to Lower Proterozoic to Middle Proterozoic, and basic intrusive rocks. These basement rocks are intruded by tholeitic and doleritic dikes. Overlying these are unconsolidated Quaternary deposits distributed at low areas along the river, gentle mountain slopes, and flat areas in the watershed vicinities.

South of Ituni located at the watershed on the east side of the reservoir there are remains of strip mining of bauxite deposits. These remains are at higher than EL. 60 m so that leakage from the reservoir will not occur. However, Wallaba Creek, approximately 2 km southeast of Ituni, is adjacent to where the watershed (of elevation approximately 50 m) is a narrow ridge. Since there is concern that leakage may occur from this part high water level of the reservoir should be planned to be lower than EL. 46 m.

(2) Geology of dam site

a) Selection of dam site

With regard to selection of the dam site, detail studies have been conducted in the past, and the Tiger Hill site was selected as the optimum site for hydro power development within the Demerara River Basin.

Investigations and studies have been made on this Tiger Hill site in the study, "Power Potential of Demerara River (1957)" by the Aluminium Laboratories Limited of Canada, "Power Development Survey of Guyana (1967)" by the Shawinigan Engineering Company Limited, and "Hydro Power Study (1982)" by SWECO.

b) Topography

The Tiger Hill site is an outcrop from Arisaru Mountain located near the watershed of the Essequibo River where the ridgeline is at elevations of 120 to 150 m, the highest point being at 165 m. The slopes upstream of the proposed site for the dam are gentle with elevations under 60 m and are covered by jungle growth.

The water level at the dam site is approximately 2 m in the dry season, the river width is 60-70 m, and the water depth is 3 to 6 m. Both banks have slopes of 25 to 30 deg with the highest point being EL. 110 m, forming a topography which is advantageous for construction of a dam.

c) Geology

The rocks distributed at the dam site consist of Precambrian granite and gabbro. These rocks are overlain by surface deposits. The granite is biotite granite which is medium- to coarse-grained, and has narrow veins of pegmatite and apalite.

The gabbro is a melanocratic, dense rock, mainly distributed in sill form at the left bank above EL. 30 m. Dikes are seen at several places along the river bed, with weathered gabbro found in part at the right bank. The contact planes between gabbro and granite are mostly tight, although shearing has occurred in part and there are numerous fissures.

The surface deposits distributed at the dam site consist of slope deposits and river deposits. The slope deposits are composed of topsoil, laterite, and clay, and are approximately 10 m thick at parts of higher elevation. The river deposits consist of silt, sand, and gravel, and are 5 to 10 m deep at the river bed and approximately 10 m at both banks.

d) Geological considerations regarding design and construction

According to past geological investigations, the granite is more susceptible to weathering than the gabbro. Especially, weathered granite is thick at the right bank and the elevation of bedrock is below 20 m.

Above EL. 30 m on the left bank, gabbro is distributed overlying granite, and the weathered zone at this part is thin. The depth to bedrock below EL. 30 m on the left bank is approximately 20 m. The gradient of the bedrock line on the right bank is more gentle than the gradient of the ground surface line.

In view of the geological considerations above, it would be desirable for the principal structures to be constructed on the left bank, and the dam of fill-type structure.

(3) Earthquake

Earthquake records are kept at the Meteorological Division of the Department of Agriculture. Records of earthquakes of magnitudes 5 or greater since 1940 are shown in Fig. 9-3.

Table 9-15 General geologic sequence of Tiger Hill Project Area

Era	Stratigraphic unit	Lithology	Main distribution area
Cenozic	Quaternary system	Fluvial deposits Residual lateritic deposit	In the basin of Demerara, vicinity of watershed
Triassic	Apatoe suite	Dolerite dikes	Dikes
		Tholeitic dikes (not distinguished on map)	Dikes
Middle Proterozoic	Avanavero suite	Gabbro-norite sills and large dikes	Damsite and upstream
	Roraima group	Fluviatile sandstone conglomerate	90 km upstream
	Iwokrama formation	Acid/intermediate volcanics	80 km upstream
	Muruwa formation	Fluviatile sandstone Cherty mudstone	70 km upstream
Trans Amazonic	Younger granites	Granitoid (Granite to Diorite)	40 km upstream
		Migmatite (Granite gneiss)	Damsite and upstream
Lower Proterozoic	Barama-Mazaruni Super group	Greenstone belts	20 km upstream

Source: Geological map of Guyana, 1987, published by the Guyana Geology and Mines Commission.

