CHAPTER 3

WATER SUPPLY SYSTEM

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3.1 General

3.1.1 Components of the Priority Projects

The stage I of the augmentation of Salaulim Water Supply Scheme (WSS) was selected as the priority projects from the urgency point of view because it has the most serious problem for water shortage, as described in Volume II Main Report: Master Plan. The project scale was set based on a careful examination of water demand, supply capacity, raw water availability and the PWD's financial capabilities. The selected priority projects are described below:

- Expansion of the Salaulim Water Treatment Plant (WTP) by 100,000 m^3/day, resulting in a total capacity of 260,000 m^3/day
- Rehabilitation and Improvement of the Existing Salaulim WTP, which has a production capacity of 160,000 m^3/day
- Construction of a 20,000 m^3 Master Balancing Reservoir (MBR) at Sirvoi rock hill
- Installation of 73.65 km of Transmission Mains, ϕ 150 to ϕ 1400
- Rehabilitation of 13.8 km of the Existing Transmission Mains, ϕ 1200
- Construction of six Reservoirs
- Construction of five Pumping Stations
- Replacement of 4 units of Pumping Equipment at Verna Pumping Station
- Improvement of Operation and Maintenance, including installations of flow meters, float valves and flow control valves and improvement of safety standard of WTPs for all 7 WSSs
- Establishment of Central Laboratory

In addition to the above components, the PWD should develop the distribution network systems for expanded service areas where are newly covered by the priority projects in order to supply the increased capacity of 100,000 m^3/day, which includes the installation of distribution pipelines and house connections. For the economic and financial analysis of the feasibility study explained in Chapter 9 of this volume, the costs for the analysis includes not only of selected priority projects listed above but also of the distribution network systems which will be improved by the PWD.

3.1.2 Staged Development Plan

To meet the increased water demand, the water supply capacity of the Salaulim WTP will be expanded in two stages until the year 2025 as shown in Figure 31.1. Under the first stage the capacity will be expanded by 100,000 m^3/day, to meet the daily maximum water demand in year 2018. The first stage of the Salaulim WSS was selected as the priority projects considering its urgency, importance and efficiency. The second stage also consists of an expansion of 100,000 m^3/ day.

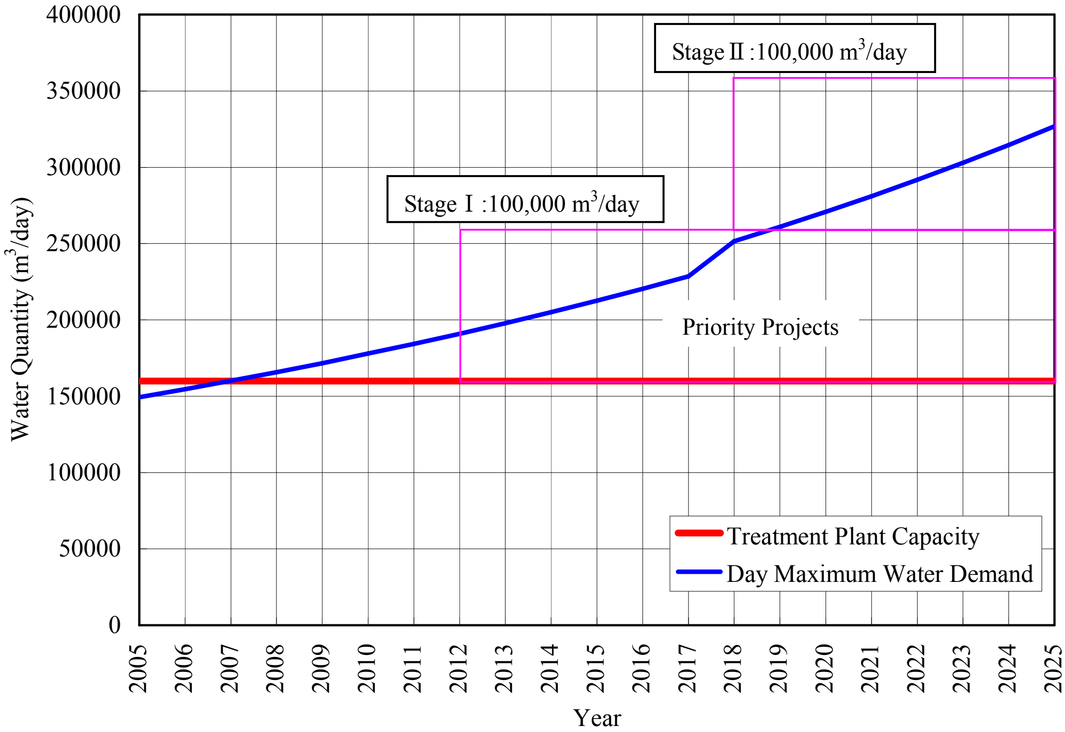


Figure 31.1 Staged Development Plan for the Salaulim WSS

3.1.3 Availability of the Raw Water

The raw water requirement for the existing WTP (which have a capacity of 160,000 m^3/day) is 176,000 m^3/day, including plant loss of 10 %. On the other hand, the raw water requirement for the proposed WTP (which is a capacity of 100,000 m^3/day) is 110,000 m^3/day. Therefore the total raw water requirement of the Salaulim WTP becomes 286,000 m^3/day.

According to the Department of Water Resources, Government of Goa, the raw water source availability from Salaulim Dam Reservoir for the Salaulim WTP is 380,000 m^3/day as detailed in Volume II Chapter 5 Master Plan for Water Supply. This means that there is no problem and no limitation for the augmentation of Salaulim WTP from the viewpoint of raw water source.

3.2 Design Conditions

3.2.1 Water Treatment Plant (WTP)

(1) Design Criteria of WTP

The WTP is designed using the 'The Government of India, Manual on Water Supply and Treatment, CPHEEO, May 1999' as summarised in Table 32.1. Any design criteria not stipulated in this Indian manual were based on the 'Japan Water Works Association, Design Criteria for Waterworks Facilities, 2000'.

Table 32.1 Design Criteria of WTP

Type	Design Parameter	India*		Japan**	
Coagulation	G value	300	s^{-1}	—	
(Rapid Mixer)	Detention time	30 - 60	seconds	60 - 300	seconds
	Ratio of impeller diameter to tank diameter	0.2 - 0.4		—	
Flocculation	G value	10 - 100	s^{-1}	10 - 75	s^{-1}
(Flocculator)	Detention time	15 - 20	minutes	20 - 40	minutes
	Water Velocity	0.1 - 0.3	m/s	0.15 - 0.3	m/s
	Water depth	1.0 or more	m	—	
	Clear distance between baffles	0.45 or more	m	—	
	Clear distance between end of baffle and wall	0.6 or more	m	—	
Sedimentation	Surface Loading	30 - 40	$m^3/m^2/d$	21.6 - 43.2	$m^3/m^2/d$
(Clarifier)	Detention Time	2 - 2.5	hours	—	
	Length of tank (rectangular)	30 - 100	m	—	
	Ratio of length to width	3:1 - 5:1		3:1 - 5:1	
	Length of square tank	up to 20	m	—	
	Diameter of tank	up to 60	m	—	
	Depth of tank	2.5 - 5	m	3 - 4 (Water	m
	Inlet velocity	0.2 - 0.3	m/s	less than 0.4	m/s
	Weir Loading	up to 300	$m^3/d/m$	500	$m^3/d/m$
Rapid Sand Filtration	Filtration rate	4.8 - 6	m/hr	5 - 6.25	m/hr
(Sand Filter)	Number of filter beds (minimum)	4 or 2 (small plants)		2	
	Maximum Filter areas	up to 100	m^2	up to 150	m^2

* The Government of India, Manual on Water Supply and Treatment, May 1999
**Japan Water Works Association, Design Criteria for Waterworks Facilities, 2000

(2) Design Flow of WTP Facilities

WTP facilities are designed based on the daily maximum water demand and operation / maintenance process water (plant loss). In this study the plant loss is estimated to be 10% of the daily maximum water demand. Therefore the base flow of the WTP design is 110 % of the daily maximum water demand.

(3) Raw Water Quality and Water Treatment Process

The raw water quality was considered for selecting water treatment processes, because iron and manganese were found in the raw water during the reconnaissance survey. Basically the rapid sand filtration process was adopted for water treatment process of the proposed WTP.

(4) Rehabilitations and Improvements of Water Treatment Facilities

The existing WTP facilities are planed to be rehabilitated based on those life times. In general the design life for civil works is 50 years and the design life for mechanical and electrical equipment is 15 years.

The proposed improvements to the existing facilities planned and these were based on plant safety, process control and the need for continuous water supply. Plant safety is the most important aspect of the proposed improvements. The existing WTP does not have safety equipment especially for chlorine gas. Therefore safety and health improvements have been selected as part of the priority projects. The priority projects also include process control improvement for providing continuous water supply such as installing flow meters at inlet and outlet of WTP.

3.2.2 Transmission System

(1) Proposed System

The transmission system design is mainly based on the "Manual on Water Supply and Treatment, Third Edition – Revised and Updated, CPHEEO, MOUD, May 1999". The key components are outlined below.

a. Formula for Hydraulic Calculation: Hazen-Williams Formula

There are a number of formulae available to calculate the velocity of flow (e.g. Hazen-Williams formula, Manning's formula, Darcy-Weisbach's formula and Colebrook-White formula). The Hazen-Williams formula is the best for situations involving pressure conduits. The formula is:

$$V = 0.84935\ C\ R^{0.63}\ I^{0.54}$$

For circular conduits, the formula is restated as

$$hf = 10.666\ C^{-1.85}\ D^{-4.87}\ Q^{1.85}\ L$$

Where,
V = Velocity (m/s)
C = Hazen-Williams coefficient
R = Hydraulic Radius (m)
I = Hydraulic Gradient, hf/L
hf = Friction Head Loss (m)

D = Diameter of Pipe (m)

Q = Discharge (m^3/s)

L = Pipe Length (m)

b. Hazen-Williams Coefficient (C Value): 110 for all materials

The manual recommends that the Hazen-Williams coefficient (C value) for new pipes made from cast iron, ductile iron or mild steel with cement mortar lining should be between 130 and 145. However, it is generally recommended that in the absence of specific data, a C value of 110 should be adopted. Therefore, a C value of 110 was adopted when designing the transmission system, including the existing pipelines.

c. Hourly Peak Factor: 2.0

When designing the distribution system hourly demand fluctuations must be considered. For example, during the night, people use less water, but in the morning and evening people use much more water. Figure 32.1 shows the distribution flow to Lamgao at Bicholim City. This flow data was obtained during the first Phase Reconnaissance Survey.

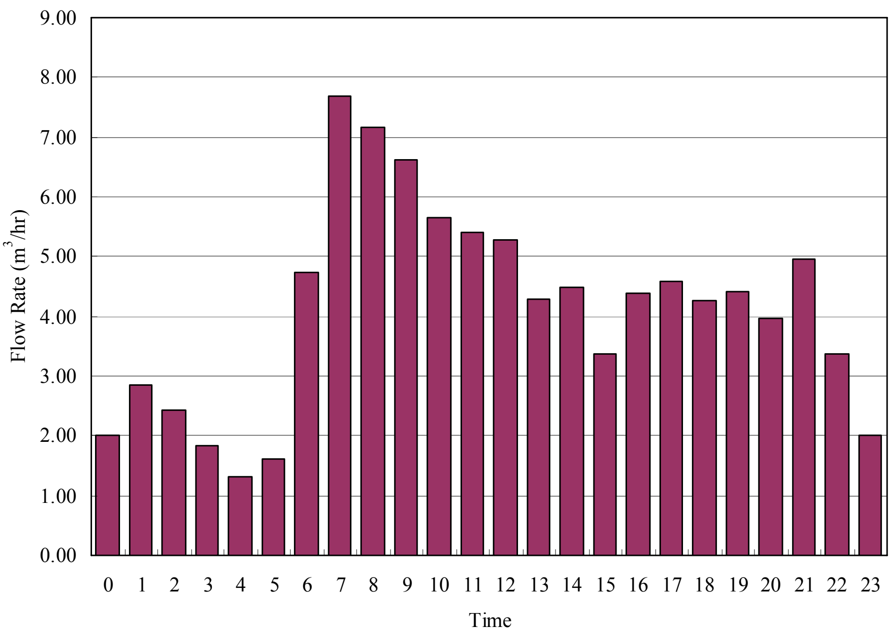


Figure 32.1 Distribution Flow to Lamgao at Bicholim City, Bicholim Taluka

In this case, the hourly peak flow is about 1.9 times of the average distribution flow rate. Therefore, when designing the distribution system an hourly peak factor of 2 was adopted as well as the fluctuation pattern shown in Figure 32.1.

d. Software for Hydraulic Analysis: WaterCAD v7.0, Haestad Methods Inc

The hydraulic analysis was conducted using a computer software program called WaterCAD v7.0 for 500 pipes, which runs under the AutoCAD environment, Haestad Methods Inc.

