THE GOVERNMENT OF MAURITIUS
MINISTRY OF ENERGY, WATER RESOURCES AND POSTAL SERVICES
CENTRAL WATER AUTHORITY

THE DETAILED DESIGN ON THE PORT LOUIS WATER SUPPLY PROJECT IN MAURITIUS

FINAL REPORT (2)

DESIGN REPORT

FOR

LOT III : RAW WATER TRANSMISSION PIPELINE AND TREATMENT FACILITIES

MARCH 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of Mauritius, the Government of Japan decided to conduct a Detailed Design Study on Port Louis Water Supply Project in Mauritius, and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Mauritius a study team headed by Mr. Norizo FUJITA, Nippon Koei Co.,Ltd., and composed of members from Nippon Koei Co.,Ltd. and Nihon Suido Consultants Co.,Ltd., for four times from May 1990 to December 1991.

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

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

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

March, 1992

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

March, 1992

Mr.Yanagiya Kensuke
President
Japan International
Cooperation Agency
Tokyo

Dear Sir,

LETTER OF TRANSMITTAL

We have the pleasure of submitting to you the Final Report (2) of the Detailed Design on Port Louis Water Supply Project in Mauritius prepared for the implementation of Lot-III work on Raw Water Transmission Pipeline and Treatment Facilities in the Project.

The report on Lot-III work is composed of nine (9) volumes consisting of the Summary Report, Design Report (Two (2) Volumes of English and Japanese Version), Tender Document (Four (4) Volumes), Cost Estimate and Data Book. The Summary Report summarizes outlines of the detailed design carried out for Lot-III work. The Design Report contains the results of the detailed design. The Tender Documents are composed of (i) Vol.I presenting the instructions to tenderers, conditions of contract, various forms for bonds and agreement, etc., (ii) Vol.II presenting the general and technical specifications, (iii) Vol.III presenting the form of tender, bill of quantities and schedules of particulars, and (iv) Vol.IV presenting the tender drawings. The Cost Estimate contains the unit cost analysis and construction cost estimate for each work item included in the Bills of Quantities. The Data Book contains the detailed design calculations, work quantities calculations and field investigation data, etc.

All members of the Study Team wish to express grateful acknowledgement to the personnel of the Advisory Committee, Ministry of Foreign Affairs, Embassy of Japan in Madagascar as well as officials and individuals of Mauritius for their assistance extended to the Study Team.

In conclusion, the Study Team sincerely hopes that the study results would contribute to the further water resource development for water supply to Port Louis and to socio-economic development and well-being in general.

Truly yours,

N Fujita

Norizo Fujita
Team Leader
The Detailed Design on
Port Louis Water Supply
Project

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1. INTRODUCTION

1.1 Background of the Project

The water supply system in the City of Port Louis was established in 1790 and reached to the present status after three expansion projects for coping with increased water demand due to the development of the City.

Raw water depends on the Grand River North West (GRNW), and is conveyed by gravity flow to the treatment works, having a capacity of 60,000 m^3/d. Treated water is transmitted to eight service reservoirs and distributed to the consumers from these reservoirs.

The population increase and industrial development of the City have made the water demand increase year by year. In addition, raw water flow during the dry season becomes low every year, so that sufficient raw water could not be drawn. Therefore, constant output from the treatment works could not be maintained throughout the year. To cope with the situation, the Government of Mauritius planned to construct a dam for storing the river water to secure a reliable supply of raw water and to expand the existing treatment works to cope with future demand increase till 2030.

The Japan International Cooperation Agency (JICA), the executing agency for technical cooperation programme of the Government of Japan, carried out the Feasibility Study on the Port Louis Water Supply Project in response to the request of the Government of Mauritius in 1988. The Feasibility Study recommended the project be implemented in two phases.

Succeeding the feasibility study, the detailed design study was started from preparing the Basic Design Report on Water Supply Facilities, Phase 1, in 1990. Finally, all technical information and data related to the design are compiled in this report as the Final Design Report inclusive of the hydraulic and structural analyses.

1.2 Relevant Studies

For water resource development and improvement of water supply facilities, the following study reports are available:

1) Master Plan Study for Water Resources for Port Louis,
2) Updating of Master Plan for Water Resources,
3) Leakage Control Project in the Port Louis City Water Supply System, and
4) Operation, Maintenance and Organization of the Water Treatment Works of the Central Water Authority, Follow-Up Report.

2. DESCRIPTION OF THE PHASE 1 PROJECT

2.1 Existing Water Supply System

The City of Port Louis is supplied with drinking water from Pailles Treatment Works through 8 service reservoirs. The raw water is taken from GRNW at the Municipal Dyke and transmitted to the treatment works by 3 raw water mains of 18", 19" and 27" in diameter. In addition, the system is temporarily supplemented with raw water from the Montebello dam irrigation system of the Profonde River during drought period. Upon completion of this project, the water right from the Montebello source will have to be returned.

The treatment works is a slow sand filtration system, and has been established in 1925, and expanded in 1960 and 1981. The present system has a design capacity of 60,000 m^3/d, and consists of 12 slow sand filter beds, chlorination facility, a clear water tank and workshops. The clear water tank and distribution flowmeters were constructed during the expansion in 1981, and the raw water flowmeters were repaired in the same period.

Filtered water flows into the clear water tank by gravity after chlorination, and a certain portion of the water is pumped up to high land reservoir of Anse Courtois. The rest of the water is distributed directly from the clear water tank and also through 7 service reservoirs by combination of gravity flow and pumping.

The outline of water supply facilities is as described below:

1) Intake chamber and dyke

Elevation of the dyke	+ 76.177 m

2) Raw water transmission pipelines

19" cast iron pipe (CIP)	2,100 m (installed before 1925)
18" cast iron pipe (CIP)	2,100 m (installed before 1925)
27" reinforced concrete pipe (RCP)	2,100 m (installed in 1960)

3) Treatment works

(1) Slow sand filters

(old)	F. No.1 - No.2	929 + 903 = 1,832 m^2
	F. No.3 - No.4	686 + 686 = 1,372 m^2
	F. No.5 - No.6	603 + 601 = 1,204 m^2
(new)	E. No.1 - No.6	945 x 6 = 5,670 m^2
	Total filter area	10,078 m^2

E: Constructed by British aid

F: Constructed by French aid

(2) Clear water tank

Number	2 units
Capacity	20,900 m^3 (8.4 hr of detention time)
T.W.L.	+ 65.943 m

(3) Chlorination facility

Number and type	2 units, pressure type chlorinator, 13 number of chlorine gas containers

(4) Flow-meters

Municipal Dyke system	Orifice type of 450 mm, 475 mm and 675 mm in dia.
Montebello system	Orifice type of 300mm in dia.
Anse Courtois system	Orifice type of 300 mm in dia.
Distribution system	Pulsation type of 600mm and 400 mm in dia.

(5) Workshops — 3 workshops for chlorinators, pump/pipes/fittings and instruments

(6) Service reservoirs

Name of Reservoir	Capacity (m^3)	T.W.L.(m)
a) Plaine Lauzun reservoir	7,000	+ 53.0
b) Priest Peak reservoir	6,600	+ 76.0
c) Upper Monneron reservoir	2,000	+ 85.0
d) Labourdonnais reservoir	2,725	+ 54.0
e) Lower Monneron reservoir	6,135	+ 54.0
f) Diego Garcia reservoir	3,615	+ 46.0
g) Anse Courtois reservoir	4,000	+ 117.0

Note: T.W.L. means Top Water Level from sea level

2.2 Water Demand and Design Flow Rate

The water demand forecasts up to the year 2030 for six water use categories are summarized below:

Category	1988	1990	2000	2010	2030
- Domestic use	23,190	24,320	29,090	32,500	35,370
- Commercial use	4,480	5,600	8,100	9,000	9,900
- Industrial use	2,320	5,000	6,560	8,600	11,150
- Educational use	1,500	1,500	1,750	2,000	2,500
- Hospital use	200	240	320	400	450
- Government/Enterprise use	1,800	2,500	2,500	2,500	2,500
Total Consumption	**33,490**	**39,160**	**48,320**	**55,000**	**61,870**
- Unaccounted-for-water (*1)	28,530 (46 %)	21,090 (35 %)	20,710 (30 %)	23,570 (30 %)	20,620 (25 %)
Average Water Demand	**62,020**	**60,250**	**69,030**	**78,570**	**82,490**
Max. Water Demand (*2)	**74,450**	**72,300**	**82,900**	**94,300**	**99,000**

Note: (*1) : (%) shows unaccounted-for-water ratio for Average Water Demand
(*2) : Average Water Demand x 1.2
This shall be the production capacity of treatment works.

Based on the water demand projection in the Feasibility Study, the production capacity of the treatment works has been planned at 90,000 m^3/d targeted in 2005 (Phase 1) and 100,000 m^3/d in 2030 (Phase 2). In the Phase 2, the capacity is expanded by 10,000 m^3/d.

As for the treatment capacity for expansion system, water treatment loss of 5 % is added to the production capacity.

		Phase 1	Phase 2
Production Capacity	Existing System	60,000 m^3/d	60,000 m^3/d
	Expansion System	30,000 m^3/d	40,000 m^3/d
	Total	90,000 m^3/d	100,000 m^3/d
Treatment Capacity	Existing System	60,000 m^3/d	60,000 m^3/d
	Expansion System	31,500 m^3/d	42,000 m^3/d
	Total	91,500 m^3/d	102,000 m^3/d

2.3 Water Source and Raw Water Quality

2.3.1 Water Source

GRNW, which is the raw water source for Pailles Treatment Works, has five tributaries:

- Terra Rouge River
- Cascade River
- Profonde River
- Moka River
- Plaines Wilhelms River

To secure sufficient raw water for constant water supply, the dam was proposed to be constructed at the confluence of the Terra Rouge and the Profonde Rivers. During the dry season, raw water is to be released from the dam and abstracted at the Municipal Dyke together with water from the Moka and Wilhelms Rivers. Outline of the dam is as below:

(1) Dam

– Type	:	Rockfill
– Height (from river bed)	:	75 m
– Crest length	:	230 m
– Crest elevation	:	+ 195.000 m
– Embankment volume	:	1.485 million m^3
– Spillway	:	side channel type with 90 m wide

(2) Reservoir

– Catchment area	:	55 km^2
– Annual basin rainfall	:	2,400 mm
– Gross storage capacity	:	6.7 million m^3
– effective storage capacity	:	6.3 million m^3
– Effective water depth	:	50 m
– Planned max. intake flow in Pailles treatment works	:	60,000 m^3/d (existing) 42,000 m^3/d (expanding) Total 102,000 m^3/d

2.3.2 Raw Water Quality

1) Characteristics of raw water quality

Major characteristics of the raw water quality are separately described below and the results of water analyses are shown in Appendix 1.

(1) Turbidity, pH, Colour and Alkalinity

The important characteristics of the raw water quality are low turbidity and colour in the dry season, and high turbidity and colour, occasionally during wet season.

Low turbidity of less than 10 FTU were observed throughout the dry season together with relatively high pH. This trend of stable low turbidity during dry season is expected to continue in the future.

In the wet season, however, both turbidity and colour increased occasionally during and after heavy rainfall. According to the past water quality data, the turbidity was detected up to 80 FTU, but higher values can be expected as the quality records are very limited. In contrast to turbidity, pH and alkalinity decreased due to the dilution of river waters by rainfall.

Moreover, high values of colour over 70 units were detected after ordinary rainfall as shown in Table 2.3.2.

The trend of the occasional high turbidity and colour in the wet season is expected to last in the future.