9.2.3 Construction materials

(1) Dam embankment materials

a) Core materials

In the investigations carried out in 1957 by Aluminium Laboratories Limited, it was confirmed that impervious core material exists at the right bank approximately 2 km upstream from the dam site. There is also talus deposits having a maximum thickness of 10 to 15 meters distributed at the mountain-top on the right bank of the dam site, and core material can be borrowed from these locations on the right bank immediately upstream of the dam site.

These materials are composed of reddish brown, sandy and clayey silt originating from weathered products of gabbro and contain laterite. The percentages of these materials passing a #200 (0.074 mm) sieve are from 40 to 77 percent.

b) Filter materials

Gravel-bearing sandy soil is distributed to a thickness of around 10 m at the river-bed of the dam site. This material contains much silt and is not homogenous, and is not suitable as filter material. Fluvial sand is distributed at both banks, but this cannot be used as filter material for the same reason. Consequently, it will be difficult to obtain filter material in the vicinity of the dam site.

Material with a possibility of being considered as filter material would be white sand, which is ubiquitously found in the Demerara River Basin. Much white sand is seen in the surroundings of the proposed reservoir. The characteristics of this material should be investigated.

c) Embankment materials

Excavated muck from spillway and from other excavations in the project area is to be used for random fill of the dam, and compacted by roller, while core and filter materials are to be borrowed from within the reservoir area in the vicinity of the dam site.

The approximate excavation volumes for the principal structures at the Tiger Hill site are as follows:

Spillway	1,350,000
Dam	211,000
Diversion tunnel	72,000
Intake	28,000
Headrace	19,000
Powerhouse	70,000
Total	1,750,000 m^3

(2) Concrete aggregates

Quarries presently being operated are concentrated in the Essequibo and Mazaruni river basins, and almost all concrete aggregates used in Guyana are being supplied from these areas.

There will be concrete structures such as a spillway, diversion tunnel, and powerhouse at the Tiger Hill site, and approximately 80,000 m^3 of concrete will be required.

What will pose a problem with concrete aggregates will be obtaining coarse aggregate. For fine aggregate, the white sand found in abundance in Guyana is being used. The coarse aggregate to be used at the site would either be transported from the Essequibo-Mazaruni region or be manufactured by installing an aggregate manufacturing plant at the site. This option must be decided by studying the economics of both alternatives.

9.2.4 Development scheme

(1) Basic conditions

a) Topographical maps

The topographical maps below were used in carrying out the study.

Scale, 1:1,000,000	Entire Guyana
Scale, 1: 50,000	Entire river basin
Scale, 1:1,200	Dam and powerhouse sites
	Prepared in 1957 by Aluminium Laboratories Limited

The topographical maps of 1:1,200 scale are expressed in feet, and moreover, the Mackenzie System is adopted for the datum plane. The topographical maps used for the study were 1:1,000 maps prepared by converting these maps to the Terra System with mean sea level as the datum plane.

The elevation of the datum plane in the Mackenzie System is -25.98 m.

b) Catchment area and storage capacity

The data in "Guyana Power Study" prepared by SWECO in February 1983 was used as reference.

c) Water level and rating curve of power station site

The data in the abovementioned SWECO report were referred to.

(2) Basic considerations

a) Dam location

Regarding the location of the dam, detailed examinations have been made in past studies, and the Tiger Hill site has been proposed as the hydro power development site.

It was confirmed in the field reconnaissance made this time also that within the Demerara River Basin the Tiger Hill site is advantageous from the standpoints of topography, geology, proximity to load centers, short transmission line, short transportation distance, etc.

b) Power generation system

The Tiger Hill dam site is located approximately 170 km upstream from the mouth of the Demerara River, and the dam site water level at average annual discharge is EL.3.10 m and the river gradient is extremely gentle at approximately 1/50,000. Accordingly, there will be practically no increase in head even if a long headrace were to be provided, therefore the powerhouse will be located immediately downstream of the dam.

c) Layout

Except for the study carried out in 1957 by Aluminium Laboratories Limited, studies made subsequently by MONENCO and SWECO have proposed a tunnel spillway.