It should be noted that since there is no recorded data or drawings of the existing transmission systems or details of the reservoirs, the modelling for the hydraulic analysis was prepared based on information obtained through interviews with the PWD's engineers, for the following system components:

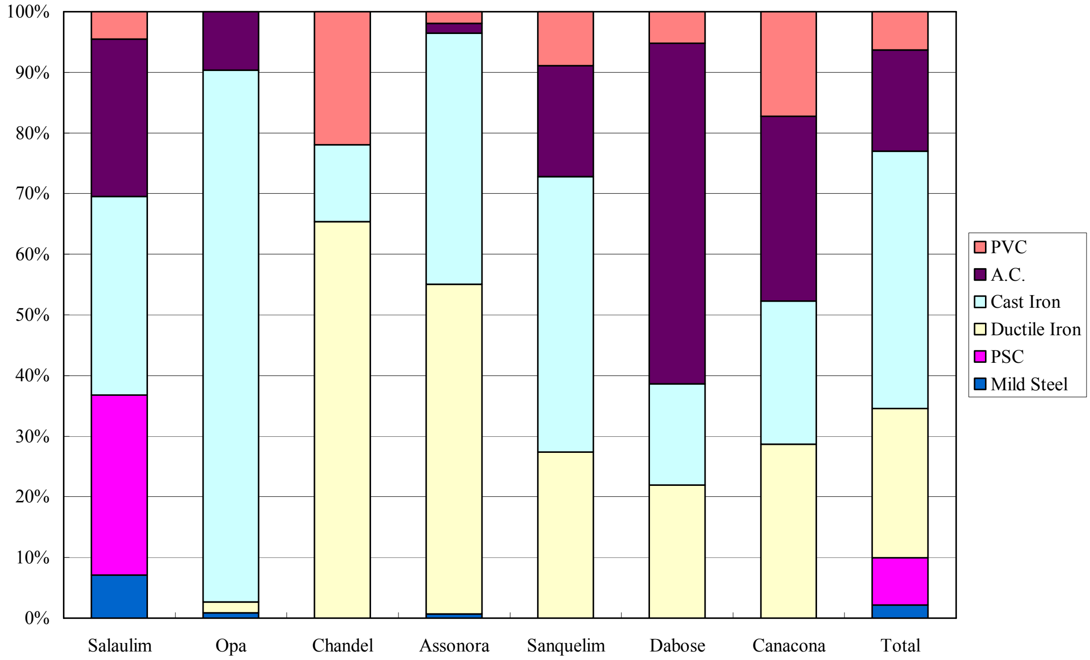
- routes, materials and diameters of transmission mains; and
- locations, capacities and water level of reservoirs.

(2) Rehabilitation and Replacement of the Existing Transmission Mains

The rehabilitation and replacement of the transmission mains will include the replacement of the following:

- all asbestos cement pipes which were installed before 1990; and
- 30 % of the all pipes that were installed before 1975.

For reference, the proportions of different materials used in the existing transmission system are shown in Figure 32.2.



Source: Sector Status Study – WSS Goa, 2004

Figure 32.2 Percentage of Pipe Materials for each Scheme

3.2.3 Reservoirs

(1) Proposed Reservoirs

New reservoirs will be proposed at expanded service areas to supply treated water. Basically the locations will be proposed based on the consultation with the PWD and the site investigation, and the reservoir volumes will be decided by the hydraulic calculation.

(2) Rehabilitation of the Existing Reservoirs

The Salaulim WSS has 85 reservoirs except reservoirs at Salaulim WTP, Margao MBR and Verna MBR. A detailed list of the reservoirs is attached in Volume IV Appendix M31 Existing Water Supply System. Although the design life of the concrete structure is 50 years as mentioned in previous section, the master plan targeted upto the year 2025 assumes that about 20 percent of the existing reservoirs will be rehabilitated by 2025. This means that about 20 percent of the existing reservoirs are considered to be constructed before 1975, because the data of construction years of all reservoirs were not available.

3.2.4 Distribution Pipelines and House Connections

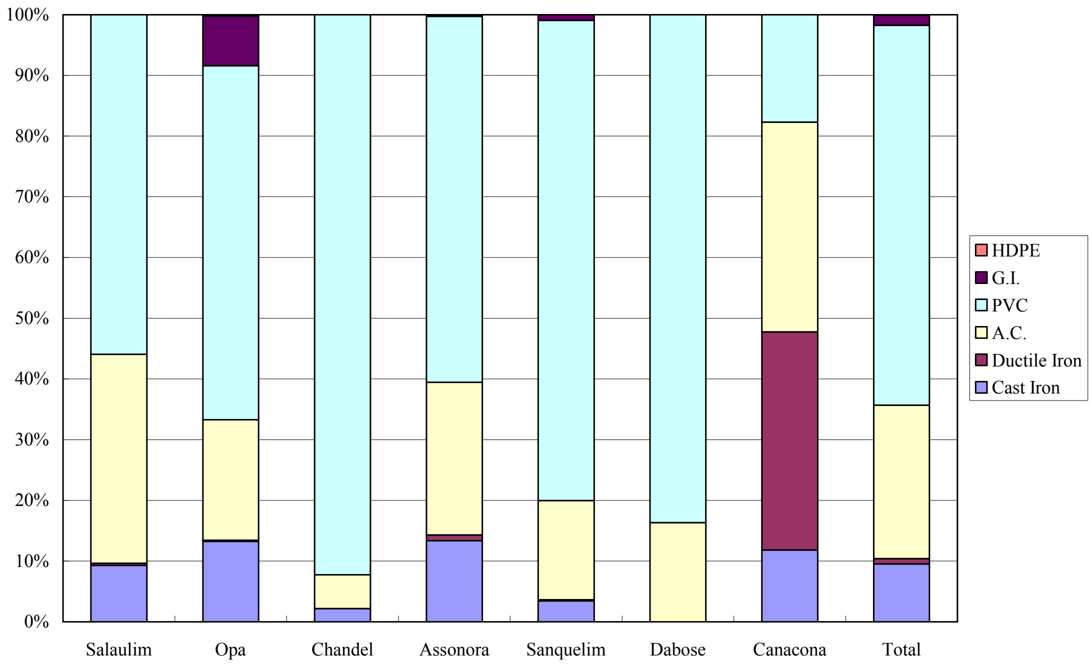
(1) Proposed Distribution Pipelines and House Connections

The required length of the new distribution pipelines that will be installed when the supply area expands was estimated from the existing distribution pipeline lengths and the existing number of house connections, giving a unit length of 14.26 m. This means 14.26m of distribution pipeline is needed to provide one additional house connection. The number of domestic house connections was based on the increase in the population served.

(2) Rehabilitation of the Existing Distribution Pipelines and House Connections

It was assumed that distribution pipelines need to be rehabilitated / replaced after 50 years. It is planned that 2 % of the existing distribution pipelines will be replaced every year. Figure 32.3 shows the proportion of distribution pipe materials for each scheme, for reference.

It was assumed that house connections need to be rehabilitated / replaced after 10 years. It is planned that all the existing water meters will be replaced within 10 years.



Source: Sector Status Study – WSS Goa, 2004

Figure 32.3 Proportion of Distribution Pipe Materials for each Scheme

3.3 Service Area and Water Demand

3.3.1 Service Area

In principle, each taluka is served by one WSS, however due to topographical features, some WSSs supply water to an area exceeding the taluka administrative boundary. The existing Salaulim WSS supplies water treated at the Salaulim WTP to four talukas (Sanguem Taluka, Quepem Taluka, Salcete Taluka and Mormugao Taluka). However, the northern part of the Sanguem Taluka is supplied from the Opa WSS. It would be best if the northern part of the Sanguem Taluka were covered by the Opa WSS, as is currently the case. The Study recommends, therefore, that until 2018 the proposed service area for the Salaulim WSS is the same as the existing area as shown in Figure 33.1.

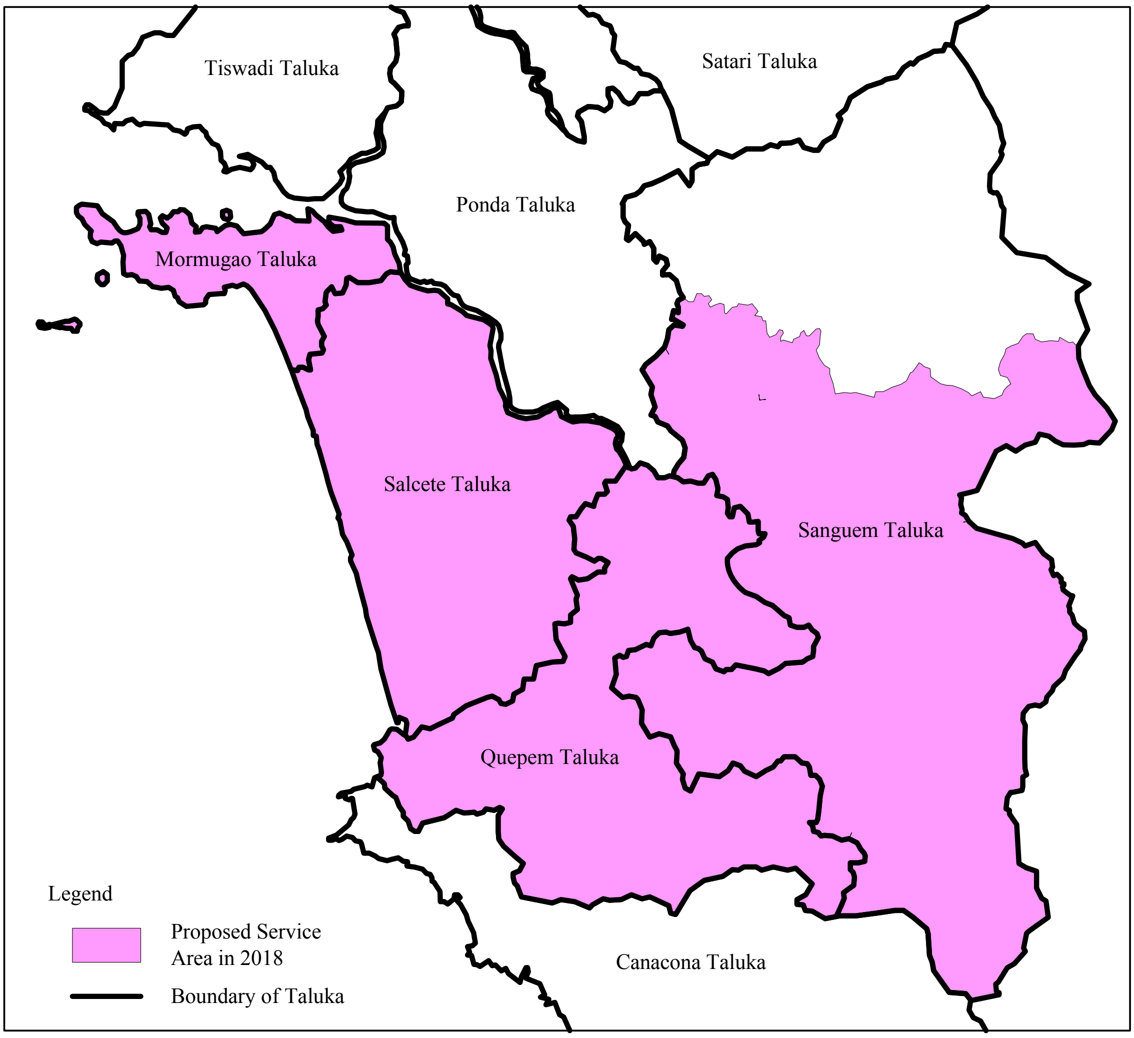


Figure 33.1 Supply Area of Salaulim WSS until 2018

3.3.2 Water Demand

As discussed in Volume II Main Report: Master Plan, the study adopted per capita water consumption for urban area is 150 lpcd and for rural area is 100 lpcd. The water demand of the Salaulim WSS was calculated based on the service area and the water demand for each taluka as presented in Volume II Chapter 4 Future Population and Water Demand and detailed in Volume IV Appendix M51 Service Area and Water Demand.

The daily maximum water demand for the Salaulim WSS is summarised in Table 33.1 and shown in Figure 33.2.

Table 33.1 Daily Maximum Water Demand for the Salaulim WSS until 2018

Year	2005	2006	2007	2008	2009	2010	2011
Demand (m^3/day)	149,324	154,596	160,066	165,765	171,686	177,851	184,234
Year	2012	2013	2014	2015	2016	2017	2018
Demand (m^3/day)	190,881	197,798	205,010	212,520	220,335	228,481	236,977

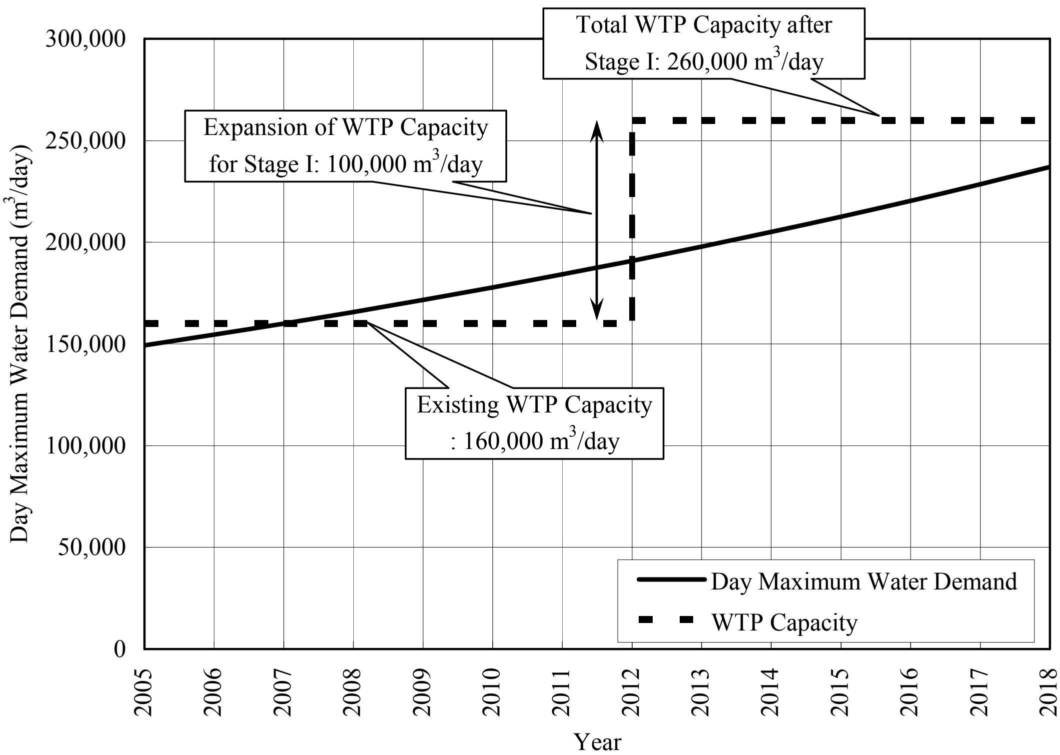


Figure 33.2 Daily Maximum Water Demand for the Salaulim WSS until 2018

To meet the increased water demand, the water supply capacity of the Salaulim WTP will be expanded in two stages as mentioned previous section. As shown in Figure 33.2 under the first stage the capacity of the Salaulim WTP will be expanded by 100,000 m^3/day, to meet the daily maximum water demand in year 2018.