(2) Ammonia-Nitrogen, Nitrite-Nitrogen and Nitrate-Nitrogen

Ammonia-Nitrogen concentrations of the raw water source showed low values.

Nitrate and Nitrite concentrations showed also low values, which are less than the WHO Guideline value of 10 mg/l for drinking water.

(3) Iron and Manganese

Concentrations of both iron and manganese are detected at less than 0.3 mg/l, which is the WHO Guideline value.

(4) Organic Matter

Biochemical Oxygen Demand (BOD) and Potassium Permanganate consumption, which are indexes of organic pollution indicated low values except the samples for potassium permanganate consumption taken on 23/12/'88 which showed relatively high value.

(5) Heavy Metals and Other Toxic Substances

No heavy metals and other toxic substances were detected in excess of the WHO Standards.

(6) Pesticides

The drainage area of GRNW is covered with the vast area of sugar-cane field. As pesticides are commonly used in the sugar-cane plantation in the country, concentrations of pesticides were analyzed. Organo-phosphorus was not detected.

(7) Coliforms and Faecal Coliforms

Coliforms were detected from all the samples, and faecal coliforms from several samples. It is presumed that contamination by human excreta may occur occasionally in the raw water source. Adequate treatment will be required.

2) Treatment Targets

In order to attain finished water quality conforming to the WHO Standards, quality contaminants to be removed or reduced by treatment processes are described below.

(1) Removal of Low Turbidity (less than 10 FTU)

In the dry seasons raw water turbidity is expected to be as low as the present level and be constant below 10 FTU. To remove such low turbidity by a conventional rapid sand filtration system more than 25 mg/l of alum dosage will be required according to the results of the jar tests. However, the bench scale test using the laboratory filter paper indicated that the filtrate after the rapid coagulation with small dosage of alum showed lower turbidity. This result suggests the possibility of applying direct filtration method during the periods of low and stable turbidity. The average alum dosage to achieve filtered turbidity of less than 2 FTU was found to be 8 mg/l.

(2) Removal of Moderate to High Turbidity (over 10 FTU)

Moderate to high turbidity will appear during the wet season although the period will be generally short. Result of the test proved that the coagulation with a pH level of around 7.0 creates good floc and high turbidity is removed effectively. In the wet season, pH and alkalinity concentration will decrease due to dilution of the river waters. Accordingly, pre-alkali dosing will be needed to achieve good coagulation.

(3) Removal of Colour

Colour tends to increase during and after rainfall. The results of Jar tests indicates that Colour can be effectively reduced by coagulation and sedimentation with pH below 6.0. Accordingly, post-alkali dosing is needed for pH adjustment to 7.0.

(4) Removal of Other Items

Other items of water quality which were found in raw water samples in excess of the WHO Drinking Water Standards are coliforms and faecal coliforms. The levels of these items detected are within those which can be removed by ordinary rapid sand filtration system with chlorination as well as slow sand filtration.

Concentrations of iron, manganese and ammonia-nitrogen are presently low. Rapid sand filtration system with proper chlorination can reduce these items to a lower level even though the concentrations of these matters in raw water increase due to the eutrophication of the reservoir in the future. Algae which may occasionally appear in raw water in the future are expected to be removed partially by coagulation and sedimentation following pre-chlorination.

Toxic substances such as heavy metals and pesticide were not detected in raw water, so that special treatment for these substances are not necessary. However, periodic analyses for these substances are recommended to be carried out by the CWA Laboratory in the future.

2.4 Outline of the Phase 1 Project

Water supply facilities to be constructed under the Phase 1 Project are raw water transmission pipeline including an intake and treatment facilities with a production capacity of 30,000 m^3/d of rapid sand filtration system.

Drawings of the major facilities of raw water transmission pipeline and treatment facilities are shown on Fig. A2-1 to A2-21 in Appendix 2.

1) Raw water transmission pipeline

New raw water pipeline is constructed to augment transmission capacity together with the existing pipeline to comply with the requirement in the year 2030.

- Design capacity : Max. 55,000 m^3/d (in 2030)
  (47,000 m^3/d for existing raw water mains)
- Pipe materials : Ductile iron pipe (DIP)
- Diameter : 800 mm
- Length : 2,100 m

2) Treatment facilities

(1) Receiving tank
- Design capacity : 55,000 m^3/d
- Number of tank : 1 unit
- Dimensions : Rectangle,
  5.0 L x 4.75 B x 2.80 D (m)

(2) Rapid mixing tank
- Design capacity : 42,000 m^3/d
- Number of tank : 1 unit
- Type : Hydraulic mixing (waterfall)
- Dimensions : Rectangle,
  5.7 L x 3.2 B x 4.65 D (m)

(3) Flocculation tank
- Design capacity : 31,500 m^3/d
- Number of tank : 3 units
- Type : Hydraulic flocculator
  (up-and-down flow by baffle walls)

- Dimensions : Rectangle,
  - 1st channel 9.6 L x 0.8 B x 2.89 D (m)
  - 2nd channel 9.6 L x 1.0 B x 2.72 D (m)
  - 3rd channel 9.6 L x 1.4 B x 2.67 D (m)

(4) Sedimentation tank

- Design capacity : 31,500 m^3/d
- Number of tank : 3 units
- Type : Horizontal flow type
- Dimensions : Rectangle,
  30.4 L x 9.6 B x 3.0 D (m)
- Desludging : Periodical desludging by man-power

(5) Rapid sand filter

- Design capacity : 31,500 m^3/d
- Number of filter : 6 units
- Type : Constant rate filtration
  (flow splitting and water level rising)
- Dimensions : Rectangle,
  9.6 L x 3.9 B (m)
- Backwash system : Water backwashing with air scouring
- Backwash water tank : 1 unit with 150 m^3 capacity

(6) Wastewater and sludge ponds

- Design capacity : 42,000 m^3/d
- Number of pond : 4 units
- Dimensions : rectangle,
  25.0 L x 8.0 B x 2.0 D (m)

3) Chemical dosing equipment

(1) Aluminum dosing equipment

- Solution tank : 2 units of 2.5 L x 2.5 B x 3.0 D (m)
- Mixer : Vertical mixer, 2.2 kW x 2 units
- Dosing pump : Rotary type tubing pump, 3 units of 14 l/min x
  0.55 kW

(2) Lime dosing equipment

– Solution tank	:	2 units of 1.5 L x 1.5 B x 3.0 D (m)
– Mixer	:	Vertical mixer, 1.5 kW x 2 units
– Dosing pump	:	Rotary type of tubing pump, 2 units of 15 l/min x 0.55 kW
– Injection pump	:	Volute type pump, 2 units of 150 l/min x 2.2 kW

(3) Chlorination equipment

– Chlorinator	:	Vacuum injection type, 3 units, 6 kg/hr x 2 units and 5 kg/hr x 1 unit (existing 7 kg/hr x 2 units)
– Booster pump	:	Volute type pump, 180 l/min x 47 m x 3.7 kW x 2 units and 80 l/min x 30 m x 1.5 kW x 1 unit
– Weighing scale	:	Platform load cell type, 2 units x 2,000 kg capacity
– Container handling hoist	:	Manual chain hoist 1 units x 3 ton capacity

4) Mechanical equipment other than chemical dosing equipment

(1) Blower for air–scouring	:	Roots blower, 2 units x 31.8 m^3/min x 4,000 mmAq. x 30 kW
(2) Plant water pump	:	Centrifugal pump, 2 units x 1.2 m^3/min x 18 m x 7.5 kW
(3) Flush water pump	:	Centrifugal pump, 2 units x 1.0 m^3/min x 30 m x 7.5 kW

5) Electrical facilities

(1) Power receiving and distribution	:	– Low–voltage switchboard – Motor control panel

		- Auxiliary relay panel - Local control panel - Emergency generator 150 kVA
(2) Control and monitoring system	:	- Raw water flow meter - Filtered water flow meter - Clear water tank level meter - Electrode level detectors - Central monitoring panel - Intercommunication system - Laboratory equipment

6) Buildings

(1) Operation building	:	2-story x 10 x 24 m = 480 m^2, electric room, laboratory, generator room, control room, office and conference room
(2) Chemical building	:	3-story x 10 x 16 m = 480 m^2, chemical solution tank room, storage room, working space of chemical dissolving, and elevated tank
(3) Chlorination building	:	Remodelling and expanding existing chlorination building x 183 m^2
(4) Workshop building	:	1-story x 460 m^2, Chlorinator, instruments, generator set repair, office and store rooms

3. RAW WATER TRANSMISSION PIPELINE

3.1 Route Alignment

The route and profile of the raw water transmission pipeline are shown on Figs. A2.2 and A2.3 in Appendix 2.

The new raw water pipeline is to be aligned parallel to the existing pipelines of 18"and 19" CIP and 27" RCP. The pipeline is to go across GRNW by means of river bed crossing at two points of 180 m and 940 m from the intake.

From results of test drillings, the route of the pipeline consists of rocky soil up to the 2nd river crossing point from the intake. It is considered that the pipeline should be protected from falling stones in this section.

3.2 Selected Pipe Materials

Ductile iron pipe (DIP) has been selected with the following specification for the raw water transmission pipe.

- Standard	:	BS 4772 - 1988, ISO 2531-1980 and JIS G 5526-1982 and G 5527-1982, or equivalent approved
- Inner lining	:	Cement mortar lining
- Outer coating	:	Coal-tar coating
- Dimensions	:	DN 800 mm and 5.5 m long per one pipe
- Joint type	:	Push-in joint with elastomer gasket

3.3 Hydraulic Design

The normal intake level is fixed at + 76.20 m above mean sea level based on the river water overflowed on the crest of the dyke. The receiving water level at the treatment works is set at + 70.80 m. Design flow rate is 55,000 m^3/d (637 l/s).

The friction loss is computed by Colebrook and White formula. For mortar lined pipes pipe

roughness is assumed to be 0.15 mm.

$$h = f \times \frac{L}{D} \times \frac{V^2}{2g}$$

$$\frac{1}{(f)^{0.5}} = 1.74 - 2 \log \{\frac{2k}{D} + \frac{18.7}{Re \times (f)^{0.5}}\}$$

where,

f	:	coefficient of friction loss, 0.0143
L	:	pipe length, 2,145 m
D	:	inside diameter of pipe, 0.8 m
V	:	velocity in pipeline, 1.66 m/sec
g	:	acceleration of gravity, 9.8 m/sec^2
k	:	roughness, 0.15 mm for mortar lined pipe
Re	:	Reynolds number Re = V*D/v = 1,314,210
v	:	coefficient of kinematic viscosity, 1.01 x 10^{-6} m^2/sec, 20 C degree
h	:	76.20 - 70.80 = 5.40 m
Q	:	0.834 m^3/sec = 72,000 m^3/d

Based on the above formula, the flow rate is calculated at 72,000 m^3/d. The raw water transmission pipe of 800 mm dia. has enough capacity to transmit the maximum design flow rate of 55,000 m^3/d.

The flow is to be controlled by a control valve installed just before the receiving tank of the Pailles treatment works.

Five (5) air-release valves of ND 75 mm, quick exhaust type, and one washout valve with ND 150 mm are to be installed on the pipeline.

3.4 Structural Design

3.4.1 Installation of Pipes

Pipes are to be embedded in trench. The trench will be backfilled by selected material among excavated soils.

The pipeline is to be covered either by concrete because of difficulty of deep excavation of rocky soil and protection from stone falling, or by crusher-run (5 mm in diameter) up to 30 cm above the pipe crown.