In the present study, the spillway is a surface type in consideration of the risk of blocking of the spillway by driftwood in the flood season and ease of maintenance of facilities. Also, savings in the construction cost can be achieved by the use as dam embankment materials of excavated earth and rock produced in large volume from the spillway site.

The principal structures of the power generation facilities are to be located on the left bank which is more advantageous geologically.

d) Essequibo River diversion proposal

Diversion of water from the Essequibo River to the Kuruduni River at the upstream part of the Demerara River has been considered in the past.

It was decided not to include this diversion plan in the present study but to include it in the next hydro power development scheme to be studied after completion of the Tiger Hill Project. (see Section 9.3)

(3) Study of development scheme

a) Examination of reservoir capacity

The reservoir capacity was examined preparing a mass curve for the proposed dam site using runoff data of Saka and Great Falls Runoff Gauging Stations from 1950 to 1986.

1) Limit to reservoir high water level

In 1957, surveying of elevations in the entire watershed of the Demerara River Basin necessary for deciding the reservoir high water level was done by Aluminium Laboratories Limited.

According to the results of the surveying, the areas that would influence selection of the high water level at the Tiger Hill site from a topographical standpoint are the ridges at Ituni on the east bank of the Demerara River and the right bank of the Kuruabaru River, where the minimum elevations are at 50 m. The elevations of the these areas are shown in Fig. 9-2.

From the results of the abovementioned surveying, it is thought that the upper limit to the high water level of the reservoir would be around El. 46 m.

2) Reservoir area and storage capacity

The reservoir capacity and area of the Tiger Hill site are shown in Fig. 9-8, Fig. 9-9 and Table 9-10.

Table 9-10 Storage area and storage capacity

EL (m)	Storage area (km^2)	Storage capacity (100×10^6 m^3)
10	10	0.3
20	35	2.4
30	120	9.5
34	196	15.5
35	220	17.0
40	345	31.1
42	409	39.6
45	505	52.4
46	534	57.6
47	565	63.2
50	670	81.6

3) Dam height and effective storage capacity

In studying dam height and reservoir high water level, consideration was given so that the effects would be minimum on Demerara Woods on the left bank upstream of Great Falls where timbering is being performed.

In studying the storage capacity, consecutive dry years from 1957 to 1967 obtained from the mass curve were taken into consideration.

The effective storage capacity necessary for supplementing the runoff during these dry years were determined for the respective alternatives and the firm discharges were calculated.

The mass curve at the dam site for the 37-year period from 1950 to 1986 is shown in Fig. 9-7.

At the Tiger Hill site, there is very little sediment carried down from the river basin and sedimentation will not be the decisive factor in determining the low water level of the reservoir. Therefore, in this Project, the low water level should be selected at a position as high as possible which can secure the required effective storage capacity and maintain the design head.

b) Annual energy production

The annual energy production was calculated considering the firm discharges in the various alternatives, the reservoir water level determined from the mass curve, and the monthly evaporation losses from the reservoir surface.

The annual energy production calculated is the average for the 30-year period from 1957 to 1986.

c) Determination of dam height and storage capacity

Preliminarly studies were made for the following 5 cases to determine the optimum dam height and the effective storage capacity.

Study of dam height and reservoir capacity

	Alternative				
	No. 1	No. 2	No. 3	No. 4	No. 5
High water level (m)	42	45	46	47	47
Low water level (m)	30	30	34	35	30
Effective capacity (x 10^6 m^3)	3010	4390	4220	4260	5370
Storage area (km^2)	409	505	534	565	565
Normal effective head (m)	32.0	34.5	36.0	36.5	35.7
Firm discharge (m^3/sec)	89.5	94.8	94.2	95.0	98.0
Installed capacity (MW)	43	50	52	53	54
Energy production (GWh)	223	246	254	263	261
Dam height (m)	58	61	62	63	63
Dam volume (x 10^4 m^3)	128	144	150	158	158
Plant factor (%)	59	56	56	56	55
Construction cost (USx10^6$)	164.8	167.4	170.2	177.3	179.3
B/C	0.948	1.063	1.084	1.067	1.066
B - C (US$1,000)	-733	898	1225	1013	1007

According to the results above, so long as there are no problems from geological and topographical standpoints, it will be more advantageous to construct the dam as high as possible. There will be no increase in electric energy output even if reservoir low water level is lowered to increase the effective storage capacity as in Alternative No. 5. On the other hand, in case the reservoir high water level is raised to above EL. 46 m, watertightness works against leakage at the low ridges will be required.