3.3.3 Water Transmission System

As mentioned in Section 3.3.1, the study proposes that the Salaulim WSS will supply treated water to four Talukas (Samguem, Quepem, Salcete and Mormugao) in 2018. Figure 33.3 shows the schematic transmission plan for the Salaulim WSS in 2018.

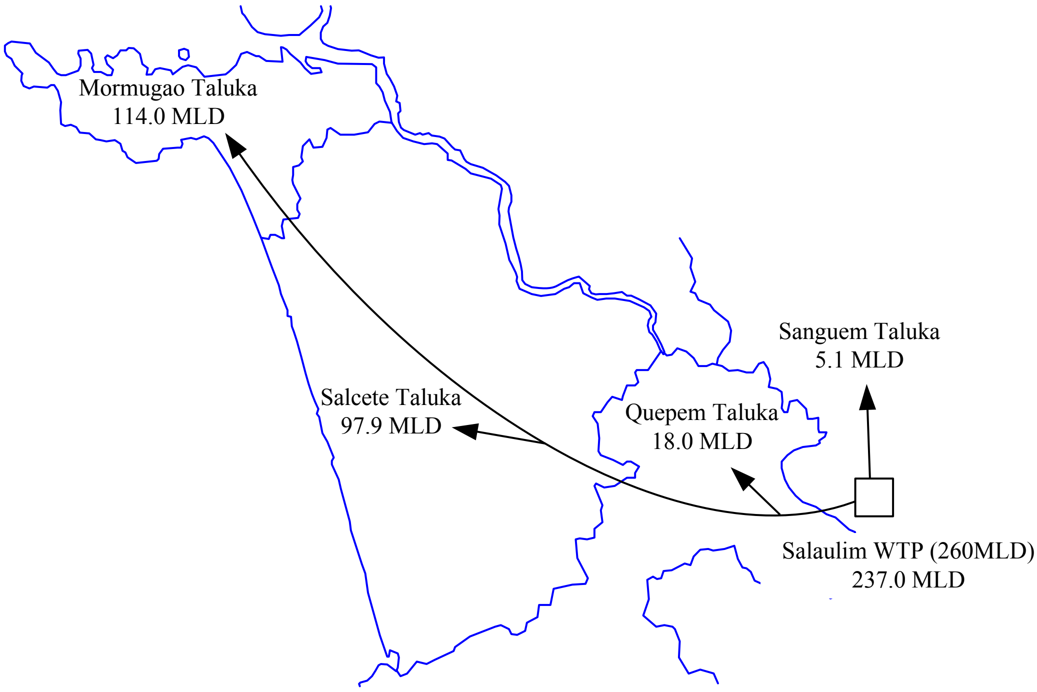


Figure 33.3 Schematic Transmission Plan for the Salaulim WSS in 2018

3.4 Facility Planning and Preliminary Design of Salaulim Water Supply Scheme

3.4.1 Expansion of Salaulim Water Treatment Plant

The existing WTP has a capacity of 160,000 m^3/day. It is proposed to increase this capacity by 100,000 m^3/day, to cope with future demands in 2018. Therefore, the total capacity will become 260,000 m^3/day. The proposed plant has the following facilities and is described in detailed hereinafter:

- Raw water intake facilities including intake and pumping house, pumps and motors.
- Raw water transmission mains from the intake pumping house to the treatment facility.
- Treatment facilities including receiving well, coagulation basin (rapid mixing), flocculator and clarifier, filtration basin and clear water reservoir.
- Chemical feeding facility for alum, lime and chlorine including chemical building and feeding equipment.
- Electrical and instrumentation facilities.
- Transmission facilities including transmission pumping house, pumps and motors.
- Power sub-station including transformer and diesel generator.
- Administration building with laboratory.

(1) Treatment Process

1) Existing Treatment Process

For the existing treatment process, the rapid sand filtration system is adopted as shown in Figure 34.1.

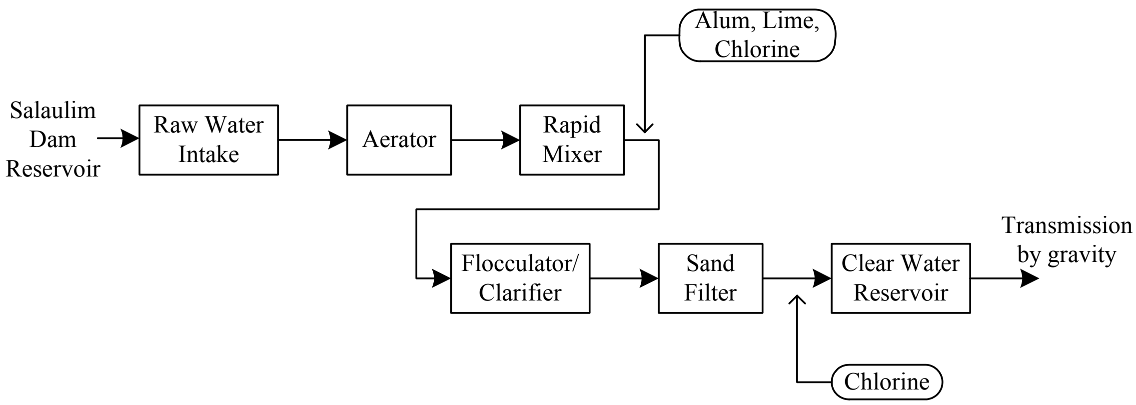


Figure 34.1 Treatment Process of the existing Salaulim WTP

2) Feature of Raw Water

The results of raw water quality analysis for raw water of the Salaulim WTP are summarised in Table 34.1.

Table 34.1 Raw Water Quality of Salaulim WTP

Parameters	Max	Min	Ave
1. Turbidity（NTU）	28.0	0.4	2.7
2. Iron(mg/L)	0.8	0.01	0.07
3. Manganese(mg/L)	3.6	0.05	0.5
4. Ammonia-N(mg/L)	1.1	0.25	-

Data Sources; Parameters 1 to 3: Daily test results of Salaulim WTP Laboratory, Jan. 2003 to Dec. 2004
Parameter 4: PHE Tonca-Caranzalem Laboratory, Test results during the study
(Detailed figures of test results are referred to Volume IV Appendix for Master Plan)

Features of the raw water at the Salaulim WTP Plant are;

- The maximum raw water turbidity was 28 NTU in June 2004, and except 12 days of June and July in 2003 raw water turbidity was recorded below 10 NTU.
- Iron concentrations exceeded the 0.1 mg/l (acceptable level specified in "Manual on Water Supply and Treatment, CPHEEO, May 1999") several times a year, the average iron concentration was 0.07 mg/l. Therefore it is necessary to apply any measures for iron removal. The correlation between turbidity and iron concentration is shown in Figure 34.2. As shown on this figure, iron concentration and turbidity shows correlation, therefore, iron can be removed effective coagulation and sedimentation since concentration of dissolved iron is low.

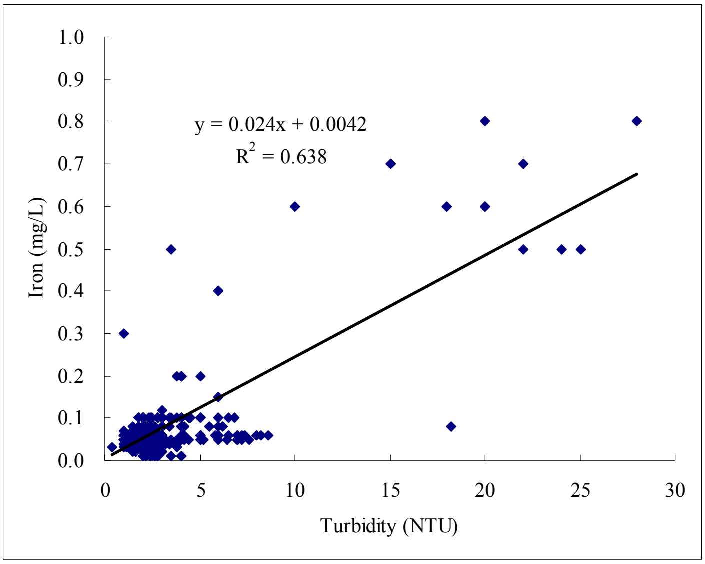


Figure 34.2 Relationship between Turbidity and Iron Concentration

- Manganese concentrations exceeded the 0.05 mg/l (acceptable level specified in "Manual on Water Supply and Treatment, CPHEEO, May 1999") several times a year, and the relatively high concentrations were showed in March, April, June, July and December. Therefore it is necessary to apply any measures for manganese removal. The correlation between turbidity and manganese concentration is shown in Figure 34.3. As shown on this figure, manganese concentration and turbidity shows correlation, therefore, manganese also can be removed effective coagulation and sedimentation since concentration of dissolved manganese is low.

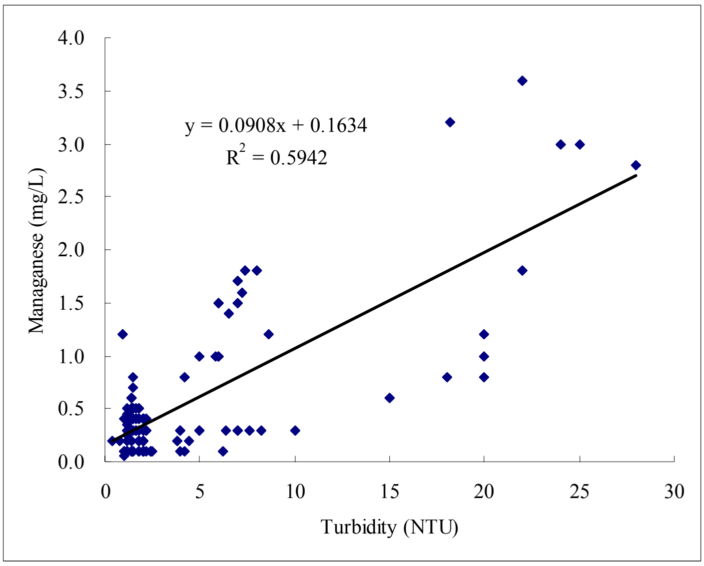


Figure 34.3 Relationship between Turbidity and Manganese Concentration

- As the results of the raw water quality analysis of the Salaulim WTP raw water during the study period, ammonia nitrogen of 0.25 - 1.1mg/L was detected. It may be necessary to apply the biological treatment or the chlorination to remove ammonia nitrogen. It is noted that chlorine of about 8 times ammonia nitrogen should be needed to maintain sufficient residual chlorine.
- The coliforms had been detected in almost all raw water sanples.

3) Proposed Treatment Process

As well as the existing process, the conventional coagulation-sedimentation and rapid sand filtration system is recommended for the proposed treatment process. As mentioned above, the raw water contains ammonia nitrogen and manganese. Iron can be oxidised by pre-chlorination without difficulties, but manganese oxidation is rather difficult because of its slow reaction rate. Proposed treatment processes for ammonia nitrogen and manganese are as follows.

a. Removal of Ammonia Nitrogen

According to the results of quality analysis of raw water of Salaulim WTP, concentration of ammonia nitrogen (NH_3-N) was as shown in Table 34.2.

Table 34.2 Concentration of Ammonia Nitrogen in Salaulim Raw Water

Season	Surface water of Salaulim Dam (mg/l)	Bottom water of Salaulim Dam (mg/l)
Dry Season	0.85	1.1
Rainy Season	0.25	0.33

Souce: Analysis by PHE Laboratory in 2005

As shown on table above, concentrations of NH_3-N in dry season were rather high. Concentrations shown on above figure were results of just one sample for each analysis. It is recommended that PHE should continuously monitor the concentration of NH_3-N, since concentration of NH_3-N has significant relation of chlorine dosage rate. One mg/l of NH_3-N will consume about 8 mg/l of Chlorine. To secure/maintain adequate residual chlorine concentration of treated water, it is indispensable to monitor NH_3-N concentration and to decide sufficient chlorination dosage rate based on the NH_3-N concentration.

If the NH_3-N concentration was found as high level through the year by the PHE continuous quality monitoring, it is recommended to install/construct biological contact filtration basin as pre-treatment to remove NH_3-N.

The NH_3-N contained in the water will be oxidized (nitrification) by biological film which consists of nitrification bacteria. The biological contact filtration basin is upflow or down flow basin equipped with plastic or ceramic media which propagate biological film and with aeration system to supply oxygen to nitrification bacteria. Typical biological contact filtration basin is as shown on Figure 34.4.

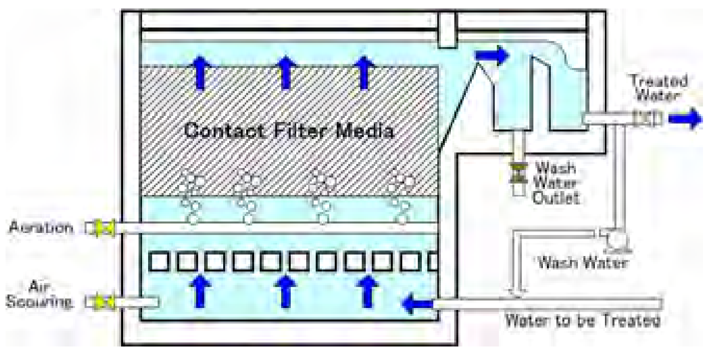


Figure 34.4 Typical Biological Contact Filtration

The treatment plant is preliminary designed for reserving land space and required water head loss to accommodate the biological contact filtration basin if it is required in future.

b. Manganese Removal

Manganese (Mn) can be present in water in one of three basic forms:

1. Dissolved: Manganous (Mn^{2+})
2. Particulate: Manganic (Mn^{4+})
3. Colloidal

Manganese exists as particulate can be removed by effective coagulation and sedimentation as mentioned in the previous section. In this section, removal or treatments of dissolved manganese are discussed.