3.4.2 River Crossing

Two river-bed crossings are to be constructed in the transmission pipeline. The inverted syphon-type structure is employed from the economical point of view. Earth cover from the river-bed to top of concrete protection is set at 1.0 m to prevent the pipe from a flood scouring of the river-bed. The pipe is to be covered by concrete protection.

Length of the river crossing is as follows:

- No.1 river crossing	:	L = 86 m at points of 134.0 m to 220.0 m from the intake chamber
- No.2 river crossing	:	L = 127 m at points of 874.9 m to 1,001.4 m

4. WATER TREATMENT FACILITIES

4.1 Plant Layout

General layout of the Pailles water treatment works is shown on Fig A2.5 in Appendix 2.

The proposed receiving tank is located close to the existing chamber No. 1 so as to receive raw water transmitted by the proposed pipeline, 800 mm in diameter, and distribute the water to the proposed rapid sand filtration system as well as the existing filters.

The location of the proposed treatment facilities was selected on unoccupied land located between the existing filters and the clear water tank. The proposed system is arranged in parallel to the existing slow sand filters.

The ground level around the existing filters is + 68.4 m. The land for the proposed system slopes downward from the east to the west with difference of the elevation, approximately 4 m. The facilities are designed to make the most of the natural gradient for gravity flow, and arranged from the east to the west in order of rapid mixing tank, flocculation and sedimentation tanks, and rapid sand filters.

The chemical building is to be located near the rapid mixing tank to minimize the length of alum and lime dosing pipes and for better operation and maintenance. The operation building should be located such that all the facilities can be observed from there.

The existing maintenance road in the premises is to be used as an access road from the entrance near the clear water tank to the site.

4.2 Design Criteria

4.2.1 Treatment Capacity of the Facilities

The planned production capacity of the proposed treatment works is 30,000 m^3/d in Phase 1, and 40,000 m^3/d in Phase 2 of which 10,000 m^3/d is to be added. Five (5) per cent loss in the treatment processes is added to the above production capacities. Accordingly, the design capacity of each facility is:

Receiving tank	:	55,000 m^3/d (637 l/s)
Rapid mixing tank	:	42,000 m^3/d (486 l/s)
Flocculation/sedimentation tanks	:	31,500 m^3/d (365 l/s)
Rapid sand filters	:	31,500 m^3/d (365 l/s)
Chemical dosing facilities	:	42,000 m^3/d (486 l/s)
Wastewater and sludge ponds	:	42,000 m^3/d (486 l/s)
Elevated water tank (on the 2nd floor of the chemical building)	:	42,000 m^3/d (486 l/s)
Operation and chemical buildings	:	42,000 m^3/d (486 l/s)

4.2.2 Treatment Facilities

The design criteria for each facility are as follows:

1) Receiving tank

(1) Number of tank	:	1 unit
(2) Retention time	:	2.0 min.
(3) Appurtenances	:	Flowmeter and control valve, overflow weir

2) Rapid mixing tank

(1) Number of tank	:	1 unit
(2) Type	:	Hydraulic type (waterfall) mixing
(3) Height of waterfall	:	65 cm
(4) Appurtenances	:	Flowmeter and control valve, chemical dosing pipes

3) Flocculation tank

(1) Number of tanks	:	3 units
(2) Type	:	Hydraulic type (up-and-down baffle wall)
(3) Mixing intensity (G)	:	80 to 20 (tapered) sec^{-1}
(4) Mixing time (t)	:	20 min (1,200 sec)
(5) Gt value	:	23,000 to 210,000

4) Sedimentation tank

(1) Number of tanks	:	3 units
(2) Type	:	Horizontal flow type
(3) Overflow rate	:	1.5 $m^3/m^2/hr$ (25 mm/min)
(4) Mean velocity	:	Less than 40 cm/min
(5) Weir load	:	Less than 350 $m^3/d/m$
(6) Desludging	:	Periodic manual desludging

5) Rapid sand filter

(1) Number of filters	:	6 units
(2) Type	:	Constant rate filtration and variable water level depending on the filter loss increase
(3) Filtration rate	:	6 $m^3/m^2/hr$(144m/d)
(4) Maximum head loss	:	1.2 m
(5) Air-scouring rate	:	Max 0.85 $m^3/m^2/min$
(6) Backwashing rate	:	0.3 $m^3/m^2/min$
(7) Filter sand	:	Effective size 1.0 mm uniformity coefficient less than 1.5
(8) Filter sand depth	:	1,100 mm
(9) Supporting gravel	:	100 mm thick
(10) Underdrain type	:	Nozzle type
(11) Backwash tank	:	150 m^3

6) Wastewater and sludge ponds

(1) Number of ponds	:	4 units
(2) Capacity	:	400 m^3 each, two ponds for retaining backwash wastewater for 4 filter backwash in a day, and two for desludging of sedimentation tank carried out once a year

4.2.3 Chemical Dosing

1) Alum dosing

(1) Aluminum sulphate	:	Chemical strength of 17 to 18 % as Al_2O_3
(2) Dosing rate	:	Max. 100 mg/l Min. 6 mg/l Aver. 30 mg/l
(3) Solution concentration	:	10 %
(4) Dosing equipment	:	3 sets of metering pump
(5) Dosing point	:	Rapid mixing tank, and before filters (for direct filtration mode)
(6) Storage	:	3 months consumption

2) Alkali dosing

(1) Hydrated lime	:	Average content of approx. 80 % as $Ca(OH)_2$
(2) Dosing rate of pre- and post-alkali	:	Max. 50 mg/l Min. 0 mg/l Aver. 10 mg/l
(3) Solution concentration	:	10 %
(4) Dosing equipment	:	2 sets of metering pump and 2 sets of injection pump
(5) Dosing point	:	Rapid mixing tank for pre-alkali and filtered water effluent weir for post-alkali
(6) Storage	:	3 months consumption

3) Chlorine dosing

(1) Chlorine	:	Liquid chlorine gas
(2) Dosing rate Pre-chlorination	:	Max. 3.0 mg/l Min. 0.5 mg/l Aver. 1.0 mg/l

Post-chlorination	:	Max. 2.0 mg/l Min. 0.5 mg/l Aver. 1.0 mg/l
(3) Chlorinator	:	3 sets of vacuum type and pressure water injection
(4) Dosing point		
Pre-chlorination	:	Rapid mixing tank
Post-chlorination	:	Filtered water effluent weir
(5) Weighing scale	:	2 sets
(6) Storage	:	2.5 months consumption
(7) Safety measurements	:	Chlorine gas leak detector, Water pits to submerge a leaked container, Gas masks

4.2.4 Electrical Facilities

1) Instrumentation

(1) Flow measuring device

Differential pressure and low pressure loss type.

(2) Level measuring device

Diaphragm sensing flanged type and electrode level switch type.

(3) Monitor and control panel

Self-standing, metal-enclosed, graphic type.

2) Emergency generator

(1) Number of generator	:	1 set
(2) Type	:	Diesel engine driven
(3) Capacity	:	150 kVA of generator and 215 PS of engine

4.2.5 Building

1) Operation building : Electric room, engine generator room, control room, laboratory, offices, etc.

2) Chemical building : Chemical solution tanks and dosing pumps, chemical storage and working space, and elevated water tank

3) Chlorination building (Remodeling the existing building) : Chlorinator and booster pump, and chlorine gas container rooms

4) Workshop : For pumps/engines/pipes, chlorinators and instruments

4.3 Hydraulic Design of Treatment Facilities

The Hydraulic Profile throughout the treatment facilities are shown schematically on Fig. A2.6 in Appendix 2 and summarized below:

Facilities	Water Level HWL	(in El.m) LWL
(1) Receiving tank	+ 70.800	-
(2) Rapid mixing tank	+ 70.400	-
(3) Sedimentation tank	+ 69.360	+ 66.360
(4) Filter	+ 68.700	+ 67.500
(5) Clear water tank	+ 65.940	+ 61.490
(6) Elevated tank	+ 78.550	+ 77.100

Hydraulic calculation for the design of treatment facilities is attached in Appendix 3.

4.3.1. Receiving Tank

The volume of the receiving tank is designed to be 66.5 m^3 with internal dimensions of 5.0

m L x 4.75 m B x 2.80 m D. The retention time for the inflow-rate of 55,000 m^3/d is 1.74 min.

The flow-rate of raw water to be allocated to the existing system is estimated as follows:

1) Case 1 (Using only the existing 27" pipeline in future)

- Required production capacity (in 2030)	100,000 m^3/d
- Carrying capacity of 27" pipeline	32,400 m^3/d
- Treatment capacity of the existing system	60,000 m^3/d
- Raw water distribution to the existing system	27,600 m^3/d
- Treatment capacity of the new system	42,000 m^3/d
- Required max. flow rate of new pipeline	69,600 m^3/d

2) Case 2 (Using the three existing pipelines in future)

- Required production capacity (in 2030)	100,000 m^3/d
- Carrying capacity of three pipelines	47,000 m^3/d
- Treatment capacity of the existing system	60,000 m^3/d
- Raw water distribution to the existing system	13,000 m^3/d
- Treatment capacity of the new system	42,000 m^3/d
- Required max. flow rate of new pipeline	55,000 m^3/d

Considering that the old cast iron pipes which are to be used for more than 100 years will not be in use in the year 2030, the interconnection pipe between new receiving tank and the existing system is designed as 700 mm in diameter with max. flow-rate of 27,600 m^3/d.

4.3.2. Rapid Mixing Tank

Aluminum sulphate is to be dosed at the overflow weir, and pre-lime is to be added upstream of the alum dosing point. Pre-chlorine is to be dosed with diffuser which is installed close to the tank inlet.

The rapid mixing tank is composed of an inlet chamber and an outlet chamber. The internal dimensions of the inlet chamber are 4.9 m L x 3.2 m B x 4.65 m D and those of the outlet chamber are 3.2 m L x 1.2 m B x 0.8 m D. The total storage capacity is 73 m^3 providing

a retention time of 2.5 min. for the treatment flow-rate of 42,000 m^3/d.

The overflow weir with 3.2 m length between the inlet and outlet chambers is placed for mixing alum by a free waterfall of 65 cm for 42,000 m^3/d and 62 cm for 31,500 m^3/d of the treatment capacities in the year 2030 and 2005, respectively. The overflow depth is computed as 16 cm for 31,500 m^3/d and 19 cm for 42,000 m^3/d. The water level in the outlet chamber is calculated at + 69.740 m.

4.3.3. Flocculation Tank

The flocculation tank consists of three (3) compartments of width 80 cm, 100 cm and 140 cm with up-and-down baffles, and the total length of the compartments is 57.6 m. Total capacity is 155.35 m^3 which corresponds to a retention time of 21.3 min. "G" values are selected at 80 sec^{-1} for 1st compartment, 52 sec^{-1} for 2nd compartment and 20 sec^{-1} for 3rd compartment to provide tapered flocculation.

"Gt" value is computed as 60,983. This value is between the range for good flocculation condition of Gt 23,000 to 210,000.

The outlet arrangements are so designed to distribute flocculated water uniformly to the sedimentation tank without excessive turbulence, which would break up floc. End baffles and perforated baffle walls are placed between the flocculation tank and sedimentation tank for this purpose. The perforation ratio is 7 % and the hole diameter is 100 mm.