Therefore, Alternative No. 3 with a reservoir high water level of 46 m was adopted taking into consideration the points below in determining the dam height and reservoir high water level.

1) Assuming safety against leakage to adjacent river basins from the low ridges.

2) Conserving of forest resources by minimizing the area to be submerged.

3) Minimizing the effect on Demerara Woods.

d) Powerhouse location

The location of the powerhouse was selected immediately downstream of the dam on the left bank where the geology is relatively good.

e) Installed capacity and energy production

A study was made of available discharge and maximum output based on the high water level and effective storage capacity determined in Item c) above.

The annual energy production was calculated giving consideration to evaporation loss corresponding to fluctuation of reservoir water level.

	Alternative			
	A	B	C	D
High water level (m)	46	46	46	46
Low water level (m)	34	34	34	34
Effective storage capacity (x 10^6 m^3)	4,215	4,215	4,215	4,215
Normal intake level (m)	41.5	41.5	41.5	41.5
Normal tailrace level (m)	3.5	4.1	4.4	5.1
Head loss (m)	1.4	1.4	1.4	1.9
Effective head (m)	36.6	36.0	35.7	34.5
Max. discharge (m^3/sec)	141	186	215	279
Unit capacity (kW)	21,500	28,000	32,000	28,000
Max. output (kW)	43,000	56,000	64,000	84,000
Firm discharge (m^3/sec)	94.2	94.2	94. 2	94.2
Annual energy production (GWh)	269	265	263	250
Plant factor (%)	71	54	47	34
Equivalent peak duration time (hr)	16	12	10.5	8
Construction cost (US$ x 10^6)	165.1	174.5	182.7	196.2
B/C	1.024	1.125	1.166	1.289
B - C (US$ x 10^3)	343	1,863	2,599	4,852

1) River runoff downstream of dam

The harmless discharge downstream of the dam was taken as 326 m^3/sec, the average value of annual maximum runoff at the dam site during the past 37-year period, and the maximum available discharge for power generation was decided at less than this runoff.

The river discharge required for maintaining the environment of the downstream is to be not less than the annual minimum runoff of 12 m^3/sec, and this quantity is to be constantly discharged through power generation or from dam outlet works.

2) Maximum installed capacity

The relationship between peak duration time and installed capacity for the firm discharge of 94.2 m^3/sec obtained from the mass curve are as follows:

Peak duration time (hr)	16	12	10.5	8
Installed capacity (MW)	43	56	64	84
Plant factor (%)	70	54	47	34

(4) Optimum development scheme

The optimum development scheme for the Tiger Hill Site, as a result of the foregoing study, would be alternative D, but the facilities will be excessive as seen from the trend of demand. Therefore, Alternative B is adopted having 3 units of 28,000 kW each, and initially two generators would be installed and one generator would be added in the future corresponding to growth of demand.

Civil structures such as the headrace and penstock are to be designed considering this addition of capacity.

The outline of the optimum scheme for the Tiger Hill Hydroelectric Development Project is as follows:

Power generation system	Dam type
Catchment area	4,100 km^2
Storage area	534 km^2
Average annual inflow	36 x 10^9 m^3
Design flood discharge	960 m^3/sec
Design flood discharge during construction	580 m^3/sec
Recorded maximum runoff	454 m^3/sec
Recorded minimum runoff	12 m^3/sec
Average annual runoff	113.7 m^3/sec
High water level	EL. 46 m
Low water level	EL. 34 m