The majority of manganese treatment systems employ the process of oxidation followed by filtration. The oxidation chemically oxidizes the manganese. Oxidation followed by filtration is a relatively simple process. The raw water must be monitored to determine proper oxidant dosage, and the treated water should be monitored to determine if the oxidation process was successful.

Before manganese can be filtered, it needs to be oxidized to a state in which they can form insoluble complexes. Oxidation involved the transfer of electrons from the manganese. Reduced manganese (Mn^{2+}) is oxidized to (Mn^{4+}), which forms insoluble (MnO^2). The most common chemical oxidants in water treatment are chlorine or chlorine dioxide.

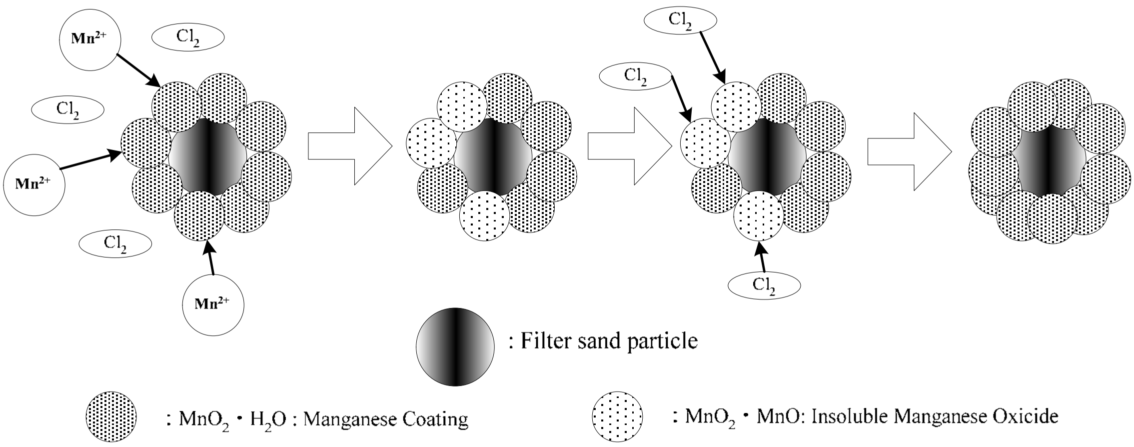
In general, manganese oxidation is more difficult than iron oxidation because the reaction rate is slower. A longer detention time (10 to 30 minutes) following chemical dosage is needed, prior to filtration, to allow the reaction to take place (Iron and Manganese Removal, New York Rural Water Association). The sand particle will be coated with manganese oxide by continuous dosage of chlorine and will give the sand media a catalytic effect in the chemical oxidation reduction reactions necessary for manganese removal. This coating will remain sand particle and effective for manganese removal.

Contact oxidation of manganese coated sand takes place when manganese ion contacts the surface of the manganese coated sand, Manganese ion is absorbed as oxidized manganese and removed from water as follows:

$3Mn^{2+} + MnO \cdot H_2O + H_2O \rightarrow MnO_2 \cdot MnO \cdot H_2O + 2H^+$

The product, $MnO_2 \cdot MnO \cdot H_2O$, is inert and does not have oxidize effect. To maintain oxidization, it is required to continuous chlorine feeding which enable continuous Manganese absorption as shown below:

$MnO_2 \cdot MnO \cdot H_2O + Cl_2 + H_2O \rightarrow 2MnO_2 \cdot H_2O + 2H^+ + 2Cl^-$



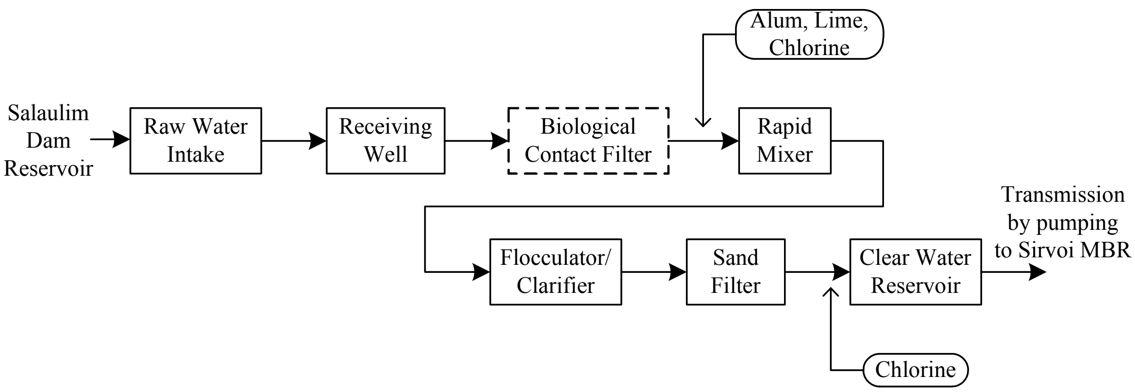
(Source: Guideline of Water Treatment, Japan Water Research Center, 2000)

Figure 34.5 Schematic of Contact Oxidation of Manganese

For the manganese oxidation at the sand filter, it should be necessary to control the residual chlorine concentration of filtered outlet water 0.5 to 1.0 mg/l.

c. Proposed Treatment Process

As the results, Figure 34.6 shows the proposed water treatment process for the expansion of Salaulim WTP, which is "coagulation-settling process plus manganese sand filtration process".



Note: Biological Contact Filter will be installed if it was judged necessary based on results of continuous water quality monitoring on Ammonia-Nitrogen.

Figure 34.6 Treatment Process of the Proposed Salaulim WTP

As the first step of the ammonia nitrogen removal, it is recommended to monitor the concentration of ammonia nitrogen. If the ammonia nitrogen concentration was found as high level through the year, it is recommend constructing biological contact filter as pre-treatment to remove ammonia nitrogen. Preliminary design reserved land space and require water head loss to accommodate the biological contact filter if required in future.

In conclusion at the Salaulim WTP it is necessary to treat the following parameters surely.

1. Turbidity
2. Iron
3. Manganese
4. E. coliform
5. Ammonia nitrogen

(2) Intake Facilities

1) Water Source for the Stage I Project

The proposed WTP will take raw water from the Salaulim Dam Reservoir as well as the existing WTP. The raw water requirement for the existing WTP is 176,000 m^3/day, including plant loss of 10 %. In addition, the raw water requirement for the proposed WTP is 110,000 m^3/day. Therefore the total raw water requirement of the Salaulim WTP becomes 286,000 m^3/day.

From the quantitative point of view, according to the Department of Water Resources, Government of Goa, the raw water from Salaulim Dam Reservoir for the Salaulim WTP is quite sufficient.

The intake structure will be constructed for the capacity of Stage I and Stage II which is 220,000 m^3/day in total, because of the difficulty of construction works. Only the pumping equipment for Stage I will be installed as the priority projects at the pump house and a space for the pumping equipment for Stage II is reserved.

2) Selection of Intake Type

A new intake facility is proposed to be constructed at adjacent to the existing intake facility. There are two major alternative types for intake facility, as listed below and shown in Figure 34.7.

a. Intake Gate Type (Existing Type)
b. Intake Tower Type

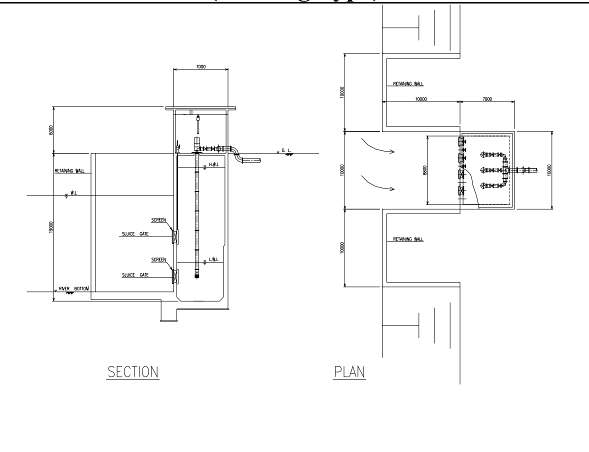
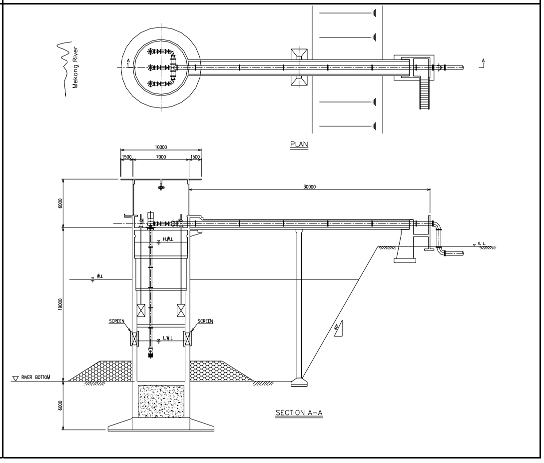
a. Intake Gate (Shore Intake) Type (Existing Type)	b. Intake Tower Type
	

Figure 34.7 Alternative Types for Intake Facility

Of these different systems, the existing type (intake gate type) is recommended as the new intake facility for the expansion of the Salaulim WTP, since in case adopting the intake tower type the very high self-standing structure (more than 40 m) has to be constructed inside the Salaulim Dam Reservoir.

Intake gate type may have misgivings about sedimentation or accumulation of mud in front of gate at the lowest position by soil sliding or erosion on the adjacent slope. This is because the water fluctuation of Salaulim Dam Reservoir is very big. The water level fluctuation may cause side slope erosion on the adjacent slope, that is, it may require side slope protection along the intake canal.

3) Selection of Pump Type

Available raw water intake pump types for the intake facility are:

a. Submersible Type Pump

b. Vertical Type Pump

The difficulty associated with using a submersible mixed flow pump is the requirement to send the pump to the pump manufacturer in situations of pump failure since the submersible type pump can not be repaired on site. And the study had not confirmed that the submergible type pump of large capacity was popularly used in India. On the other hand, the vertical type pump can be repaired by the PWD in case of pump failure and the existing intake pumps are this type. The vertical type pump is recommended to be adopted in proposed intake.

A horizontal centrifugal pump is also one of the alternatives for the selection of pump type. However if a centrifugal pump was used at the intake facility, the pumps should be placed below the low water level of the Salaulim Dam reservoir and therefore construction costs will be much higher compared with the other type of intake pumps and the pumping house should be constructed as the strict water tight structure.

4) Raw Water Transmission Main

Although the existing raw water transmission main has two lines, single line of diameter 1,400 mm MS pipe with a flow meter and flow control valve is recommended as the proposed raw water transmission main. The proposed raw water transmission main has a capacity of flowing 220,000 m^3/day for Stage I and Stage II.

5) General Layout Plan of Intake Facility

The general layout plan of the intake facility is shown in Figure 34.8.

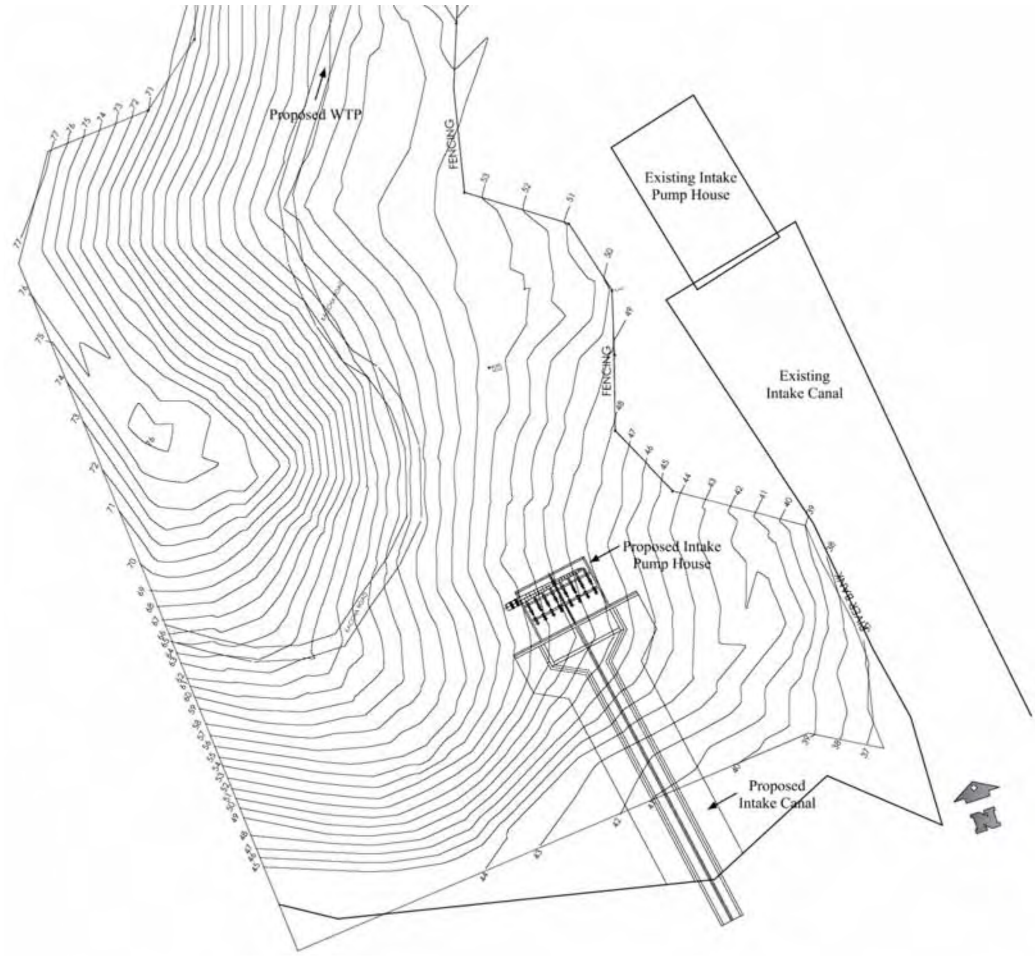


Figure 34.8 General Layout Plan of Intake Facility for the Proposed WTP

(3) Receiving Well

The proposed WTP constructed by the priority projects has a capacity of 100,000 m^3/day for one series. At Stage II the WTP of 100,000 m^3/day will be constructed as a second series and the total treatment capacity will be 200,000 m3/day. Therefore the proposed WTP has two series for Stage I and Stage II respectively. In order to divide the inlet flow into two series as shown in Figure 34.9, the receiving well should be constructed before the treatment process.