4.3.4. Sedimentation Tank

Three sedimentation tanks of horizontal-flow type are to be used. The required area of each tank is calculated at 292 m^2 based on the surface loading of 1.5 $m^3/m^2/hr$ (settling velocity of 36 m/d) for the treatment capacity of 10,500 $m^3/d/unit$ (437.5 $m^3/m^2/hr$). As shown on the drawing, configuration of the tank is 9.6 m B x 30.4 m L x 3.0 m D (effective depth) and mean velocity in the tank is calculated at 25 cm/min, which is less than the design criteria of 40 cm/min. The tank has an allowance of 296 m^3 for settled sludge. The base slab gradient is 3.5 %. A perforated baffle wall is placed before troughs to prevent short-circuit flow. The perforation ratio is 6 % and the hole diameter is 100 mm.

Sludge is to be washed out to the sludge ponds through a drain pit by manual operation once a year. To facilitate the sludge removal, flushing valves are installed on the bottom along longitudinal wall.

Settled water is collected by troughs aligned after perforated wall with the following principal features:

– Trough loading	:	292 $m^3/m/d$ < 350 $m^3/m/d$
– Number of troughs	:	6 sets per one unit
– Dimensions of trough		
shape	:	rectangular
width	:	300 mm (upper) x 250 mm (lower)
height	:	350 mm
length	:	3.23 m
– Water depth at the end of trough	:	90 mm
– Orifice	:	diameter of 30 mm 140 mm pitch

4.3.5. Rapid Sand Filter

Constant–rate filtration type with hydraulic control of variable water level for filtration losses is employed. Sand medium is to be used. Air–scouring system is adopted as an auxiliary scouring for the filter backwashing. Backwash water is to be supplied from the elevated tank on the top of chemical building.

1) Filter

Six (6) filter units are to be constructed under the Phase 1 Project and 2 units are to be added in the Phase 2 Project. The dimensions of each unit are 3.9 m B x 9.6 m L (37.4 m^2). The design filtration rate is 5.8 $m^3/m^2/hr$, and 7.0 $m^3/m^2/hr$ during backwashing of other filters.

The influent flow is equally allocated by a rectangular weir to each unit through the inlet channel and chamber. Each filter unit is equipped with a water level indicator. When the water level reaches the allowable high water level, an alarm on the operation room monitoring panel will be activated.

2) Filter medium

The filter media and supporting beds are designed as follows:

(1) Filter medium

- Medium	:	quartz sand
- Thickness of layer	:	1,100 mm
- Effective grain size	:	1.0 mm
- Uniformity coefficient	:	1.5 less

(2) Supporting bed

- Material	:	gravel
- Effective grain size	:	2.38 mm - 4.76 mm
- Thickness of layer	:	100 mm

3) Backwashing and auxiliary scouring

(1) Backwash rate

Since air-scouring is employed as the auxiliary scouring, the back-wash rate is applied at 0.3 $m^3/m^2/min$. Required volume of water for each backwashing is estimated at 90 m^3 (0.3 m/min x 37.4 m^2 x 8 min). Backwash water is to be supplied from the elevated tank with a capacity of 150 m^3.

(2) Air-scouring

Air-scouring is used to assist in cleaning filter media. The rate is designed to be 0.85 $m^3/m^2/min$ in accordance with the criteria. Nozzles are employed in the underdrain system to distribute air and water evenly in the entire filter bed.

4) Direct filtration

For low turbid raw water, less than 10 FTU in the dry season, the system can be operated in direct filtration mode as an operation option bypassing the flocculation and sedimentation tanks. Raw water is conveyed into a weir immediate before filters where

alum is dosed and mixed with raw water by waterfall.

4.3.6. Wastewater and Sludge Ponds

Two wastewater ponds are designed to receive wastewater of backwash carried out daily for each filter. Two sludge ponds are designed to receive wash-out from each sedimentation tank once a year. The wastewater pond capacity is 400 m^3 each which can accommodate backwash wastewater from four filters (37.4 m^2 x 0.3 $m^3/m^2/min$ x 8 min x 4 beds = 360 m^3). The ponds are to be used alternately for filter washing. Waste water is discharged to the river through drain pipe regulating waste water by removing stop logs.

Wash-out from the sedimentation tank is to be conveyed to the sludge ponds to settle the sludge. The supernatant is to be discharged to the river. Settled sludge is to be left for dry-up and sludge cake be disposed for land reclamation.

4.3.7. Flow Measurement and Control

Flow meters are to be installed at necessary positions for monitoring and control. Flow rates are indicated on a panel in the operation room. The control of the valves is to be done manually at local sites.

1) Raw water flow-rate

(1) Gross flow meter

Gross flow meter is installed before Receiving Tank. As the raw water pipeline is designed for future water demand in the year 2030, the flow rate is to be regulated so as to meet occasional water demands. The gross flow includes a flow to be allocated to the existing filtration system.

The flow rate is regulated by two valves for control and shut-off to prevent cavitation.

Total flow is indicated on the arithmetical meter, to be equipped newly, as a summation of flow rates of the new pipeline and the existing three pipelines.

(2) Raw water flow meter in new system

The flow meter is to be installed before the rapid mixing tank for regulating the flow to the new filtration system. The flow rate can be monitored on the panel.

(3) Raw water flow to be allocated to the existing system

The raw water required for the existing system is to be allocated in the receiving tank. An arithmetical meter is to be installed to indicate the difference between gross flow rate and flow-rate to the new system.

2) Filtered water flow-rate

(1) New system

A flowmeter is to be installed, before the junction with the existing filtered water main of 900 mm diameter, to monitor the filtered water flow rate from the new system.

(2) Existing system

There are two flow meters to measure filtrate from the existing filters. One is a flowmeter for total flow from E. filters and F. filters. The other is for F. filters.

The existing flowmeter for the total flow will be replaced with a new flow meter to measure the total filtrate flow from all the filters including that from the new filters. An arithmetical meter is to be installed to indicate the flow rate of the existing E. filters by deducting the flow rates of F. filters and the new filters from the total flow rate.

3) Backwashing water flow rate and airscouring flow rate

Both flowmeters are to be installed to ensure effective backwashing. They are not indicated on the panel in the operation room since the fixed flow rates are usually adopted.

4) Clear water distribution flow-rate

Two flow meters have been installed in the clear water tank. They are for distribution flow and transmission flow to service reservoirs. A flow meter installed in the existing pump station is for transmission flow to the Anse Courtois service reservoir. These flow rates are to be totalled and indicated on the panel.

4.4 Structural Design

4.4.1. Design Criteria

The structural calculations in the detailed design for such treatment facilities as sedimentation tank, filters, etc. were made by the following major design criteria.

1) Dead loads

Reinforced concrete	:	2,500 kg/m^3
Plain concrete	:	2,300 kg/m^3
Compacted soil	:	1,800 kg/m^3
Water	:	1,000 kg/m^3

2) Live loads

<u>Area</u>		<u>Minimum Live Load</u>
Passage floor	:	300 kg/m^2
Pipes, valves and pump floor	:	500 kg/m^2
Ground around structure	:	1,000 kg/m^2

3) Seismic loading

The seismic coefficient was set forth and applied to the treatment facilities as follows:

Horizontal force : $H = K \times W$
Seismic coefficient : $K = 0.05$, W = loads

4) Dynamic water pressure

Dynamic water pressure was calculated using Housner's formula.

$$p = 3^{1/2}KWH\{y/H - 1/2(y/H)^2\}\tanh(3^2 l/H)$$

where, p : Dynamic water pressure (ton/m^2)
K : Seismic coefficient
W : Unit weight of water (ton/m^3)
y : Water depth from the surface (m)
H : Total water depth (m)
l : Width of tank x 1/2 (m)

5) Earth pressure

The earth pressure acted to treatment facilities were calculated with coefficient of earth pressure at rest Ks = 0.5 assuming structures restrained from movement.

6) Allowable stress

Allowable tensile stress of reinforcing steel bar:

Against permanent load : 1,600 kg/cm^2
Against temporary load : 2,400 kg/cm^2

Allowable compression stress of concrete:

Against permanent load : 70 kg/cm^2
Against temporary load : 105 kg/cm^2

Allowable shearing stress of concrete:

Against permanent load : 4.25 kg/cm^2
Against temporary load : 6.38 kg/cm^2

7) Net concrete cover

Underside of base slab	:	10 cm
Upperside of base slab and walls	:	7 cm
Other slabs	:	5 cm

4.4.2. Structural Analysis

The structural analysis for receiving tank, rapid mixing tank, flocculation tank, sedimentation tank, rapid sand filter and wastewater pond are conducted by a computer with the elastic design.

The analysis is done for every cross section of the above structures as one body of slab, wall and base giving the following combined loads of dead weight, earth pressure, water pressure and seismic load. Each member is designed for maximum stress of the combined loads.

1) For permanent load

(1) dead weight + earth pressure
(2) dead weight + earth pressure + water pressure
(3) dead weight + water pressure

2) For temporary load

(1) dead weight + earth pressure + seismic load
(2) dead weight + earth pressure + water pressure + dynamic water pressure + seismic load

Details of structural analysis are presented in Data Book of Lot III.

4.5 Chemical Dosing System

4.5.1. Design Concept

The chemical dosing systems for aluminium sulphate, hydrated lime and chlorine gas for the proposed system were designed based on the raw water quality data and the results of Jar Test.

1) Chemical Application

(1) Considerations for the selection of chemicals:

- Easily available in Mauritius
- Currently used in other waterworks in the country.
- Costs
- Results of jar tests, as proven to work effectively in the tests

(2) Availability of chemicals

At present, the chemicals used in the existing waterworks are:

- Coagulant	:	Solid aluminum sulfate (alum), 50 kg/bag imported from Korea.
- Coagulant aid	:	Slaked lime powder (lime), 25kg/bag produced locally
- Disinfectant	:	Liquid chlorine gas imported from India, provided in 50 kg, 100 kg and 1,000 kg containers

(3) Chemicals to be used in the proposed treatment system

- Solid alum as coagulant	:	50 kg/bag (17% strength)
- Hydrated lime as coagulant aid	:	25 kg/bag
- Chlorine gas as disinfectant	:	1000 kg container

2) Design Concept for Chemical Dosing System

(1) Equipment

As only chlorine gas is being used in the existing Pailles treatment works, the application of additional chemicals, alum and lime, was designed referring to the current practice in the other rapid filtration plants at Piton Du Milieu and Nicoliere.

The dosing equipment should conform to the requirements of accurate dosing, and adjustable dosage ranges to cope with the quality fluctuations in raw water.

(2) Operation and Maintenance

For the operation and maintenance of the equipment, the following factors are considered in the design.

- Easy operation of the equipment
- To integrate a new chlorination system to the existing system for streamlining the operation and control of equipment
- To provide enough work and storage spaces on the basis of the present practice at other treatment works

3) Dosing System

Lime dosing is applied as pre-alkali treatment for coagulation and flocculation process during the period when raw water turbidity is moderate or high, and as post-alkali treatment for pH adjustment after removal of colour by coagulation and flocculation in low pH range.

Pre-chlorination is to be applied to suppress algal growth, and to oxidize ammonia, iron and manganese during the limited period whenever these substances appear in high concentrations in the future raw water.

Alum and lime dosing system are to be equipped in the chemical building. Chlorine dosing system in the existing chlorination building is to be integrated to the present system. The existing chlorination building is to be expanded.

(1) Alum and Lime dosing system

Alum and lime solutions are to be made up in respective solution tanks with mechanical agitators, and dosed with rate-adjustable chemical dosage pumps. Lime solution is mixed with pressured water through an injection pump and sent to the dosing point.

(2) Chlorine gas dosing system

Chlorine gas is dosed as concentrated chlorine solution produced by chlorine gas and water mixed by vacuum induced by the pressured water. Weighing scales are to be equipped to indicate remaining chlorine amount in the container.