Available drawdown		12 m
Total storage capacity		5760×10^6 m^3
Effective storage capacity		4220×10^6 m^3
Normal intake level	EL.	41.5 m
Normal tailrace level	EL.	4.1 m
Gross head		37.4 m
Head loss		1.4 m
Normal effective head		36.0 m
Maximum available discharge		186 m^3/sec
Maximum output		56,000 kW (28,000 kW x 2 units)
Firm discharge		94.2 m^3/sec
Firm output		20,880 kW
Annual energy production		265 GWh
Primary energy		237 GWh
Secondary energy		28 GWh
Evaporation loss		480 mm/yr
Equivalent peak duration time		12 hr
Peak duration		8 hr
25% load duration		16 hr
Dam		Fill-type
Dam height		62 m
Dam volume		1,498,000 m
Dam crest length		365 m
Spillway		Surface chute type
Design discharge		960 m^3/sec
Spillway gates		Radial gate, 2 units
Headrace tunnel length		235 m
Headrace diameter		8 m, 1 line
Penstock		Dia. 4.5 m, 3 lines, length 215 m
Powerhouse		Semi-underground
Turbine-generator		28 MW, 2 sets 28 MW 1 set (future)

9.2.5 Preliminary design

(1) Diversion tunnel

A diversion tunnel 650 m in length and 580 m^3/sec in discharge capacity is to be constructed in the left bank. The tunnel cross section would be a standard horseshoe shape with a diameter 10.5 m at unlined portions and 9.5 m at lined portions, with shotcrete placed at unlined portions as necessary.

The design flood discharge during construction is a 100-year return period flood. The water level at the upstream side of the dam at such time would be EL. 13.80 m.

A gate is to be provided at the inlet portal, and this gate is to be used for impounding of water in the reservoir and at the time of plugging of the diversion tunnel. Plugging of the tunnel is to be performed at the intersecting point with the dam axis and below the spillway gate. After placing plug concrete, thorough grouting is to be executed to stabilize the surrounding rock and to prevention leakage.

(2) Spillway

A 10,000-year return period flood was used for the design flood discharge of the spillway. Two 12.5 m wide radial gates and control facilities are to be provided. The width of the chute is to be 28 to 20 m, and a stilling basin is to be provided at the end. Layout is shown in Dwgs. 9-2 and 9-3.

Excavated muck from the approach waterway and the chute portion is to be used as concrete aggregate and dam embankment material.

(3) Dam

It is judged that a fill-type dam would be the most economical for the Tiger Hill site according to the geological conditions and the ease of obtaining construction materials. A rock quarry for embankment materials will not be specified, and the embankment material for the dam is to be excavated muck which is to be banked and compacted.

(4) Intake

The intake is to be constructed allowing sufficient water cover below the low water level of the reservoir to prevent vortex phenomena at the time of intake of water. An intake gate is to be provided at the intake for the purpose of maintenance and inspection of the headrace tunnel and the penstock. A screen rake will not be provided since the intake screen will be installed at approximately 6 m below the low water level.

(5) Headrace and penstock

A pressure tunnel of inside diameter 8 m is to be consructed with provision to serve the additional turbine to be installed in the future. The penstock is to have a manifold branching out into 3 lines at the end of headrace. Inlet valve are to be provided at the end of each penstock.

An outlet conduit is to be connected with penstock to discharge water into the stilling basin of the spillway to release water to the downstream during impounding of water in the reservoir. (See Dwg. 9-2)

(6) Power generation facilities

The power generation facilities are to be initially for a maximum output of 56,000 kW with two sets of 28,000 kW equipment installed, with provision to add one set of 28,000 kW generating equipment in the future.

Consequently, penstocks, inlet valves, draft tubes and draft gates for three sets will be installed from the beginning, but only two sets of turbines, generators, main transformers and outdoor switchyards installed initially.