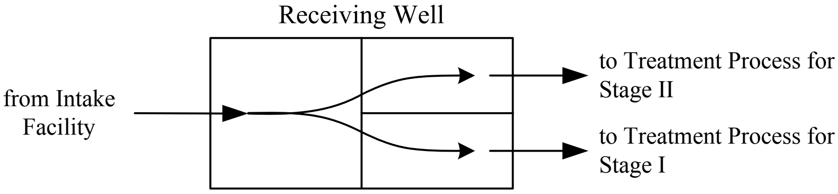


Figure 34.9 Function of Receiving Well

(4) Rapid Mixing

The coagulation-sedimentation process involves three processes; mixing, flocculation and sedimentation. The mixing of chemicals and the coagulation process coagulates the fine particles or colloidal particles to minute flocs by the rapid mixing after feeding coagulant to raw water. Available mixing types are (see Figure 34.10):

a. Machinery mixing,
b. Pump power mixing, and
c. Gravitational force mixing by weir.

Although there are three kinds of the rapid mixing such as mixing by machine, pump or gravity, the mixing by gravity is recommended for the study, taking into account the required future maintenance. Comparison of the mixing types is detailed in Volume V Appendix F32 Comparative Study on Treatment Process.

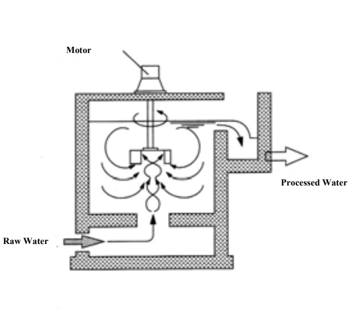
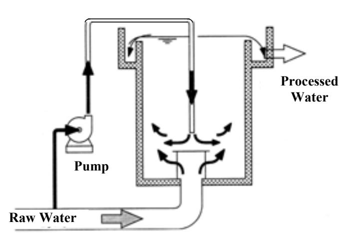
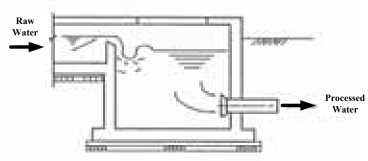
Machinery Mixing	Pump Power Mixing	Gravity Weir Mixing
		

Figure 34.10 Type of Rapid Mixing

Chemicals of chlorine for the oxidations of iron, manganese and ammonia nitrogen, alum as the coagulants and lime for adjusting alkalinity are dosed at the rapid mixer, just before the weir.

(5) Flocculation and Sedimentation (Clarification)

One of the most common water treatment unit processes is sedimentation, also known as clarification. Sedimentation is broadly defined as the separation into a clarified fluid and a more concentrated suspension.

The sedimentation process is designed to remove a majority of the settleable solids by gravitational settling, thereby maximizing efficiency of downstream unit processes such as filtration. Available sedimentation types are (see Figure 34.11):

a. Rectangular type (Horizontal flow),
b. Radial-upflow type (Clariflocculator),
c. Reactor clarifier type, and
d. Sludge blanket clarifier type.

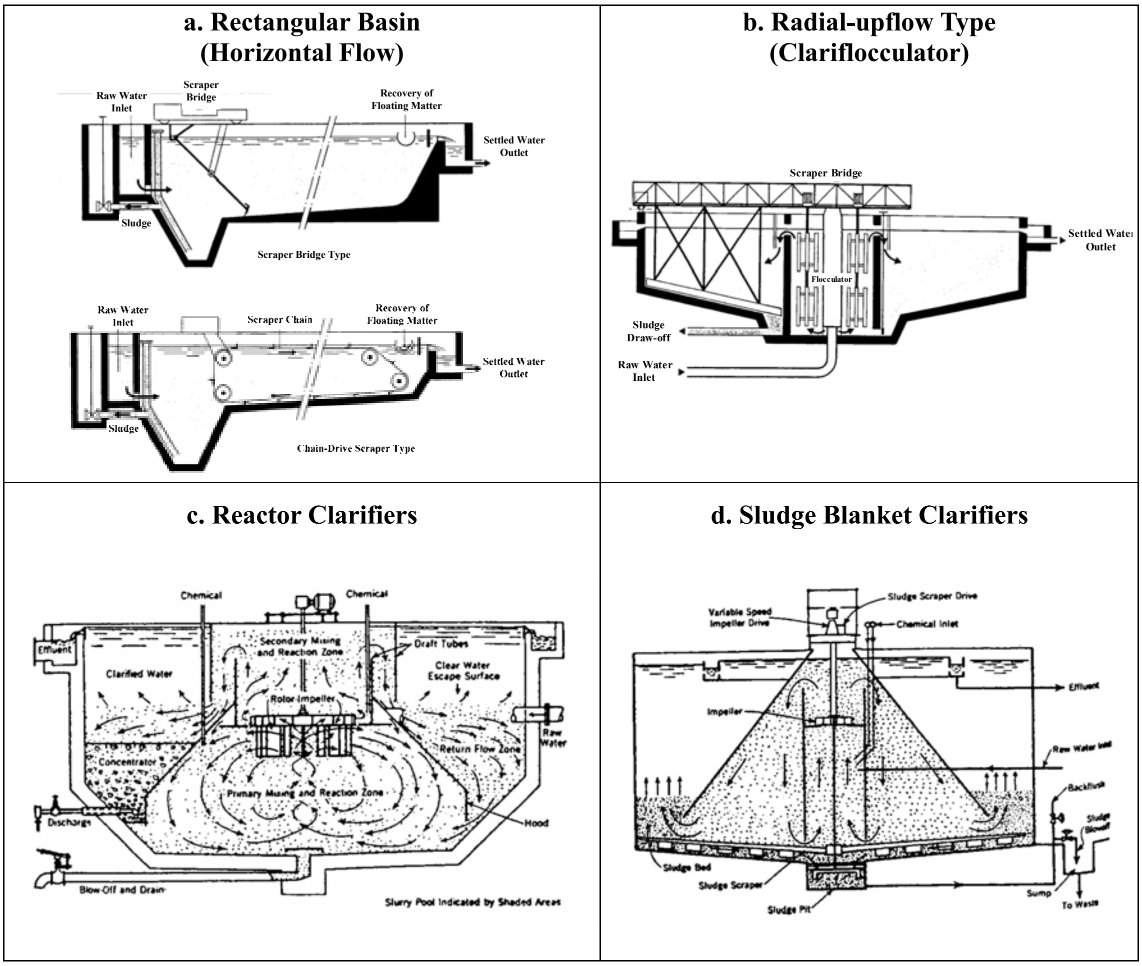


Figure 34.11 Types of Sedimentation

The radial-upflow type (Clariflocculator) for sedimentation basin which is applied for the existing Salaulim WTP is adopted for the proposed sedimentation process. Comparison of sedimentation types is detailed in Volume V Appendix F32 Comparative Study on Treatment Process. If this type was applied to the proposed WTP, it is not necessary to construct flocculation basin separately. This is because this type has a flocculation basin at the centre part of the sedimentation basin as shown in Figure 34.11. PWD staff are familiar to this type, therefore, operation and maintenance will not be difficult for the staff.

(6) Filtration Basin

Rapid sand filtration is the final process to finish and obtain safe and hygienic water; the fundamental objective of waterworks for supplying clean water to the user by improving water quality to the required level. In the process, the fine flocs not removed in the sedimentation basin are removed by passing through a filter medium such as a sand layer; at the same time, the substances inside the flocs might consume the free residual chlorine and make the water non-resistant to the contamination from outside of the distribution pipes as well, as cause secondary affections inside the pipes, are removed. Available rapid sand filtration types are (see Figure 34.12):

a. Air scouring type (existing Salaulim WTP Type),
b. Standard-type,
c. Automatic backwashing type, and
d. Automatic backwashing and air scouring type.

Among these types, the air scouring type (a) and standard-type (b) of rapid sand filtration process requires high levels of technical skills in adjustment of the filtration volume as well as in operational control due to the number of devices used. The automatic backwashing type (c) and the automatic backwashing and air scouring type (d) have the characteristics of easy operation, control, and require less frequent maintenance practice owing to less system devices. The automatic backwashing and air scouring type (d) has the advantages of using less backwashing water. The examination and comparison of these 4 types is shown in Volume V Appendix F32 Comparative Study on Treatment Process in details. In consequence, the automatic backwashing and air scouring type (d) is recommended to be adopted in the proposed process for the filtration.

As mentioned above, manganese is oxidised at the filter basins. For the manganese oxidation at the sand filter, it should be necessary to control the residual chlorine concentration of filtered outlet water 0.5 to 1.0 mg/l. If the manganese removal is going well, the colour of filter sand will change to black colour.

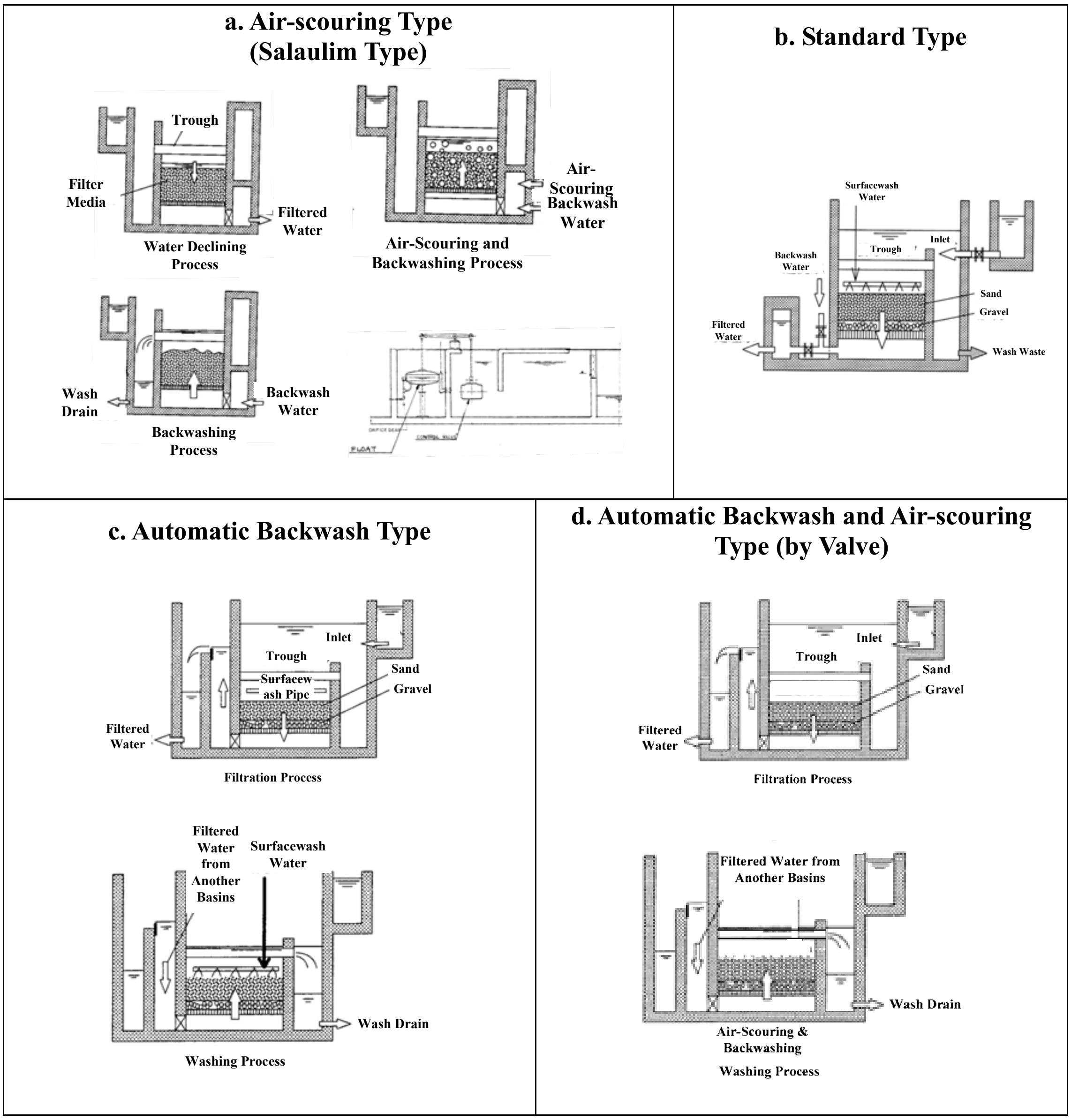


Figure 34.12 Types of Sedimentation

(7) Chemical Feedings

The proposed WTP uses three kinds of chemical i.e. aluminium sulphate (alum), calcium hydroxide (lime) and chlorine. Based on the water quality data, analysis on chemical feeding at the Salaulim WTP is discussed as follows. The chemical feeding plan mentioned hereinafter is only for the preliminary design for expansion of the Salaulim WTP. It is, therefore, recommended that the optimum chemical dosage rates should be found out during the actual operation and maintenance period after the start of operation of the proposed WTP.

1) Raw Water Quality

Features of raw water quality is mentioned in previous sub-section and shown in Table 34.1.

2) Alum (Aluminium Sulphate)

Alum (aluminium sulphate) will be dosed as a coagulant which is applied at the existing WTP. Since correlation with that the dosage rate of aluminium sulphate and raw water turbidity at the existing Salaulim WTP is deficient, it is difficult to calculate the dosage rate of coagulants from the actual records of the Salaulim WTP. Then, alum dosage rates were derived from the general dosage rates referred to "Design Criteria for Waterworks Facilities, Japan Waterworks Association, 2000" for descriptive purposes and are shown in Table 34.3.