4.5.2. Alum Dosing System

1) Design Conditions

(1) Planned treatment flow-rate

- For Phase 1	:	Min. Q = 4,500 m^3/d
		Max. Q = 31,500 m^3/d
- For Phase 2	:	Max. Q = 42,000 m^3/d

(2) Dosing rate

The dosing rates were decided based on the Jar-test results. The following rates are employed for design of the equipment.

Mode of operation	DOSING RATE Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)
- For wet season, conventional rapid filtration mode	100	10	30
- For dry season, direct filtration mode	9	6	8

(3) Dosing points

Alum is to be dosed in the rapid mixing tank for the operation in the conventional rapid filtration mode. Another dosing point was designed immediately before rapid sand filters for the operation in direct filtration mode.

2) Design of Dosing Equipment

(1) Calculation of dosing amount

The dosage is determined by the following equation, and calculated for each case of the operation:

$$V = Q \times Rs \times 100/C \times 1/r \times 10^{-6}$$

where,				
	V	:	dosing amount	(m^3/d)
	Q	:	treatment flow-rate	(m^3/d)
	Rs	:	dosing rate	(mg/l)
	C	:	concentration	(10%)
	r	:	specific gravity of liquid	(1.05)

Dosing Amount for Operation in Conventional System (wet season)

Q	max.(100 mg/l) m^3/d	l/min	ave.(30 mg/l) m^3/d	l/min	min.(10 mg/l) m^3/d	l/min
(Phase-1)						
4,500 m^3/d	4.29	2.98	1.29	0.90	0.43	0.30
31,500 m^3/d	30.0	20.83	9.0	6.25	3.0	2.08
(Phase-2)						
42,000 m^3/d	40.0	27.78	12.0	8.33	4.0	2.78

Dosing Amount for Operation in Direct Filtration Mode (dry season)

Q	max.(9 mg/l) m^3/d	l/min	ave.(8 mg/l) m^3/d	l/min	min.(6 mg/l) m^3/d	l/min
(Phase-1)						
4,500 m^3/d	0.39	0.27	0.34	0.24	0.26	0.18
31,500 m^3/d	2.70	1.87	2.40	1.67	1.80	1.25
(Phase-2)						
42,000 m^3/d	3.60	2.50	3.20	2.22	2.40	1.67

(2) Dosing pump

Adjustable dosage ranges of the chemical pumps were designed from the above dosing rates as follows:

- Wet season : 0.30 to 27.78 l/min
- Dry season : 0.18 to 2.50 l/min

Tube pumps, with a capacity of 14 l/min and control range of 50:1 are to be used. Number of pumps are three (3) (2 for duty and 1 for standby). Usually one pump is in operation and the other pump is to be operated together during the period of high turbidity.

(3) Solution and storage tank

(a) Solution tank

Two tanks are provided for alternate use. The capacity of each tank is designed at 12 m^3 which corresponds to one day dosing volume as 10% solution at an average dosing rate of 30 mg/l in Phase 2. Dimensions of the tank are as follows:

2.5 L x 2.5 B x 3.0 H (m)
(interior dimensions, effective depth of 2.0 m)

(b) Amount of alum (Vm) to be dissolved

Vm = 12 m^3 x 10/100 (density) = 1.2 ton = 24 bags as 50 kg/bag

(4) Agitator

The solution tanks are to be equipped with agitators to dissolve lump alum and prevent the solution from crystallizing. The specifications are as follows:

- Type : vertical mechanical mixer, flange coupling with drive unit, reduction gear drive
- Power : 2.2 kW x 50 Hz x 400 V
- Number : 2 sets for two tanks

(5) Solid alum storage

Storage space is to be 3-month requirement for 30 mg/l, average dosing rate, for 42,000 m^3/d of treatment capacity in Phase 2. The calculation is shown below:

- Storage volume : 12 m^3/d x 10% solution x 90 days
  = 108,000 kg = 2,160 bags as 50 kg/bag
- Area : assuming 2.0 m of piling height,
  6 m x 10.0 m = 60 m^2

4.5.3 Lime Dosing System

1) Design Condition

(1) Planned flow-rate

Same as alum dosing system.

(2) Lime dosing rate

According to the raw water quality and jar test results, pre-lime dosing is necessary during high turbidity and post-lime dosing is necessary when colour is high. When pre-alkali dosing is applied for removal of high turbidity, post-lime dosing will not be required. On the other hand, when colour is removed in low pH range, pre-lime dosing is not necessary but post-lime dosing will be required.

Although lime dosing rates in practical operation should be determined by Jar-test, the design employed the max. dosing rate of 50 mg/l and average dosing rate of 10 mg/l for both pre-lime and post- lime treatments.

The dosing rates for pre-lime and post-lime treatments are shown on the following table:

Item	Dosing Rate (mg/l)		
	max.	ave.	min.
For operation in conventional system (wet season)	50	10	0
For operation in direct filt-ration mode (dry season)	0	0	0

(3) Chemical

Slaked (hydrated) lime is selected as a coagulant aid, among others, soda ash, caustic soda etc. for this filtration system owing to the following reasons:

(a) locally produced and inexpensive
(b) easier to handle
(c) possibility for longer storage

(4) Dosing system

The manual dosing system with batch storing and dosing by tube pumps is designed.

(5) Dosing point

The dosing point for pre–lime is located before the alum dosing point in the inlet side of the rapid mixing tank, and that for post–lime is after the filtered water effluent weir.

2) Design of Dosing Equipment

(1) Calculation of dosing amount

The lime dosing amount is computed by the following equation:

$$Vl = Q \times Rs \times 100/C \times 10^{-6}$$

where,	Vl :	dosing amount	(m^3/d)
	Q :	treatment flow-rate	(m^3/d)
	Rs :	dosing rate	(mg/l)
	C :	concentration	(10%)

LIME DOSING AMOUNT (V1)

Q	max.(50 mg/l) m^3/d	l/min	ave.(10 mg/l) m^3/d	l/min	min.(0 mg/l) m^3/d	l/min
(Phase-1)						
4,500 m^3/d	2.25	1.56	0.45	0.31	0	0
31,500 m^3/d	15.75	10.94	3.15	2.19	0	0
(Phase-2)						
42,000 m^3/d	21.00	14.58	4.20	2.92	0	0

(2) Dosing Pump

The minimum and maximum dosages in the above table are 0.31 l/min and 14.58 l/min, respectively. Two pumps with adjustable range of 0 to 15 l/min are to be used with the flow control range of 50 : 1.

(3) Solution and storage tank

(a) Solution tank

Two tanks are provided for alternate use. The capacity of each tank is designed at 4.2 m^3 which corresponds to one day dosing volume for average dosing rate of 10 mg/l in Phase 2. Dimensions of the tank are as follows:

1.5 L x 1.5 B x 3.0 H (m) (inside measurement, effective depth of 2.0 m)

(b) Lime amount (Vm) to be dissolved

Vm = 4.2 m^3 (capacity of storage tank) x 10/100
= 420 kg
= 17 bags as 25 kg/bag

(4) Agitator

The solution tank is equipped with an agitator to prevent the lime slurry from undissolved lime settlement. The following mixer is designed for the agitation.

- Type	:	vertical mechanical mixer, flange coupling with drive unit, reduction gear drive
- Power	:	1.5 kW x 50 Hz x 400 V
- Number	:	2 sets for two tanks

(5) Lime storage

Storage space is decided as 3-month requirement of 10 mg/l, average dosing rate for 42,000 m^3/d of treatment capacity in Phase 2. The calculation is shown below:

- Storage volume	:	4.2 m^3/d x 10% x 90 days = 37,800 kg = 1,512 bags as 25 kg/bag
- Space	:	assuming 2.0 m piling height, 6 m x 3.5 m = 21 m2

(6) Manual chain hoist

Chain hoist of manual type is designed to be provided on both ground and first floors to transfer the chemicals in the building. Specification of the hoist is as follows:

- Lifting load	:	1 ton
- lifting height	:	4 m for ground floor, and 6 m for first floor

4.5.4 Chlorination System

New chlorination system is designed to be integrated to the existing system. The existing building is remodeled to separate into three rooms for chlorinators, booster pumps and container.

1) Existing Chlorination System

(1) Outline of the system

- Treated flow-rate	:	60,000 m^3/d
- Chlorine	:	Liquid chlorine gas with 1,000 kg container
- Dosing rate	:	1 mg/l (2.5 kg/hr)
- Dosing point	:	at clear water main
- Chlorinator	:	cabinet type, capacity of 7 kg/hr, 2 sets (1-standby)
- Dosing method	:	pressure dosing
- Booster pump	:	32 mm x 1.1 kW x 1 kg/cm^2 x 1 set 32 mm x 0.63 kW x 1 kg/cm^2 x 1 set (standby)

(2) Present Operation

(a) Water to be mixed with chlorine gas is abstracted from the water main and supplied to the chlorinator by booster pump. Chlorine solution mixed in the chlorinator is dosed to downstream point.

(b) Chlorine gas is conducted to the chlorinator through a conduction pipe. No leakage detectors are installed.

(c) Container unloaded from truck is carried by manual rolling to the room and after that set by manual chain-hoist. Weighing scale is not equipped.

(d) Operation of chlorinator is done for 24 hours with three shift system.

2) Conditions of System Expansion

Two chlorination systems are to be operated for slow sand filtration and new filtration systems in the treatment works. The following conditions are taken into the design.

- Chlorine gas should be used as disinfectant.
- Safety device and equipment for chlorine gas should be provided.
- Chlorinators and booster pumps should be accommodated in separate rooms.

- Weighing scales should be equipped for containers.

3) Selection of Dosing Method

(1) Disinfectant

Chlorine gas is to be used as all the existing systems are using chlorine gas as disinfectant.

(2) Selection of dosing method

Vacuum method, which is to dose chlorine solution mixed by ejector, is selected for the new system for the following reasons:

- Gas leakage is prevented due to negative pressure in chlorinator
- Dosing to high elevation, a distant point and into pressured pipe

4) Design of Dosing Equipment

(1) Dosing conditions

(a) Treatment flow-rate

- Existing facilities	:	60,000 m^3/d
- New facilities	:	(Phase 1) min. 4,500 m^3/d max. 31,500 m^3/d (Phase 2) max. 42,000 m^3/d

(b) Dosing points

- Existing facilities	:	clear water main between filter and clear water tank
- New facilities		
pre-chlorination	:	rapid mixing tank
post- chlorination	:	after filtered water effluent weir

(c) Dosing rate

Dosing rates necessary for pre-chlorination and post-chlorination were estimated so as to maintain adequate residual chlorine in the finished water, considering raw water quality and current practice in the Pailles waterworks.