A single-line diagram is shown in Fig. 9-11.

a) Turbine

The turbine output will be 29,300 kW at a normal effective head of 36 m and maximum discharge of 93 m^3/sec. The optimum type of machine is a vertical-shaft Kaplan turbine. Further, a rated rotating speed of 212 rpm was adopted based on the specific speed of the turbine.

b) Generator

The generator requires sufficient capacity to supply reactive power and regulate the voltage of the power system since Tiger Hill Power Station will make up an extremely large proportion of the entire system capacity at the time of its commissioning. Therefore, the rated power factor adopted is 0.85 (lagging) and the generator capacity 32,900 kVA. The generator voltage of 13.8 kV, which is optimum as seen from the generator capacity, was adopted.

c) Main transformer

The main transformer for stepping up the generator voltage (13.8 kV) to the transmission voltage (138 kV) is to be an outdoor, 3-phase, oil-immersed, self-cooled type with a capacity of 32,900 kVA and is to be installed at the substation to be provided adjacent to the powerhouse. Connection to the outdoor switchyard on the opposite bank is to be by an overhead line after stepping up the voltage to 138 kV.

d) Outdoor switchyard

Types of bus connections conceivable are single bus, transfer bus, and double bus, but since the present 69 kV power system are transfer bus, this type was adopted in consideration of system operation, facility inspection, and expansion work.

The equipment layout of the outdoor switchyard is shown in Fig. 9-13.

e) Control system

A one-man control system is to be adopted, and operation and control of turbines, generators, and outdoor switchyard equipment can be performed from the control room.

(7) Substations

A substation is to be newly constructed at Linden, and another added in the premises of Garden of Eden Power Station. The bus connecting is to be transfer bus system, the same as the outdoor switchyard of Tiger Hill Power Station.

a) New Linden Substation

The existing Linden Substation has no space for expansion, and being close to a bauxite mine there is the possibility of contamination due to dust. Therefore, New Linden Substation is to be constructed at a point approximately 5.5 km to the northeast of the existing Linden Substation. This substation is to be connected to a newly-constructed 138 kV transmission line, 1 cct, and 138 kV is to be stepped down to 69 kV and connected to the existing Linden Substation. For the step-down transformer, the step-down ratio and economy are considered, and one unit of 16.7 MVA, outdoor, 3-phase, single-winding, oil-immersed, self-cooled type is to be adopted. The equipment layout is shown in Fig. 9-14.

b) Garden of Eden Substation

The existing substation in the premises of Garden of Eden Power Station is to be extended in order to transmit the electric power of Tiger Hill Power Station to load centers such as Georgetown by stepping down the voltage to 69 kV. The step-down transformers are to be of outdoor, 3-phase, single-winding, oil-immersed, self-cooled type, with two units each of 32.9 MVA installed. The equipment layout is shown in Fig. 9-15.

(8) Transmission line

The transmission line from Tiger Hill Power Station was planned considering the following points:

i) Economy was considered in the selection of voltage and conductor and type of towers.

ii) The length of the transmission line is to be as short as possible.

iii) The number of crossings over roads and streams is to be kept to the minimum.

iv) Transporting of materials and equipment will be easy to facilitate construction and maintenance work.

The length of the transmission line is to be 135 km, and the route is shown in Fig. 9-16.

a) Selection of route

With regard to the transmission line route, both the right and left banks of the Demerara River are flat as a whole and the line can be located on either banks, but the right bank where the distance would be 10 km shorter was selected.

The transmission line route from Tiger Hill is roughly perpendicular to the Demerara River to the Linden-Ituni road, and then north roughly parallel to the road to the New Linden Substation. From New Linden Substation to Garden of Eden Substation, the route is alongside the existing 69 kV transmission line.

Bauxite is being mined at Linden, and the route was selected so that dust by this operation will not contaminate the transmission line.

b) Number of circuits

Two circuits of transmission lines were adopted for this Project from the standpoint of reliability in view of the fact that the generating capacity of Tiger Hill Power Station is large in relation to the total power system capacity.

c) Selection of voltage

The transmission voltage presently adopted in Guyana is 69 kV, but the transmission voltage for this Project is to be selected giving consideration to length of transmission line and electric power to be transmitted, the economics such as construction cost, maintenance cost, and transmission loss, and stability of the power system.

In general, when it is necessary to adopt a voltage higher than the maximum voltage being used in that country, about double of that maximum voltage is considered as a yardstick. As a voltage conforming to ANSI is adopted in Guyana, 138 kV which is according to that system is adopted.

d) Design conditions

The meteorological conditions of the transmission line route were obtained from meteorological data, design standards for 69 kV, reports of other hydroelectric development projects, and regional distribution maps of isokeraunic levels of the world, and the following values were adopted for design conditions of the transmission line.