Table 34.3 Alum Dosage Rate of Salaulim WTP

	Max	Min	Ave
1. Turbidity（NTU）	28.0	0.4	2.7
2. Alum Dosage Rate (mg/L)	50	5	10

3) Lime (Calcium Hydroxide)

Alkalinity has an effect in pH adjustment and a corrosion prevention. Raw water from the Salaulim Dam Reservoir contains alkalinity of 10-40 mg/L. Residual alkalinity should be about 20 mg/L. Since it consumes alkalinity of 22.5 mg/L ($50 \times 0.45 = 22.5$ mg/L) at the maximum aluminium sulphate (coagulant) dosage, therefore, it is necessary to dose at least the same alkalinity of consumption by coagulation. Lime of 1 mg/L consists of alkalinity of 1.35 mg/L. Therefore the dosage rate of lime is proposed as shown in Table 34.4.

Table 34.4 Lime Dosage Rate of Salaulim WTP

	Max	Min	Ave
Lime Dosage Rate (mg/L)	20	5	10

4) Chlorine

Residual chlorine should be maintained in the treated water. Since chlorine is consumed by substances contained in the raw water and treated water such as ammonia nitrogen, iron, and manganese as mentioned below, dosage rate of the chlorine should be calculated from the concentrations of these substances.

a) Ammonia nitrogen of 1 mg/L consumes chlorine of 7.6 mg/L.
b) Iron of 1 mg/L consumes chlorine of 0.63 mg/L.
c) Manganese of 1 mg/L consumes chlorine of 1.29 mg/L.

The total maximum chlorine consumption therefore will be calculated as follows:

Total chlorine consumed = 1.1 x 7.6mg/L + 0.8 x 0.63 mg/L + 3.6 x 1.29 mg/L
= 13.5 mg/L

In addition the chlorine of 0.5 mg/L is needed for the manganese sand filtration process. The chlorine dosage rates are summarized in Table 34.5.

Table 34.5 Chlorine Dosage Rate of Salaulim WTP

	Max	Min	Ave
Pre-chlorination	15.0	3.0	5.0
Post-chlorination	2.0	0.5	1.0

5) Dosage Points of Chemicals

Dosage points of chemicals are shown in Table 34.6.

Table 34.6 Proposed Chemical Dosage Points

Dosage Point	Alum	Lime	Chlorine
Rapid Mixer, just before the weir	○	○	○
Inlet of Clear Water Reservoir	-	-	○

(8) Clear Water Reservoir

1) Clear Water Reservoir

The capacity of the new clear water reservoir will be 5,000 m^3, which is equivalent to 1.2 hours of the transmission capacity. The clear water reservoir has a role of adjusting the fluctuation of treated water amount and transmission amount then keeping the filtered water constant.

2) Transmission Pumping Building

The reservoirs of Stage I and Stage II will be connected by an interconnection pipe to save space for the transmission pumping building. Therefore the transmission pumping building is proposed to be constructed at the adjacent the clear water reservoir which is constructed at Stage I. The transmission pumping building has a space for the future transmission pumps of Stage II.

3) Transmission Pump Equipment

In order to transmit clear water from the proposed WTP to the proposed Sirvoi MBR, the transmission pumps are planned in consideration of the daily maximum water demand.

The type of distribution pumps to be installed will be a horizontal double suction volute pump (centrifugal pump) which is suited for a relatively large flow rate. This type of pump is the most popular for distribution and transmission pumps of waterworks. The specification of the transmission pumps is 23.2 m^3/min × H 74.0 m × 4 units including one stand-by pump.

(9) Electrical Facilities

The electrical facilities, including the following facilities, will be constructed corresponding with the proposed WTP facilities.

a. power receiving and transformer equipment,
b. power supply equipment,
c. control panels,
d. lightning protection equipment,
e. generator for emergency power during the power failures, and
f. Inter-communication System inside the WTP.

(10) Summary of Preliminary Design of Proposed Salaulim WTP

As the result of the preliminary design of the Salaulim WTP the details of each facility are summarised in the Table 34.7.

Table 34.7 Expansion Work of the Proposed Salaulim WTP

Name of Facility / Equipment		Component of Expansion Work
Intake & Raw Water Transmission Facilities		
Intake Facilities	Intake Structure	RC Structure – 2 Basins Intake Pumping Well : ^{W}8.60 m × ^{L}5.50 m × ^{D}29.00 m Pump House : ^{W}18.00m × ^{L}12.95 m (233.1 m^2) Pump House Floor : RC & Grating
	Intake Pump	Vertical Turbine Selfwater Lubricated Pump : 25.5 m^3/min × 4 Units (1 - Standby)
		Check Valve : D450mm × 4 Units Butterfly Valve : D450 mm Electric Motor-drive × 4 Units
	Inlet Valves & Interconnecting Valves	Inlet Butterfly Valve with Manual Operating Stand : 1st (L.W.L.) - D2,000 mm × 2 Units, 2nd (M.W.L.) - D2,000 mm × 2 Units, 3rd (Opening) - ^{W}2,000 mm × ^{D}1,500 mm × 2 Units Interconnecting Butterfly Valve with Manual Operating Stand : D1,800 mm x 1 Unit
	Crane Equipment	10 ton Electric Motor-drive Chain Hoist Crane × 1 Unit
Raw Water Transmission Facilities	Raw Water Transmission Main	MSP : D1,400 mm
	Flow Meter & Flow Control Valve Facility	Raw Water Flow Meter Chamber & Flow Control Valve Chamber
		Flow Control Valve : D800 mm Tooth-shaped Disk Type Butterfly Valve (Horizontal Type) × 2 Units (Electric Motor-drive Type × 1 Unit, Manual Type × 1 Unit)

Name of Facility / Equipment		Component of Expansion Work
Water Treatment Facilities		
Receiving Well & Connecting Pipe	Receiving Well	RC Structure – 1 Basin, Detention Time = 1.0 min. for 200 MLD Dimension : ^{W}5.60 m × ^{L}5.60 m × ^{D}5.50 m × ${}^{E.D}$5.00 m
	Connecting Pipe ①	MSP : D1,800 mm for 200 MLD MSP : D1,350 mm for 100 MLD
	Connecting Pipe ②	MSP : D1,200 mm of By-Pass Pipe for 200 MLD
Bio-Contact Filtration Facilities & Connecting Pipe	Bio-Contact Filtration Basin	Filtration Type : Automatic Backwash with Air Scouring Type RC Structure - 10 Basins (10 Basins/System) Filtered Area = 52.2 m^2/Basin Dimension : ^{W}4.50 m × ^{L}11.60 m Filtration Rate : 210.7 m/d
		Back Wash Rate = 0.50 $m^3/min/m^2$ Air Scouring Rate = 1.00 $m^3/min/m^2$
		Filter Media : Effective Size = 6.0 mm Depth of Media = 1.50 m
		Under drain System : Strainer with Air Distribution Type
	Operating Valves for Filtration	Inlet Valve : D600 mm Electric Motor-drive Type Butterfly Valve × 10 Units (1 Unit/Basin)
		Filtered (Back Wash) Valve : D600 mm Electric Motor-drive Type Butterfly Valve × 10 Units (1 Unit/Basin)
		Air Scouring Valve : D300 mm Electric Motor-drive Type Butterfly Valve × 10 Units (1 Unit/Basin)
		Wash Drain Valve : D800 mm Electric Motor-drive Type Butterfly Valve × 10 Units (1 Unit/Basin)
	Air Scouring Equipment	Air Blower : 26.1 m^3/min × 3 Units (1-Stand-by)
		Flow Meter : D250mm Orifice-type × 1 Unit
	Connecting Pipe ③	MSP : D1,800 mm for 200 MLD MSP : D1,350 mm for 100 MLD
Mixing Chamber & Distribution Chamber	Mixing Chamber	Mixing Type : Gravitational Force Mixing by Weir Type RC Structure - 1 Basin, Detention Time = 1.0 min. Dimension : ^{W}4.00 m × ^{L}4.00 m × ^{D}5.50 m × ${}^{E.D}$5.00 m
	Distribution Chamber	Distribution Method : By Weir Type RC Structure - 1 Basin, Dimension : ${}^{Dia.}$3.50 m ×^{D}7.70 m × ${}^{E.D}$7.00 m
	Collecting Chamber	RC Structure - 1 Basin Dimension : ${}^{Dia.}$6.50 m ×^{D}2.20 m × ${}^{E.D}$1.30 m
Flocculation & Sedimentation Facilities (Clariflocculator)	Flocculation Basin	Flocculation Type : Paddle Wheel on Vertical Shaft Type RC Structure - 4 Basins, Detention Time = 20.0 min. Dimension : ${}^{Dia.}$10.40 m × ^{D}5.00 m × ${}^{E.D}$4.50 m
	Sedimentation Basin	Sedimentation Type : Radial-upflow Type – Clariflocculator RC Structure, 4 Basins, Detention Time = 2.01 hr Dimension : ${}^{Dia.}$31.40 m × ^{D}4.00 m ×${}^{E.D}$3.50 m
	Connecting Pipe ④	MSP : D900 mm for 50 MLD MSP : D1,350 mm for 100 MLD
Filtration Facilities	Rapid Sand Filtration Basin	Filtration Type : Automatic Backwash with Air Scouring Type RC Structure - 20 Basins (10 Basins/System) Filtered Area = 40.50 m^2/Basin Dimension : ^{W}4.50 m × ^{L}9.00 m Filtration Rate : 135.8 m/d
		Back Wash Rate = 0.65 $m^3/min/m^2$ Air Scouring Rate = 1.00 $m^3/min/m^2$
		Sand : Effective Size = 0.7 mm、 Depth of Sand = 0.70 m
		Under drain System : Strainer with Air Distribution Type
	Operating Valves for Filtration	Inlet Valve : D400 mm Electric Motor-drive Type Butterfly Valve × 20 Units (1 Unit/Basin)
		Filtered (Back Wash) Valve : D600 mm Electric Motor-drive Type Butterfly Valve × 20 Units (1 Unit/Basin)
		Air Scouring Valve : D250 mm Electric Motor-drive Type Butterfly Valve × 20 Units (1 Unit/Basin)
		Wash Drain Valve : D800 mm Electric Motor-drive Type Butterfly Valve × 10 Units (1 Unit/Basin)
	Air Scouring Equipment	Air Blower : 20.3 m^3/min × 3 Units (1-Stand-by)
		Flow Meter : D250mm Orifice-type × 1 Unit
	Connecting Pipe ⑤	MSP : D1,800 mm for 200 MLD MSP : D1,350 mm for 100 MLD MSP : D900 mm for 50 MLD

Name of Facility / Equipment		Component of Expansion Work
Transmission Facility	Clear Water Reservoir	RC Structure、Effective Capacity = 4,800 m^3, Detention Time = 1.15 hr. Dimension : Reservoir - ^{W}2.0 m × ^{L}30.0 m × ^{D}4.85 m × $^{E.D}$4.0 m × 2 Basins Pumping Well - ^{W}30.0 m × ^{L}5.0 m × ^{D}6.85 m × $^{E.D}$4.0 m × 1 Basin
		Inlet Valve : D1,350 mm Butterfly Valve with Manual Operating Stand x 2 Units
		Connecting Valve : D1,350 mm Butterfly Valve with Manual Operating Stand x 3 Units
		Over-flow Pipe : D1,000mm
		Ventilation Device : 1 Lot
	Transmission Pump Building	RC Structure, Building Area = 400 m^2 Dimension : ^{W}40.0 m × ^{L}10.0 m
	Transmission Pumping Equipment	Distribution Pump : Horizontal Double Suction Volute Pump D400mm x D250 mm × 23.2 m^3/min × 4 Units (1 - Standby)
		Foot Valve : D400 mm × 4 Units Suction Valve : D400 mm Butterfly Valve (Manual Operate) × 4 Units
		Check Valve : D250 mm Unti-water-hummer Type Check Valve × 4 Units Delivery Valve : D250 mm Electric Motor-drive Type Butterfly Valve (Horizontal Type) × 4 Units
	Crane Equipment	10 ton Electric Motor-drive Chain Hoist Crane × 1 Unit
	Flow Meter & Flow Control Valve Facility	Transmission Flow Meter Chamber & Flow Control Valve Chamber
		Flow Control Valve : D1,200 mm Tooth-shaped Disk Type Electric Motor-drive Type Butterfly Valve (Horizontal Type) × 1 Unit
	Transmission Pipe	MSP : D1,400 mm
Chemical Feeding Facilities	Chemical Feeding Room	Located in the 2nd Floor of the Administration Building except the Chlorine Gas Feeding Equipment Crane Equipment : 1 ton Electric Motor-drive Chain Hoist Crane (Traversing, Traveling, Hoisting) × 1 Unit
	Aluminum Sulfate Feeding Equipment	Solution Tank : RC Structure - 4 Tanks
		Mixer : D500 mm Vertical Suspended Type × 4 Units
		Feeding Machine : 2 Units
	Lime Feeding Equipment	Solution Tank : RC Structure - 3 Tanks
		Mixer : D500 mm Vertical Suspended Type × 3 Units
		Feeding Machine : 2 Units
	Chlorine Storage Room & Chlorine Feeding Equipment	Chlorine Storage Room : Crane Equipment : 5 ton Electric Motor-drive Chain Hoist Crane × 1 Unit
		Liquid Chlorine System : Load Cell & Platform, Evaporator, Vacuum Regulating Check & Shut-Off Unit Chlorine Feeder (Injector, Rotormeter) : 5 Units (3 Units for Pre-Cl, 2 Units for Post-Cl)
		Neutralization Equipment : Intake & Suction Duct, Ejector – Venturi Scrubber, Separation Tank & Caustic Soda Solution Storage, Paoked Tower
		Safty Measures : Proveided Eye Wash, Shower, and Gas Masks of Canister Type
Electrical Facilities	Power Receiving & Transformer Equipment	Power Receiving Equipment Power Transformer
		Electric Power Generator
	Power Supply Equipment	Power Receiving Panel、Power Supply Panel & Auxiliary Power Supply Panel for Intake Pump (Located in Intake Pump House)
		Power Supply Panel for Filter's Operation Equipment (Locate in Transmission Pump Building)
		Power Receiving Panel、Power Supply Panel、Auxiliary Power Supply Panel & Local Panel for Transmission Pump
		Power Supply Panel for Chemical Feeding Facilities (Located in Transmission Pump Building)
	Control Panel	Control Panel for Raw Water Flow Rate & Transmission Flow Rate
		Control Panel for Filter's Operation (Located in Filter's Operation Gallery)
		Control Panel for Chemical Feeding Facilities (Located in Chemical Feeding Room)
	Air Conditioning Facilities	Installation of Air Conditioning Facilities (Located in Electrical Room of Transmission Pump Building and Administration Building)
	Lightning Protection Equipment	Lightning Rod Equipment (Located in Raw Water Intake House、Filtration Gallery、Administration Building、Transmission Building)
	Inter-communication System inside the Treatment Plant	Intercommunication Equipment (Located in Raw Water Intake House、Filter's Operation Gallery、Transmission Pump Building、Administration Building)