DOSING RATE (mg/l)

Dosing point	max.	ave.	min.
Pre-chlorination	3.0	1.0	0.5
Post-chlorination	2.0	1.0	0.5

(2) Dosing amount

(a) Calculation of dosing amount

$$V = Q \times Rs \times 1/24 \times 10^{-3}$$

where,	V	:	chlorine dosing amount	(m3/hr)
	Q	:	treatment flow-rate	(m3/d)
	Rs	:	dosing rate	(mg/l)

(b) Dosing amount

From the above equation, the following dosages were computed:

unit : kg/hr

Q	Pre-chlorination			Post-chlorination		
	max.	ave.	min.	max.	ave.	min
(m^3/d)	(3mg/l)	(1mg/l)	(0.5mg/l)	(2mg/l)	(1mg/l)	(0.5mg/l)
(Phase 1)						
min. 4,500	0.56	0.19	0.09	0.38	0.19	0.09
max. 31,500	3.94	1.31	0.66	2.63	1.31	0.66
(Phase 2)						
max. 42,000	5.25	1.75	0.88	3.50	1.75	0.88
(Existing)						
max. 60,000	0	0	0	5.00	2.50	1.25

(c) Chlorinator

Max. and min. dosages are as follows:

- Pre-chlorination	:	5.25-0.66 kg/hr, min. 0.09 kg/hr
- Post-chlorination	:	3.50-0.66 kg/hr, min. 0.09 kg/hr
- Existing	:	5.00-1.25 kg/hr
- Pre-chlorination	:	6 kg/hr x 2 sets 1-duty and 1-common standby for pre- and post-chlorination
- Post-chlorination	:	5 kg/hr x 1 set
- Existing	:	7 kg/hr x 2 sets 1-duty and 1-standby

(3) Flow-rate and pressure of supplied water

To make a vacuum in the chlorinator, some pressure and flow rate are required at Ejector. Chlorine solution is to be dosed by the residual pressure at the ejector to higher points than the chlorinator. The flow-rate and pressure required for water are designed as follows:

- Booster pump (Pre-chlorination)
  * Discharge : max. 180 l/min x 3.7 kW x 2 sets (1-duty and 1-standby)
  * Total head : 47 m
  * Supply source : elevated tank

- Booster pump (Post-chlorination)
  * Discharge : max. 80 l/min x 1.5 kW x 1 set
  * Total head : 30 m
  * Supply source : elevated tank

- Existing system : 2 sets of existing pump

(4) Chlorine Gas Container

(a) Containers presently in use

Capacity of each container is one ton. At an average chlorine dosing of 2.5 kg/hr, containers are exchanged every 15 days.

(b) Storage of containers

At present, liquid chlorine gas is imported from India. Containers are delivered about 4 months after placing ordered. The container room is designed to store 10 containers. Coverage of consumption days for average use is calculated as follows:

– Daily consumption		
pre–chlorination	:	1.31 kg/hr x 24 hrs = 31.4 kg/d
post–chlorination	:	1.31 kg/hr x 24 hrs = 31.4 kg/d
existing system	:	2.50 kg/hr x 24 hrs = 60.0 kg/d
Total		122.8 kg/d
– Storage time	:	10,000 kg/122.8 kg = 81.4 days
		= 2.5 months

(c) Storage space of containers

Storage space should be enough to accommodate ten containers. Two chain hoists with 3–ton capacity is equipped in the room. The area of container room is as follows:

- (3.8 m B x 2 lines) x 7.55 m L = 57.4 m^2

(d) Weighing scale

Two weighing scales are to be equipped in the room to measure the remaining chlorine amount in containers.

(e) Safety measures against chlorine gas leak

The following devices are provided in the rooms as safety measures:

- Neutralization pit to submerge a leaked container
- Exhaust fans at the lower places
- Gas masks in the chlorinator room

4.6 Buildings

4.6.1 General Description

For the operation and maintenance of Pailles treatment works, under-listed buildings have been designed to be constructed under the Phase 1 Project.

(1) Operation building	:	monitor and control of operation condition of the facilities and administration office
(2) Chemical building	:	store, dissolution and dose of alum and lime, and elevated water tank
(3) Chlorination building	:	integration of the new system to the existing system separately chlorinator, booster pump and container rooms
(4) Workshop building	:	repair and assembly of chlorinator, instruments, and engines and pumps

4.6.2 Building Works

1) Operation Building

The operation building is in two stories and covers a total area of 480 m^2. The layout and elevation of the building are shown on Fig. A2.17 in Appendix 2.

The ground and first floors cover the following rooms:

– Ground floor	:	electricity, diesel generator, laboratory, shower and locker
– First floor	:	Control, administration office, conference and manager's office

The building is arranged toward south direction to overlook the new and existing filtration systems. For the purpose of centralising the information on performance of various mechanical and electrical equipment installed, a main control panel is situated in the control room. In addition, a balcony is provided on the front side of first floor for visitors.

A laboratory is located on the front side of the ground floor to enable sampling of processed water. Shelves are to be provided for storage of laboratory apparatus and chemicals.

The choice of materials and construction of building have been determined to ensure economy and ease of maintenance. Basic materials include reinforced concrete, precast-concrete block wall, wood and steel flush doors and aluminum sash windows, rock-wool tile and asbestos cement board ceiling and vinyl and terrazzo tile floor.

Required desks and chairs are to be provided in the rooms of manager, assistant manager, control room, office and laboratory.

2) Chemical building

The chemical building is in three stories and covers a total area of 480 m^2. The layout and elevation of the building are shown on Fig. 2.16 in Appendix 2.

Each floor covers the following rooms:

– Ground floor	:	chemical store space, chemical solution tanks and dosing pumps
– First floor	:	chemical store space, chemical dissolution space and locker

- Second floor : elevated tank for backwash and chemical dissolving water

The chemical dissolving and storage tanks of Alum and Lime are grouped together and located in opening on the first floor to enable putting the chemicals into the tanks. Three-month storage of each chemical is allowed in the building. The spaces are located adjacent to their respective dissolving tanks, and thereby it ensures minimum handling of the chemicals.

A higher level of ventilation is required in the chemical storing and dissolving rooms to exhaust dust and smell resulting from the handling of the chemicals.

The floors of the chemical dissolving and storing tank rooms are finished with cement screed and the internal wall are finished with cement mortar plaster.

Two chain hoists of manual type are equipped on the ceiling of the ground and first floors to transfer the chemicals from a truck and to the storage room at the first floor.

3) Chlorination Building

The existing chlorination building is remodelled and enlarged to accommodate chlorinators, booster pumps and containers in required numbers of the new and the existing systems.

As the safety measurement for chlorine gas leak, exhaust fans are equipped at lower level in the chlorinator and container rooms to exhaust leaked gas to outside. Neutralization pit is to be constructed in the container room to put the container into the pit and to shower the water for neutralization when chlorine gas leaks. In addition, gas masks are provided in the chlorinator room.

In order to control the chlorine gas consumption, weighing scales are provided in the container room. The weight is to be indicated on the panel in the operation room.

4) Workshop

The workshop building is a single story structure with an area of 460 m^2 and separated into three compartments of engine generators and pumps, instruments, and chlorinators

for repair and assembly.

Basically, the workshop building is to be constructed of similar materials as the operation and chemical buildings.

4.6.3 Associated Works

1) Water Supply System

The water required for drinking, shower, toilet etc in the buildings is supplied from the elevated tank. The bulk meter is to be installed before the branch-point to the chemical dissolving water pipe for recording the daily water consumption.

2) Sanitary System

Septic tank is to be placed in each building. Sewerage from the septic tank is conveyed to the existing drain pit by a pump.

Any waste from the laboratory and chemical dosing room is conveyed directly to the sludge pond.

4.7 Electrical Equipment

4.7.1 Power Receiving and Distributing

1) Design Concept

The electric facilities for the new filtration system is designed for the facilities after power receiving with 400/230 V and 3-phase with 4 wires.

For the purpose of safety and reliability operation under the suitable monitor system, the electric facilities are designed in accordance with the following design concept:

(1) Indoor and cubicle type

Equipment for electric main circuit and control circuit to each load are accommodated in the cubicle, which is to be equipped and centered at electric room of the operation building, and not equipped in basement part and on outdoor.

(2) Protection device

A circuit breaker is applied with relays for over-loading and preventing short circuit current to each load. The electric source of control circuit is used insulated from the electric source of main circuit.

(3) Emergency generator

The generator is designed to be installed to maintain power supply in case of power failure. The generator still have a minimum capacity required to run the treatment works including the transmission pump.

(4) Central monitoring panel

The electric main circuit and distribution facilities are always operated with closed circuit and then no-daily on- and off-operation is made. Therefore the monitoring panel is equipped in the control room and watched by monitoring staff.

(5) Communication

For a communication between control room and each site, interphone and loudspeaker is designed to be installed.

2) Calculation of Required Power

Required power in the treatment works is estimated with existing and new load capacities as shown on summary below:

Items	Installation Load	Operation Load
- Existing system	89 kW(*1)	87 kW
- Extension	278 kW	127 kW
Total	367 kW	214 kW

Note: (*1) included pump load (75 kW) for Anse Courtois

The above load is of max. usable power. The contracted power with CEB (Central Electricity Board) is estimated by multiplying the operation load by 0.7 of a load factor as follows:

- Contract power : 214 kW x 0.7 = 150 kW

3) Power Substation Facilities

(1) Existing facilities

The existing power source receives from a common overhead line of CEB with each one line of 20 kV and 400 V separately.

- 20 kV system is installed with main transformer (22 kV/400 - 230 V) and protective cutout fuse for primary and secondary sides. This system is employed for low tension distribution system in local.

- 400 V system is applied for transmission pump (75 kW) to Anse Courtois and received at other place for 20 kV system.

(2) Power substation facilities

In order to supply the power to expanded load in the new filtration system, some extension and modification are needed for the existing substation.

The power supply is to be performed by CEB with 3-phase, 4 wire and 400 V/230 V system, including the cable works up to a distribution panel. Therefore, the equipment for substation are to be installed and maintained by CEB and excluded from the design.

4.7.2 Generator Equipment

1) Necessity of Emergency Generator

A power interruption in the treatment works causes to stop the chlorination process and un-disinfected water flows into the clear water tank. So, an immediate suspension of raw water inflow as well as entire operation of treatment works has to be done. However, stopping the inflow and the operation of treatment process is really difficult, so that a power generation system has been planned and designed.

Capacity of the generation system is considered to be minimized by limiting parts of the operation. The estimated capacity taken into account the limited operation at various level is shown below.

Load	Estimated Power Requirement
- Pumping to Anse Courtois	75 kw
- Pumping to Elevated Tank	8 kw
- Chemical Dosing and Chlorination	18 kw
- Lighting	18 kw
Total	119 kw

The emergency generator with a capacity of 119 kW is designed to be provided inclusive of capacity of transmission pump to Anse Courtois service reservoir.

The existing engine generator of 25 kW power (34.7 kVA) is to be transferred for other use.

2) Calculation Procedure of Generator Capacity

The capacity of the generator is calculated by the following equations based on the starting conditions of motor:

(1) Capacity required for constant running

$$Pg1 = (Po \times A)/(El \times PFl)$$

(2) Capacity required for voltage falling at the starting

$$Pg2 = Pm \times B \times C \times X'd \times (1 - dE)/dE$$

(3) Capacity required for last starting of the largest motor

$$Pg3 = \{(Po \times A/El - Pm/Em) + Pm \times B \times C \times PFs\}/(Rg \times PFg)$$

where,	Pg	:	required generator capacity		kVA
	Po	:	output load		119 kW
	El	:	efficiency of load		0.8
	PFl	:	power factor of load		0.8
	Pm	:	largest output load		75 kW
	Em	:	efficiency of largest load		0.915
	PFs	:	starting power factor by largest load		0.4
	A	:	load factor		0.8
	B	:	starting kVA per 1 kW output		7.8
	C	:	coefficient by starting method		
			– star–delta		Cs = 0.67
			– reactor	(65% tap)	Cr = 0.65
			– compensation	(65% tap)	Cc = 0.42
	X'd	:	direct–axis transient reactance		0.25
	PFg	:	power factor of generator		0.8
	dE	:	allowable instantaneous voltage drop		0.25
	Rg	:	endurance coefficient of generator		1.5

Results of calculation are shown below:

Starting Method	Pg1	Pg2	Pg3
– Star–delta	149 kVA	294 kVA	162 kVA
– Reactor	149 kVA	285 kVA	158 kVA
– Compensation	149 kVA	158 kVA	113 kVA

Compensation starting method is designed to be employed to minimize the generator capacity to 150 kVA of nearly rated output from computed capacity of 158 kVA.