Maximum temperature	45°C
Mean annual temperature	25°C
Minimum temperature	10°C
Design wind pressure	61 kg/m^2
Horizontal seismic coefficient	0.1 G
Annual isokeraunic level (IKL)	30 days

e) Conductor

Regarding conductor type and size, the transmission capacity, voltage drop, transmission loss, corona interference, conductor sag, and mechanical strength were considered. As a result ACSR is to be adopted, and the size is to be a Partridge single conductor (266.8 MCM, 135.2 mm^2), the same as in the existing 69 kV transmission line. The overhead ground line is to be 70 mm^2 galvanized steel stranded wire.

f) Insulator

Regarding insulators, 250 mm insulator strings are adopted with ten discs for tension towers and nine discs for suspension towers. Measures against salt contamination will not be necessary since the transmission line route will be at least 18 km away from the seashore.

g) Support structures

The support structures for the transmission line are to be steel towers using angle steel in consideration of mechanical strength, material, transportation, assembly, etc. with the spacing between towers 370 m as a standard. A standard steel tower is shown in Fig. 9-17.

(9) Access road

Access road to the project site can be constructed from both the Linden-Ituni Road on the right bank and the Mabura Hill Road on the left bank, but access from the right bank was chosen in consideration of the fact that it can serve for maintenance of the transmission line. The access road to be constructed would be approximately 15 km in length.

(10) Measures related to timber transportation by raft

Transportation of timber by raft is presently being done. This transportation by raft will become difficult by constructing a dam. Accordingly, a road 8 m in width and approximately 400 m in length for landing timber is to be constructed between the dam crest and the low water level on the right bank upstream of the dam.

9.2.6 Construction program

The following study and work will be required for implementation of the Project.

- Feasibility study
- Basic design and preparation of bid documents
- Evaluation of bid documents and award of contract

The proposed work schedule for the Project is shown in Fig. 9-18.

Contracts would be divided into approximately the four below.

Contract A : Preparatory works, access road, construction camp
Contract B : Civil works
Contract C : Turbine, generators, auxiliary equipment, gates, and penstocks
Contract D : Transmission line and substations

Contracts B, C, and D would be put out to international bidding, and it would be desirable for local construction firms to participate in the Project as subcontractors. The major construction machine, permanent equipment, and materials would be imported from abroad. For tunneling work and large-scale rock excavation, it is thought there will be a necessity for technology transfer from foreign contractor and consultant.

9.2.7 Construction cost

(1) Basic conditions for estimating construction cost

Estimation of the construction cost for the hydro power development project was performed based on the commodity price level for August 1988 giving consideration to the natural conditions of the project site, regional conditions, project scale, and the engineering level that can be expected at the present time. The exchange rate adopted between the Guyana dollar and the U.S. dollar is G$10/US$1.

(2) Scope of construction cost estimation

The scope of construction cost estimation includes the reservoir, dam, spillway, headrace, and powerhouse, transmission line and sub-stations at Linden and Garden of Eden. Preparatory works, engineering fee, administrative cost, and compensation costs are included in the construction cost.

a) Civil works cost

i) Work quantities are calculated based on the preliminary design indicated in Section 9.2.5.

ii) The unit construction cost is calculated taking into consideration cost estimates in past studies in Guyana.

b) Costs of electrical and hydraulic equipment

It is considered that hydraulic equipment, electrical equipment, transforming equipment, telecommunications equipment, and sub-station equipment will be manufactured and supplied from foreign countries. These costs include ocean freight, insurance, unloading cost, inland transportation cost, and intallation cost at the site.

c) Contingency

A contingency of approximately 15 percent of civil works cost, and approximately 5 percent of electrical equipment, mechanical equipment, transmission line, and telecommunications equipment is considered.

d) Engineering fee and administrative costs

Approximately 10 percent of the estimated construction cost, excluding camp, compensation, access road and minor works, is considered for the engineering fee and administrative costs.