Name of Facility / Equipment		Component of Expansion Work
Instrumentation Facilities	Instrumentation Equipment	Central Supervising Panel & Instrumentation Panel including Existing (Located in Operation Room of Administration Building)
		Raw Water Level Meter : Ultrasonic Type - Water Level for Raw Water Intake Pumping Well
		Raw Water Flow Meter : Ultrasonic Type
		Total Filtered Flow Meter : Suppressed Rectangular Weir – Float Type
		Filtration Resistance Meter : Electronic Type
		Clear Water Reservoir Level Meter : Ultrasonic Type
		Transmission Line Piesometer : Electronic Type
		Transmission Flow Meter : Ultrasonic Type
		Chemical Solution Tank Level Meter : Electrode Type
Administration Building		RC Structure、Floor Area = 213 m^2 × 3 F (Dimension : ^{W}19.80 m × ^{L}10.78 m × 3 F)、Management office, Laboratory, Control Room & Chemical Feeding Facilities
Laboratory		Located in Administration Building
		Water Quality Analysis Equipment & Reagent
Landscaping and Others		Site Preparation, Embankment, Roads, Lighting, Gate & Fence, others

(11) General Layout of the Plant

The location of the proposed WTP is shown on Figure 34.13. This location was selected based on land availability in consultation with the PWD.

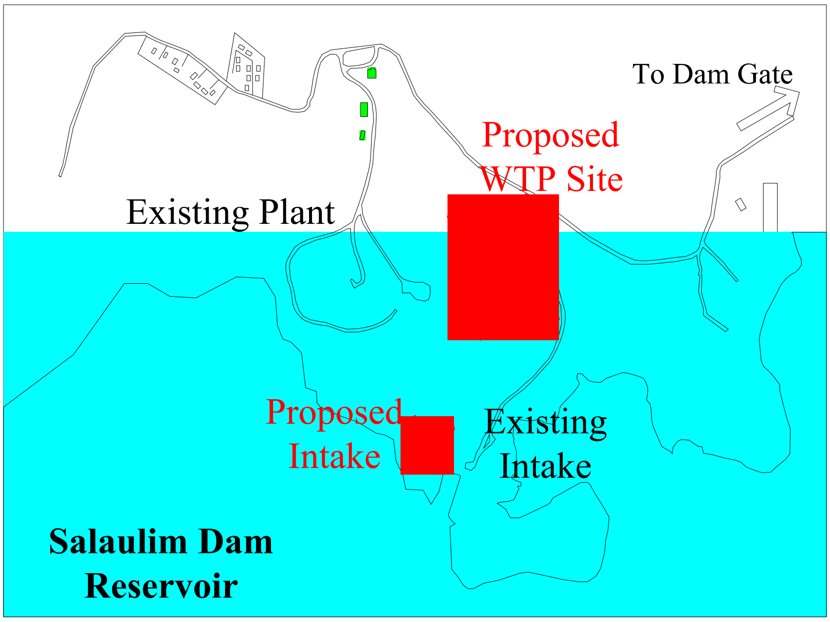


Figure 34.13 Proposed Site for the New Salaulim WTP

In order to ensure effective utilization of limited resources, the rain water harvesting is recommended to be adopted at the proposed WTP site. The rain water is collected by the drainage system and pumped to the receiving well for reuse.

The general layout plan of the proposed WTP is shown in Figure 34.14.

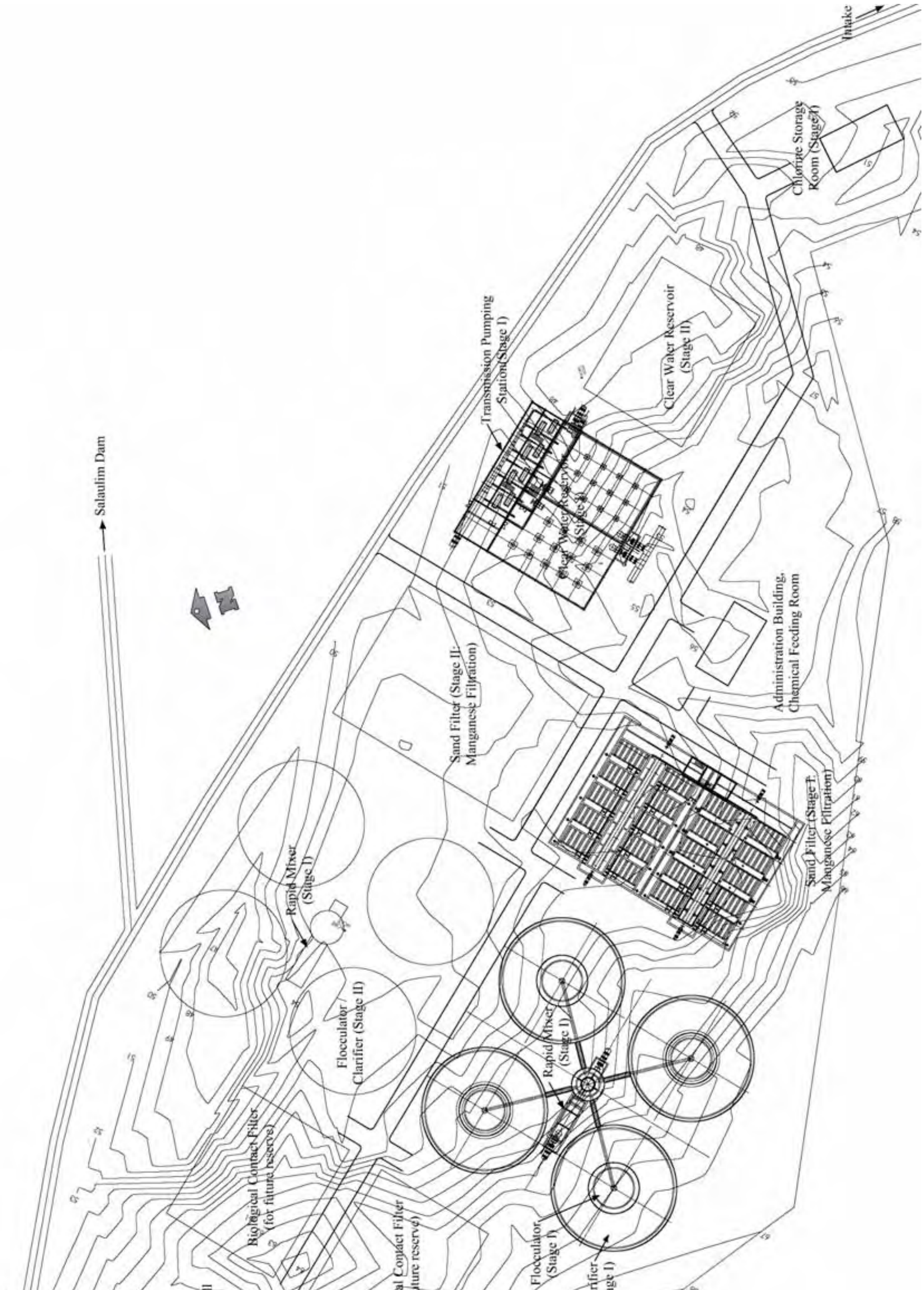


Figure 34.14 General Layout Plan of Proposed WTP

3.4.2 Transmission System and Reservoirs

(1) Network Analysis

1) Conditions of Network Analysis

Methods of the network analysis for the Stage I project in the target year of 2018 including the priority projects are detailed in previous section, Section 3.2 Design Conditions. The network analysis has been conducted using WaterCAD. Conditions of the network analysis are summarised as follows:

a. Formula for friction loss calculation	: Hazen-Williams Formula
b. C value for all pipes	: 110
c. Hourly peak factor	: 2.0

Hourly peak factor for domestic demand is estimated at 2.0. On the other hand the non-domestic demand is assumed to be 1.0.

2) Results of Network Analysis

The results of the network analysis are summarised in Volume V Appendix F34 Results of Hydraulic Analysis for Salaulim Scheme. It is, however, noted that the proposed transmission pipelines are not the appropriate development of the water supply system in 2018. The PWD should develop the distribution network systems.

It should be noted that since there is no recorded data or drawings of the existing transmission systems or details of the reservoirs, the modelling for the hydraulic analysis was prepared based on information obtained through interviews with the PWD's engineers, for the following system components:

- routes, materials and diameters of transmission mains; and
- locations, capacities and water level of reservoirs.

The proposed transmission system from the proposed Salaulim WTP to Verna MBR via Sirvoi MBR with the existing transmission system is schematically shown in Figure 34.15.

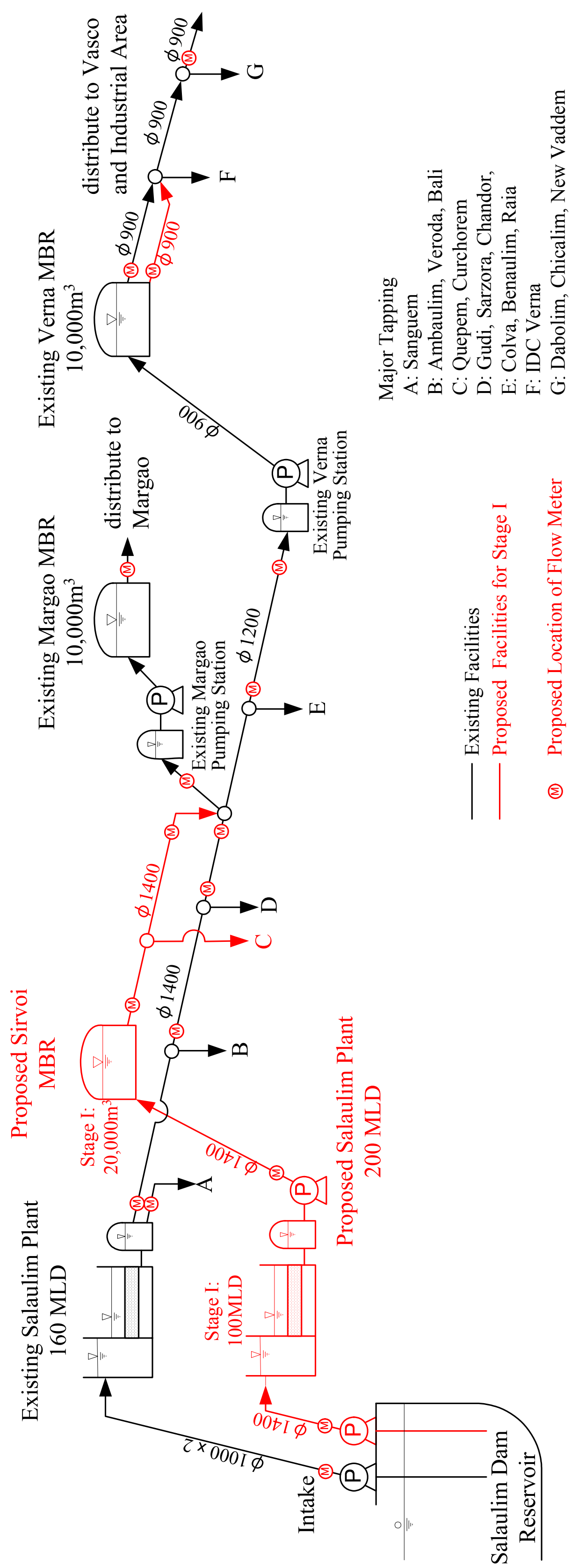


Figure 34.15 Schematic Diagram of Proposed Transmission System

(2) Proposed Transmission Mains

1) Material Selection

Given the important role of the transmission mains, the strength and durability of pipes are among the first factors to be considered. To achieve these requirements, pipes made from, Ductile Cast Iron (DI) Pipe or Mild Steel (MS) Pipe will be selected as the pipe materials for the transmission mains. For pipelines used for distribution system and which have a diameter of less than 300 mm, it is proposed to use Polyvinyl Chloride (PVC) Pipe.

The study recommends DI pipe for transmission pipelines of diameters less than 1,000 mm and MS pipe for diameter more than 1,000 mm because of the experience of the PWD and the availability of materials in India.

2) Installation of Transmission Mains

To transmit the treated water from the proposed Salaulim Plant to the existing and proposed reservoirs, via the Sirvoi master balancing reservoir, transmission mains (as listed in Table 34.8) need to be installed as shown in Figure 34.16.

Table 34.8 Proposed Transmission Mains for the Priority Projects

Material	Diameter (mm)	Length (km)
Mild Steel	1,400	26.70
Ductile Iron	900	0.85
	450	2.70
	400	3.90
	300	2.90
	250	8.80
	200	14.30
	150	13.50
Total		73.65

The proposed transmission main of diameter of 1,400 mm from the proposed Salaulim WTP to Margao which total length is 26.7 km will be mainly installed along the existing transmission main within the PWD property as shown in a right photo. Other transmission mains will be installed under the public road or road edge.