3) Calculation Procedure of Diesel Engine Output

The diesel engine output is also calculated by the following equations based on the starting condition of motor:

(1) Output required for constant running

$$Pe1 = Pg \times PFg \times 1.36/Eg$$

(2) Output required for last starting of the largest load

$$Pe2 = Pg3 \times PFg \times 1.36/(Eg \times Re)$$

(3) Output required for output falling at the starting

$$Pe3 = Pm \times B \times C \times PFs \times 1.36/(Eg \times k)$$

where,	Pg	:	generator capacity	158 kVA
	Eg	:	efficiency of generator	0.83
	Re	:	endurance coefficient of engine	1.1
	K	:	allowable loading rate	0.75

Results of the calculation are shown below:

Starting Method	Pe1	Pe2	Pe3
– Star–delta	207 PS	180 PS	343 PS
– Reactor	207 PS	175 PS	332 PS
– Compensation	207 PS	107 PS	215 PS

Rated output of 215 PS is employed for the diesel engine.

4.7.3 Instrumentation

The treatment works is equipped with various monitoring instruments as listed below:

(1) Raw water flow meters

(a)	New flow meter,	FI	1 set
(b)	Existing flow meters,	FI	3 sets
(c)	Arithmetical meter for grand total, (flow in new pipeline) + (existing flow)	FI,Q,R	1 set
(d)	New flow meter for rapid sand filtration system,	FI,Q,R	1 set
(e)	Arithmetical meter for allotted flow to slow sand filtration system (grand total flow) – (flow to rapid filtration)	FI,R	1 set

(2) Filtered water flow meters

(a)	Grand total filtered water flow meter,	FI,Q,R	1 set
(b)	Existing "F" filter flow meter,	FI,Q	1 set
(c)	Existing "E" filter arithmetical flow meter,	FI,Q	1 set
(d)	New flow meter for rapid filtration system	FI,Q,R	1 set

(3) Treated water flow meters

(a)	Existing distribution and transmission flow meter,	FI,Q,R	2 sets
(b)	Existing transmission flow meter to Anse Courtois,	FI,Q,R	1 set
(c)	Arithmetical meter for total of distribution and transmission flow	FI,Q,R	1 set
(d)	Backwash flow meter*	FI	1 set
(e)	Air-blower flow meter*	FI	1 set
(f)	Plant water flow meter*	FQ	1 set

(4) Water Level Meter

(a)	Clear water tank water level meter,	LI,R,A	2 sets
(b)	Receiving tank water level,	LA	1 set

(c)	Filter water level,	LA	6 sets
(d)	Plant water pump pit water level,	LA	2 set
(e)	Elevated tank water level,	LA	2 sets
(f)	Alum and lime solution tanks water level meter,	LI,A	4 sets

(5) Chlorine gas leakage alarm 3 sets

(6) Chlorine gas container weighing WI,A 2 sets

Note:

F	:	Flow
L	:	Level
W	:	Weight
Q	:	Totaliser
R	:	Recorder
A	:	Alarm

The above instruments excluding * marked meters are to be monitored concentrically by a monitor panel to be installed in the operation building.

1) Raw Water Flow Meter

The flow meter is designed with annubar type to be installed on the raw water main and for the rapid filtration system taking into account the following conditions:

- Head lossless type flow meter is suitable due to limitation of total head between the intake and the treatment works, and the receiving tank and the clear water tank.

- Accurate flow measurement is required for coagulants dosing

Orifice type flow meters are installed in the existing system. All the meters are equipped with a totaliser and a recorder. These meters are to be mounted on the monitoring panel.

2) Filtered Water Flow Meter for Slow Sand filtration

The flow meter for total flow of the existing slow sand filtration system is designed to

be of annubars type and be installed in the existing filtered water main with 900 mm in diameter replacing the existing orifice plate because of saving headloss.

The flow meter have been already equipped with orifice plate type in the existing "F" slow sand filtration system.

Arithmetical meters are designed to be installed on the panel for the calculation of filtered water flow rate of "E" filter (flow "E" = total flow minus flow "F" minus flow of new system).

3) Filtered Water in Rapid Sand filtration

The annubar type flow meter is to be used because of small head loss.

4) Level Meter for Clear Water Tank

Treated water from the clear water tank is transmitted by gravity flow to the other service reservoirs scattered in the City and directly distributed to the northwest zone. The transmission flow rate is to be fluctuated in accordance with the water demand. Therefore, the water level meter is designed to be equipped on the monitoring panel in the operation building to observe the following:

- No overflowing treated water from the tank
- Trend of rising and falling water level and their speed
- Securing safety and emergency water volume in the tank

The level meter of pressure type is installed at the existing level gauge and equipped with a level indicator, recorder and alarms for the low and overflow water levels.

5. IMPLEMENTATION PROGRAMME

5.1 Financial Programme

5.1.1 Construction Cost Estimates

The construction works of the Phase 1 Project is broadly divided into the following three divisions:

(1) General and Preliminary Items	:	construction of Employer's office, Contractor's camp, gurantee costs for Performance bond, Insurance of Works, third party insurance etc.
(2) Raw Water Transmission Pipeline Works	:	construction of intake, pipelaying works and river crossing and tunnel crossing works
(3) Treatment Works	:	construction of receiving tank, coagulation and sedimentation tank, filters, wastewater and sludge ponds, yard pipes, sitework, buildings and installation of mechanical and electrical equipment

The construction costs are estimated based on the Bills and Quantities applying the unit costs of the respective work items. The unit prices are estimated in accordance with the current market prices of the various construction materials and equipment. The Engineer's estimates, thus, are issued separately.

The estimated cost amounts to Mauritian Rupees (MRs.) 169.8 million in total inclusive of physical and price contingencies, at the price level of January 1991.

The Project Costs are estimated as follows:

Project Cost Estimated for Water Supply Facilities in Phase 1

Unit : MRs. 1,000

Work Items	F/C	L/C	Total
1. General and Preliminary Items	2,701	4,456	7,157
2. Raw Water Transmission Pipeline	18,887	5,289	24,176
3. Treatment Facilities	71,616	27,289	98,905
Sub-total	93,204	37,034	130,238
4. Engineering and Administration Costs	9,320	4,870	14,190
5. Physical Contingency	5,126	2,095	7,221
6. Price Contingency	9,350	8,801	18,151
Sub-total	23,796	15,766	39,562
Total	117,000	52,800	169,800

5.1.2 Annual Operation and Maintenance Costs

Annual operation cost comprises mainly personnel cost of the CWA staff to be engaged in operation and maintenance of the facilities and costs of chemicals and electricity costs. Their annual costs for maximum treatment capacity of 31,500 m^3/d are estimated as follows:

unit: MRs 1,000

	Description	unit	Q'ty	Unit Price	Amount
(a)	Personnel Cost				
	- Operation staff (44 x 12 months)	M/M	528	3.90 (*1)	2,059
(b)	Chemical Cost				
	- Alum	ton	174	8.70 (*2)	1,514
	- Lime	ton	38	3.00 (*2)	114
	- Chlorine gas	ton	45 (*4)	14.50 (*2)	653
	Sub-total				2,281
(c)	Power Cost				
	- Basic charges	kW	1,440	0.065 (*3)	94
	- Power rates	kWh	314,300	0.00145 (*3)	456
	Sub-total				550
	Total of Operation Costs				4,890
(d)	Maintenance Cost	LS(1 % of equipment costs)			155
	Total O/M Costs				5,045

Note : (*1): as of Jan. 1991 added 10% increase to the average unit salary in 1989
(*2): added 10% increase to the unit rates in Jun 1990
(*3): added 10% increase to the unit rates in 1990
(*4): including chlorination for the existing filtration system

The total operation and maintenance costs are estimated at MRs. 5.045 million/year. The chemical and electrical costs vary in accordance with the production capacity every year. The estimation of O/M costs is shown on Table 5.1 in Appendix 4.

5.1.3 Preliminary Financial Analysis

The financial aspect of the Phase 1 Project could be evaluated by means of preparing a financial statement for the expanded production capacity and its investment. The preliminary financial statement is prepared under the following conditions assumed multilateral agency's loan.

(1) Loan condition for foreign currency portion
- Repayment period 20 years
- Grace period 6 years
- Annual interest rate 7.93 %

(2) The capital investment for the local currency portion is financed by the Mauritian Government without interest.

(3) Financial calculation period is for 30 years after commissioning the service in fourth fiscal year after commencement of the construction works.

(4) Disbursement schedule of the capital investment is planned as tabulated below:

unit : MRs.1,000

Fiscal Year	Loan	Mauritian Government	Total
1st	42,600	23,400	66,000
2nd	53,700	21,200	74,900
3rd	20,700	8,200	28,900
Total	117,000	52,800	169,800

The financial statement is shown on Table 5.2 in Appendix 4. Revenue is computed based on the accounted-for-water volume and assumed water charges of MRs.6 per m^3 as shown

on Table 5.3 in Appendix 4. The revenue will be changed to a surplus from a deficit at 15 years after the operation of the new system.

5.2 Implementation Programme

5.2.1 Construction Work Plan

1) Construction Method

(1) Access road to the intake site

The access road to the intake site is to be constructed in the preparatory works of the dam construction. The road is designed to be 4 m wide between the shoulders. Gravel bed of 40 to 70 cm thick will be applied on the surface. Two submerged concrete bridges are constructed for river-crossing.

(2) Intake chamber

Temporary cofferdam of sheet piling is to be constructed in the river for making dry area to demolish the existing intake. Demolition of the concrete is to be done by a big-breaker mounted on backhoe from access approach. After pipes and sluice-gate are installed, the demolished intake should be immediately restored with concrete.

(3) Raw water transmission pipe

- Diameter and pipe material	:	800 mm, DIP
- Length	:	2,100 m

Trench for pipe-laying is to be excavated by back-hoe with 0.6 m^3 bucket. As the pipeline is to be protected by concrete and crusher-run, excavated soil and rock are to be disposed in the site except backfilled soil.

Pipes and fittings are to be transferred from a stock yard to the site by trucks. Loading and unloading of pipes are to be made by truck- crane. Setting of pipes in the trench is to be also done by the truck- crane on concrete sleepers placed both

sides of pipe considering the concrete lining for pipe protection.

(4) River crossing

- Diameter and pipe material	:	DN 800 mm DIP
- Length	:	2 river crossings of 88 m and 127 m, in length

The construction work is to be carried out in the dry season. River water is to be diverted downstream of the site with the temporary cofferdam and uPVC pipe during the construction work.

The river-bed consists of hard rock so that the excavation is done by a big-breaker. Backfilling is made with selected material of excavated rock. River crossing pipe should be encased in concrete, and be backfilled with at least 1 m depth of selected materials.

(5) Treatment facilities

- Receiving tank	:	1 unit
- Rapid mixing tank	:	1 unit
- Flocculation and sedimentation tank	:	3 units
- Rapid sand filter	:	6 units
- Wastewater pond	:	2 units
- Sludge pond	:	2 units

The site is planned to be graded into three formation levels. FGL (Formation Ground Level) for major treatment facilities including the chemical and operation buildings is +68.00 m, for the wastewater pond +66.00, and for the sludge pond +65.00. The land grading is to be initially done by bulldozer up to the respective formation levels, and further excavation is made by backhoe. As excavation for deep structures may encounter rock, a big-breaker is to be used for the rock excavation.