(3) Total construction cost

The estimated total construction cost for implementation of the Tiger Hill Hydroelectric Power Development Project is US$174.5 x 10^6. Detailed costs and disbursement schedule are given in Table 9-16 and 9-18 respectively.

9.2.8 Economic analysis

A study was made of the four alternatives selected. The alternative thermal used in the study was a steam generating facility with a service life of 25 years, and fuel cost of US$13/bbl, and discount rate of 7 percent were applied.

	Alternative			
	A	B	C	D
Installed capacity (MW)	43	56	64	84
Annual energy production (GWh/yr)	269	265	263	250
Plant factor (%)	71	54	47	34
Construction cost (US$$10^6$)	165.1	174.5	182.7	196.2
B/C	1.024	1.125	1.166	1.289
B - C (US$$10^3$)	343	1,863	2,599	4,852
kWh construction cost (US$/kWh)	0.052	0.056	0.059	0.067
O & M cost (US$$10^3$/yr)	2,147	2,268	2,375	2,551

The results of the foregoing indicate the relative advantage of the larger the installed capacity, but Alternative B is to be adopted in view of the demand predicted, with provision for expansion Alternative D corresponding to growth of demand in the future.

9.2.9 Further investigations

It will be necessary for the investigations below to be carried out in order to conduct a feasibility study and detailed design work. In particular, the bedrock line on the right bank is deep and will require detailed geological investigations.

(1) Geological investigations

. Boring and permeability tests

Dam site	11 holes	length 560 m
Powerhouse site	5 holes	length 110 m
Penstock site	4 holes	length 100 m

. Exploratory adit

Dam site	2 adits	length 100 m

. Geological investiations of right-bank ridge (near EL. 50 m)

(2) Materials investigations

. Core materials

A rough investigation was made at the Malali site upstream of the dam site in 1957, but it will be necessary for detailed soil tests to be conducted and investigations by boring and test pits to confirm the quantity available. The approximate quantities of the investigation works would be as follows:

Boring	10 holes	150 m
Test pit	6 pits	30 m
Soil tests	Necessary tests to determine the properties of the material.	

Gradation, physical properties, and permeability test will be required for filter materials also.

9.3 DIVERSION FROM ESSEQUIBO RIVER

The harmless discharge downstream of Tiger Hill Dam is estimated to be 326 m^3/s as mentioned in Section 9.2.4. The maximum power discharge of Tiger Hill Power Station should be held to less than this harmless discharge after completion of the Essequibo diversion scheme.

The maximum installed capacity possible for Tiger Hill Power Station would be 94 MW when this 326 m^3/s is made available.

Since there are heavily populated areas such as Georgetown, the capital city, Linden, etc. downstream along the Demerara River, it would be desirable for the discharges from the dam and the variations in daily discharges to be as small as possible. Consequently, in this study, the maximum power discharge and the installed capacity at the final stage of Tiger Hill Power Station were set at 279 m^3/s and 84 MW, respectivley.

The amounts of water diverted from the Essequibo River, the annual energy productions, plant factors, and breakeven amounts for investment for an installed capacity of 84 MW are given in the table below.

Plant Factor (%)	Annual Energy Production (GWh)	Dependable Discharge (m^3/s)	Diversion from Essequibo R. (m^3/s)	Breakeven amount for Investment* (US$ million)
100	708	279.0	184.6	380
90	637	251.1	156.9	355
80	566	223.2	129.0	340
70	495	195.3	101.1	320
60	425	167.4	73.2	300
50	354	139.5	45.3	283
40	255	111.6	17.4	253
Without Diversion	250	94.2	0	-

* Note: Breakeven amount with thermal alternative calculated by using a discount rate of 7% and fuel price of US$13/bbl

The proposals and considerations of the Team regarding the scheme for diversion from the Essequibo River are as follows:

- There will be no obstacle to the scheme for diversion from the Essequibo River even if the Tiger Hill Project were to be developea according to the plan proposed in this study.

- It is proposed that the Tiger Hill Project be developed without the diversion scheme in consideration of keeping initial investment as low as possible.

- The timing of commissioning of Unit No. 3 is to be studied watching the trend in power demand. A detailed study of the diversion scheme would be made after commissioning of Unit No. 3.