Soil to be used for backfilling is to be kept on the specified land adjacent to the treatment works, and surplus soil and rock are to be dumped in the reclamation area.

Upon completion of grading for bottom slabs, blinding concrete is to be placed to

enable fabrication of reinforcement steel bars for the slabs. The concrete volume necessary for the treatment facilities is at 4,900 m^3, and max. concrete volume to be placed in a day is estimated at 200 m^3. Accordingly, the design was made based on the use of ready mixed concrete without installing a concrete plant.

(6) Building works

- Operation building : 2–storyed of 480 m^2 floor area
- Chemical building : 3–storyed of 480 m^2 floor area
- Chlorination building : 1–storyed of 183 m^2 floor area
- Workshop building : 1–storyed of 460 m^2 floor area

Each building accommodates necessary treatment equipment. Installation of the equipment is to be commenced after completion of the building works. Therefore, the works is scheduled to be completed allowing for the installation and adjustment periods of the equipment.

The electricity source for the equipment is supplied by an exposed conduit method on the walls and floors. Other than the conduits, plumbing pipes are installed in the building so that an aperture portion is to be put as the need arises.

2) Allocation of Construction Machinery

The allocation schedule of construction machinery required for the transmission pipelaying works and for the treatment works construction are shown on Fig. 5.1 in Appendix 4. During the construction period, the following construction machinery are to be provided:

Machines	Specification	Q'ty	Net Period in Use (months)
Raw Water Pipeline			
– Back–hoe	0.6 m^3 Bucket	1	18
– Back–hoe	0.6 m^3 Bucket	1	20
– Big Breaker	1,300 kg	2	20
– Hand–breaker	20 kg	3	20
– Truck Crane	16 ton	1	3
– Truck crane	4.9 ton	1	18
– Dump Truck	8 ton	1	18
– Truck	8 ton	2	3

Machines	Specification	Q'ty	Net Period in Use (months)
Treatment Works			
- Bulldozer	21 ton	1	3
- Back-hoe	0.6 m^3 Bucket	2	4
- Big Breaker	1,300 kg	2	4
- Hand-breaker	20 kg	3	4
- Truck crane	16 ton	1	15
- Truck crane	4.9 ton	1	2
- Dump Truck	11 ton	1	5
- Truck	8 ton	1	13

5.2.2 Construction Schedule

The construction period for the water supply facilities is scheduled to be two years after the issuance of Notice to Proceed, including an intake chamber, raw water pipeline and treatment facilities. Upon completion of the construction, the test operation of treatment facilities is scheduled for the period of two months. The schedule for each work item is as follows:

Work Items			period
- Preparatory works :	Construction of site office, contractor's camp, transportation of construction machines, etc	:	3 months
- Pipe manufacturing delivering to site :	pipes, fittings and valves for raw water, treated water and in filter pipe gallery	:	9 months
- Equipment manufacturing/delivering :	chemical dosing equipment, pumps and air-blower equipment, flow meters and level meter, instruments and electrical equipment	:	12 months
- Pipe installation :	raw water pipeline	:	24 months
- Civil engineering and building works :	treatment facilities and buildings including yard piping and landscaping	:	21 months
- Installation of equipment :	chemical dosing equipment and other equipment	:	6 months
- Test operation :	including training of operators	:	2 months

The construction schedules by a bar chart and a critical path method are shown on Figs. 5.2

and 5.3, respectively in Appendix 4.

APPENDIX 1

WATER QUALITY DATA

Table 2.3.1 Turbidity, pH, Colour and Alkalinity in Raw Water

	Turbidity FTU	pH	Alkalinity CaCO3 mg/l
Wet Season			
09/02/91	4	7.9	36
08/02/91	10	7.4	30
07/02/91	19	7.0	28
04/02/91	1	7.7	58
31/01/91	5	8.1	54
28/01/91	4	8.0	56
24/01/91	3	8.1	58
16/01/91	3	8.1	52
04/12/90	8	7.6	36
01/02/80	4	6.8	-
24/01/80	21	7.5	-
18/01/80	8	7.6	-
17/01/80	12	7.3	-
10/01/80	21	7.8	-
23/12/79	32	7.2	-
07/12/79	80	7.2	-
Dry Season			
06/10/90	<1	7.5	50
21/09/90	1	7.5	50
14/09/90	<1	7.9	46
25/08/90	3	8.1	48
21/08/90	2	8.1	48
16/08/90	3	8.1	49
13/08/90	2	8.0	50
11/08/90	1	8.0	53
06/08/90	3	8.0	51
03/08/90	2	8.0	47
02/08/90	2	8.1	49
01/08/90	2	8.1	50
31/07/90	2	8.0	50
27/07/90	1	8.1	50
26/07/90	2	8.1	49
25/07/90	2	8.1	48
21/07/90	4	8.0	48
19/07/90	2	8.1	55
18/07/90	2	7.8	48
17/07/90	1	8.0	53
16/07/90	5	8.0	42

Table 2.3.2 Colour In Raw Water Source

	Municipal Dyke	Moka River	Profonde River	Cascade River	Terre Rouge River	Plaines Wilhems River	Analyzed by
07/02/91	>70	>70	>70	>70	>70	5	CWA Labo
28/01/91	10	-	-	-	-	-	CWA Labo
24/01/91	10	-	-	-	-	-	CWA Labo
25/08/91	5	6	5	5	11	6	CWA Labo
31/07/90	5	5	5	5	5	5	CWA Labo
20/07/90	5	5	5	5	5	5	CWA Labo
23/12/88	8	7	5	7	7	5	JICA Team
24/07/88	-	<5	<5	<5	<5	-	JICA Team

Units are Hazen Unit (True Colour).

Table 2.3.3 Ammonia, Nitrite, and Nitrate In Raw Water

	Municipal Dyke	Moka River	Profonde River	Cascade River	Terre Rouge River	Plaines Wilhems River	Analyzed by
Ammonia-Nitrogen							
18/01/91	<0.01	<0.01	0.01	<0.01	0.02	<0.01	JICA Team
16/08/90	ND	0.02	ND	ND	0.01	0.03	JICA Team
31/07/90	0.01	<0.01	0.01	<0.01	<0.01	0.01	JICA Team
20/07/90	0.03	0.01	0.02	<0.01	0.01	0.04	JICA Team
23/12/88	ND	ND	0.01	ND	0.01	0.05	JICA Team
24/07/88	-	0.04	0.10	0.10	0.06	-	JICA Team
16/06/88	0.05	-	-	-	-	-	
Nitrite-Nitrogen							
20/07/90	-	0.005	-	-	-	-	JICA Team
16/06/88	ND	-	-	-	-	-	Severn Trent
Nitrate-Nitrogen							
18/01/91	0.6	0.1	0.9	0.6	0.7	0.5	JICA Team
16/08/90	1.5	1.5	2.4	1.2	2.0	0.8	JICA Team
31/07/90	1.5	2.0	2.5	1.4	2.3	1.0	JICA Team
20/07/90	1.5	2.0	1.4	2.3	1.0	1.5	JICA Team
23/12/88	1.33	1.98	1.64	1.56	0.99	0.52	JICA Team
24/07/88	-	2.25	1.57	1.91	1.57	-	JICA Team
16/06/88	2.2	-	-	-	-	-	Severn Trent
Total Nitrogen							
25/08/90	2.3	2.2	2.9	2.0	2.1	1.4	JICA Team
23/12/88	2.1	2.2	2.0	1.9	1.1	0.9	JICA Team
24/07/88	-	2.3	3.4	2.1	1.7	-	JICA Team

Units are mg/l.

Table 2.3.4 Iron and Manganese in Raw Water

	Municipal Dyke	Moka River	Profonde River	Cascade River	Terre Rouge River	Plaines Wilhems River	Analyzed by
Iron							
18/01/91	0.06	0.15	0.12	0.08	0.09	0.04	JICA Team
25/08/90	0.09	-	-	-	-	-	JICA Team
16/08/90	0.03	0.11	0.07	0.02	0.01	0.02	JICA Team
31/07/90	0.05	0.08	0.10	0.06	0.02	0.03	JICA Team
20/07/90	0.04	0.08	0.11	0.07	0.01	0.03	JICA Team
23/12/88	0.37	0.22	0.08	0.33	0.28	0.01	JICA Team
24/07/88	-	0.06	0.06	0.08	0.15	-	JICA Team
18/06/88	0.08	-	-	-	-	-	Severn Trent
Manganese							
25/08/90	ND	-	-	-	-	-	JICA Team
20/07/90	<0.1	0.1	<0.1	0.1	<0.1	0.1	JICA Team
23/12/88	0.011	0.001	0.003	0.003	ND	0.001	JICA Team
24/07/88	-	0.01	0.01	0.01	0.02	-	JICA Team
18/06/88	ND	-	-	-	-	-	Severn Trent

Units are mg/l.

Table 2.3.5 Organic Matter In Raw Water

	Municipal Dyke	Moka River	Profonde River	Cascade River	Terre Rouge River	Plaines Wilhems River	Analyzed by
BOD							
04/02/91	0.5	ND	ND	ND	ND	ND	JICA Team
23/12/88	0.8	0.2	0.5	0.8	0.9	1.5	JICA Team
24/07/88	-	0.2	0.3	0.5	1.0	-	JICA Team
18/06/88	ND	-	-	-	-	-	Severn Trent
COD							
18/06/88	<10	-	-	-	-	-	Severn Trent
Potasium Permanganite Consumption							
23/12/88	13.3	11.9	11.2	11.1	9.4	10.4	JICA Team
24/07/88	-	1.2	1.4	1.1	3.0	-	JICA Team

Units are mg/l.

Table 2.3.6 Heavy Metals and Other Toxic Substances in Raw Water

Location	Sample Date	Cyanide	Mercury	Copper	Lead	Chromium	Arsenic	Cadmium
Municipal Dyke	25/08/90	ND	0.0005	ND	ND	ND	ND	ND
Municipal Dyke	18/06/88	-	-	ND	ND	ND	-	ND
WHO Standards		0.1	0.001	1.0	0.05	0.05	0.05	0.005
Japanese Standards		ND	ND	1.0	0.1	0.05	0.05	0.01

ND means "none detected". Units are mg/l.
Samples on 25/08/90 and 18/06/88 were analyzed by JICA Team and Severn Trent, respectively.

Table 2.3.7 Pesticide in Raw Water

Location	Sample Date	Organo-Phosphorus	Organo-Chlorine	Analyzed by
Municipal Dyke	25/08/90	ND	-	JICA
Municipal Dyke	18/06/88	ND	11	CWA
WHO Standards	individual limit for each pesticide			
EEC Standard	Total less than 500			
Japanese Standards		ND		

ND means "none detected". Units are ng/l.

Table 2.3.8 Coliforms and Faecal Coliforms

	Municipal Dyke	Moka River	Profonde River	Cascade River	Terre Rouge River	Plaines Wilhems River	Analyzed by
Coliforms							
04/12/90	14	-	-	-	-	-	CWA Labo
06/11/90	>180	-	-	-	-	-	CWA Labo
21/09/90	1	-	-	-	-	-	CWA Labo
23/08/90	300	800	-	-	-	ND	JICA Team
16/08/90	>180	>180	90	>180	>180	>180	CWA Labo
Faecal Coliforms							
04/12/90	ND	-	-	-	-	-	CWA Labo
06/11/90	>180	-	-	-	-	-	CWA Labo
21/09/90	ND	-	-	-	-	-	CWA Labo
16/08/90	9	4	18	ND	9	90	CWA Labo

Units are number/100 ml