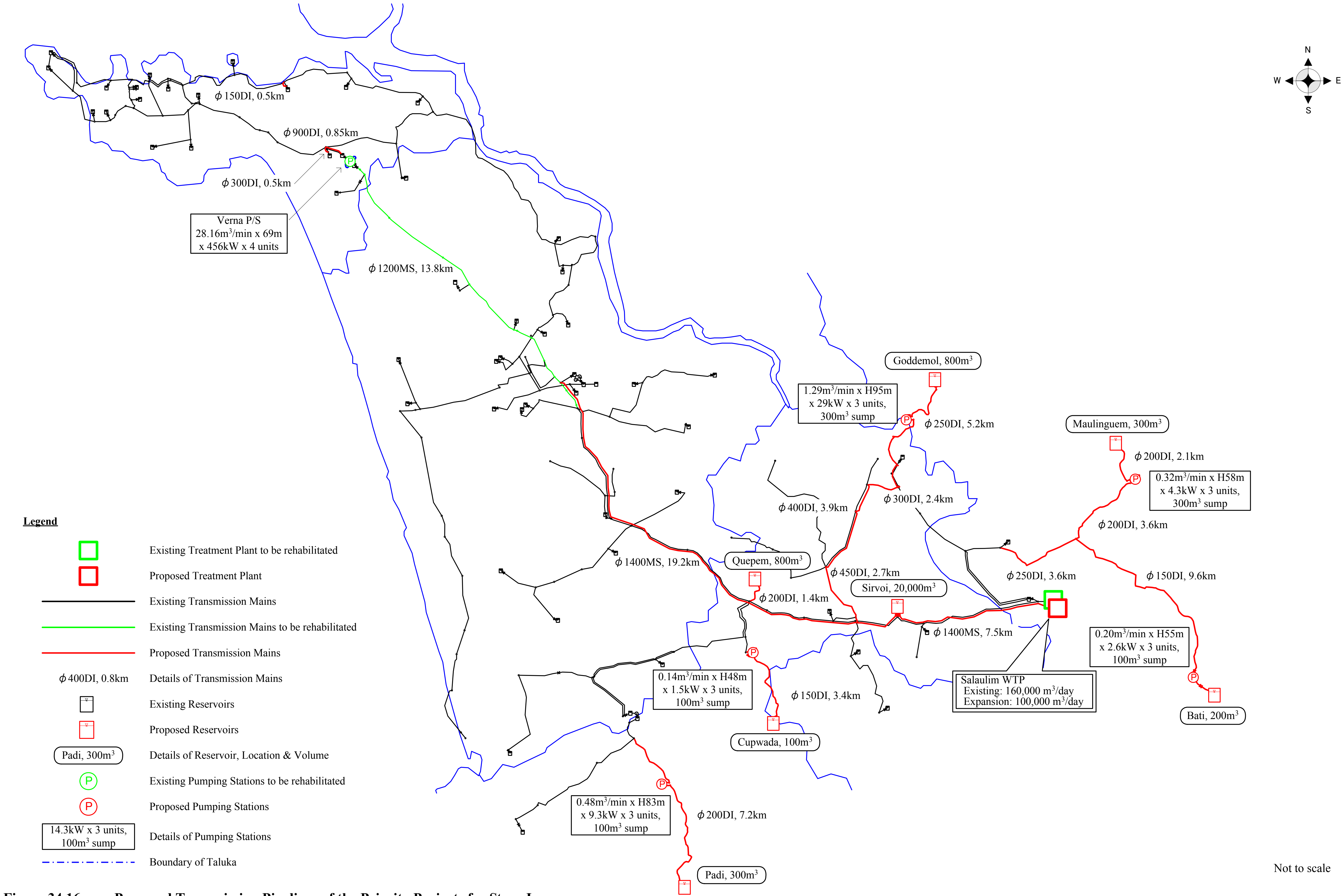


Figure 34.16 Proposed Transmission Pipelines of the Priority Projects for Stage I

(3) Proposed Reservoirs

1) Master Balancing Reservoir at Sirvoi

Since the proposed treatment plant is located at lower level of the existing plant, a pumping is required to transmit the treated water to a high altitude reservoir which is a master balancing reservoir and then from the master balancing reservoir the water will be transmitted and distributed to respective distribution reservoirs or service areas under gravity flow. The existing total storage capacity of the reservoirs of the Salaulim WSS are 72,000 m^3 which is equivalent to retention time of 10.8 hours.

Construction of a master balancing reservoir (MBR) of 20,000 m^3 at Sirvoi is proposed for adjusting the transmission amount from the proposed Salaulim WTP and the transmission amount from the MBR and securing the total retention time of reservoirs at least for 8 hours. Figure 34.17 shows the general layout plan for Sirvoi MBR.

In order to ensure effective utilization of limited resources, the rain water harvesting is recommended to be adopted at the proposed MBR and other reservoirs. The rain water is collected at the roof of the reservoir and utilised for plantation and cleaning water.

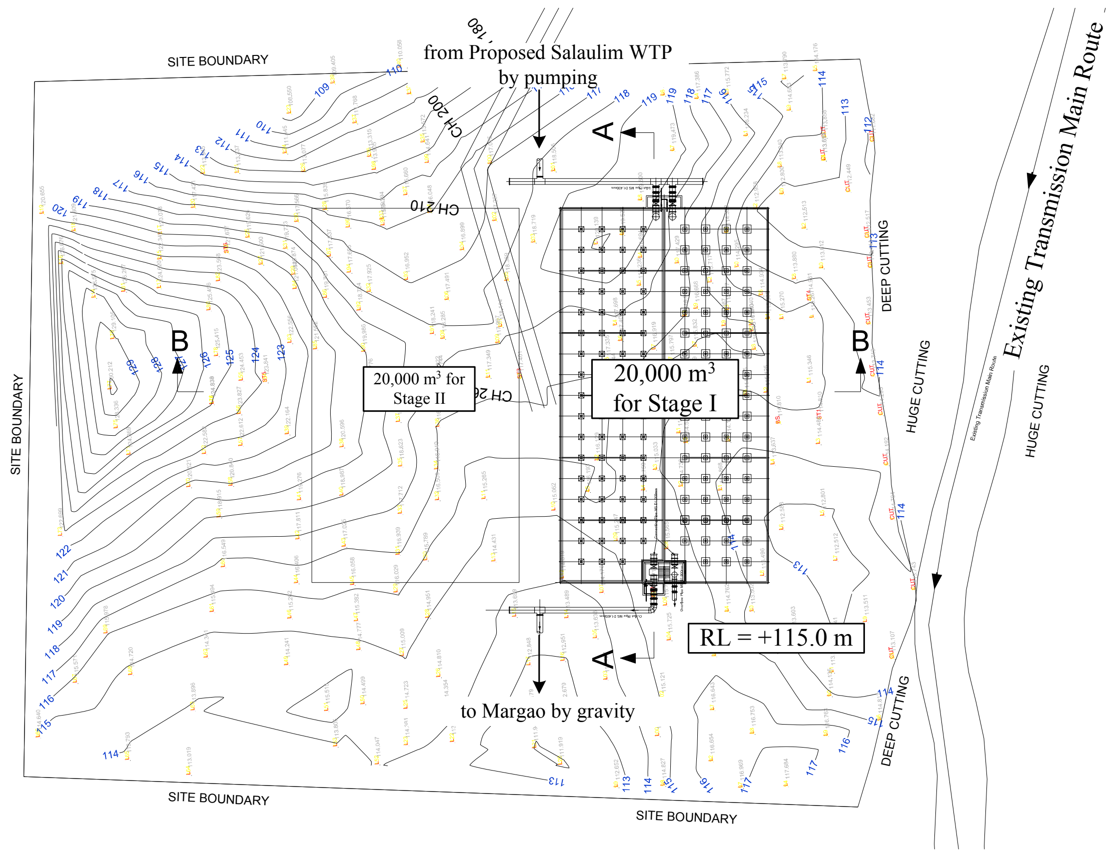


Figure 34.17 General Layout Plan of Proposed Sirvoi MBR

2) Other Reservoirs

It is proposed to construct the six reservoirs (excluding the Sirvoi MBR) listed in Table 34.9 to supply the treated water to the expanded service area and shown in Figure 34.16. The capacities of the reservoirs were decided based on the hourly peak demand.

Table 34.9 List of Proposed Reservoirs for the Priority Projects

Location	Capacity (m^3)	Remarks
Bati, Sanguem	200	with P/S (3 pump units of 2.6 kW and 100 m^3 sump)
Maulinguem, Sanguem	300	with P/S (3 pump units of 4.3 kW and 300 m^3 sump)
Guddemol, Sanguem	800	with P/S (3 pump units of 29 kW and 300 m^3 sump)
Padi, Quepem	300	with P/S (3 pump units of 9.3 kW and 100 m^3 sump)
Cupwada, Quepem	100	with P/S (3 pump units of 1.5 kW and 100 m^3 sump)
Quepem MCI, Quepem	800	-

(4) Pumping Stations

The constructions of five pumping stations are proposed as the priority projects in order to pump transmitted water into the proposed reservoirs as listed in Table 34.9 and shown in Figure 34.16. Detailed specifications are listed in Table 34.10.

Table 34.10 List of Proposed Pumping Stations for the Priority Projects

Location	Specifications	sump
Bati, Sanguem	0.20 m^3/min x H55m x 2.6 kW x 3 units	100 m^3
Maulinguem, Sanguem	0.32 m^3/min x H58m x 4.3 kW x 3 units	300 m^3
Guddemol, Sanguem	1.29 m^3/min x H95m x 29 kW x 3 units	300 m^3
Padi, Quepem	0.48 m^3/min x H83m x 9.3 kW x 3 units	100 m^3
Cupwada, Quepem	0.14 m^3/min x H48m x 1.5 kW x 3 units	100 m^3

3.4.3 Distribution System and House Connection

The proposed length of distribution pipelines were calculated by multiplying the number of house connections to be installed (which reflects the increase in population served) by the unit pipeline length per connection (which is 14.26m as mentioned in section 3.2). Table 34.11 shows the proposed number of house connections and length of distribution pipelines during the Stage I from the year 2007 until the year 2018. For the financial analysis stated in Chapter 9 of this volume, however, the costs for the installation of distribution pipelines and house connections will be disbursed from the year 2012 which is the completion year of the proposed

Salaulim WTP.

Table 34.11 Proposed Number of House Connections and Length of Distribution Pipelines for the Salaulim WSS in Stage I (incremental basis)

Year	2007	2008	2009	2010	2011	2012	2013
Distribution Pipeline (m)	41,242	42,032	42,790	43,602	44,267	45,138	46,011
Number of House Connection	2,892	2,948	3,001	3,058	3,104	3,165	3,227
Year	2014	2015	2016	2017	2018	Total of Stage I	
Distribution Pipeline (m)	46,943	47,866	48,781	49,763	52,211	550,646	
Number of House Connection	3,292	3,357	3,421	3,490	3,947	38,901	

It should be noted that since the preliminary design for the priority projects as shown in Figure 34.16 cover only transmission pipelines upto the reservoirs, the PWD should make a plan on distribution systems from the reservoirs depending of the expansion of the service area for the Salaulim WSS and install the distribution pipelines and house connections every year as shown in Table 34.12 as its routine works. Especially, the PWD should develop the distribution networks carefully in Quepem and Sanguem Taluka in order to shift from the rural water supply schemes to the Salaulim WSS, because at present there are many rural water schemes in Quepem and Sanguem Taluka as listed in Volume IV Appendix M31.8 Rural Water Supply Scheme and the PWD has little information on the strategy of transition to the regional WSS unlike with Pernem, Satari and Canancona Talukas which have also many rural water supply schemes.

3.5 Rehabilitation Works

3.5.1 Rehabilitation of the Existing Salaulim WTP

(1) Purpose of the Rehabilitation Works

The Salaulim WTP was constructed in 1989 with a production capacity of 160,000 m^3/day and is the sole WTP of Salaulim WSS. Therefore deterioration of facilities and equipment have become a significant problem for stable operation of the plant and water supply to the service area. The equipment and facilities in the Salaulim WTP are used for almost 20 years.

According to the site investigations during the study period, the equipment and facilities in the WTP have not been maintained proactively and operated based on written operation and maintenance manual. Therefore, the equipment and facilities have been deteriorated, some equipment are not able to operate properly, and many leaks have been found at piping systems. The conditions of the existing equipment and facilities are summarised in following subsection and attached to Volume V Appendix F31 Components of Expansion and Rehabilitation Works in Salaulim WTP.

In order to secure water supply to the existing service area from the Salaulim WTP, it has been judged that the rehabilitation works for the Salaulim WTP is indispensable and selected as a priority project. The rehabilitation works of the existing Salaulim WTP consist of the rehabilitation and improvement of:

- Raw water intake facility including replacement of pumps, motors and electrical equipment and installation of water level meters in pump suction well.
- Substation facility including replacement of transformers and electrical equipment and installation of a diesel generator.
- Replacement of valves and flow meters of raw water transmission mains
- Treatment facilities including replacement of flush mixers, flocculators, filter sand, backwash pumps and motors, air blowers, filter operation valves and pipings, flow meters, water level meters in the reservoir, electrical equipment and installation of UPS for instrumentation.
- Chemical feeding facilities including replacement of feeding equipment, repair of chemical storage tanks and improvement of safety equipment.
- Transmission facilities including replacement of the flow meter.
- Laboratory facilities including improvement of testing equipment.
- Other repairs such as leakages etc.

It should be reminded that the study recommends not only the rehabilitation of the existing WTP but also the improvement of operation and maintenance and institutional and capacity building. Improvement of water supply services will never achieved without such operation and maintenance aspects.

(2) Components of Rehabilitation Works for the Existing Salaulim WTP

Based on the site investigation for facilities and equipment of the existing Salaulim WTP, the proposed components for rehabilitation and improvement works are listed in Table 35.1.

Table 35.1 Components of Rehabilitation and Improvement Works of the Existing Salaulim WTP

Name of Facility / Equipment		Component of Existing	Component of Rehabilitation Work	
Intake Facilities	Civil & Archtechtural Structures	• Open Channel : 1-Channel Width 3.0 m × Height 29.0 m ×Length 210 m • Box Culvert : RC Structure Width 2.0 m × Height 2.0 m ×Length 195 m • Pump Well (Wet Well) : RC Structure, Area = 200 m^2, Width 9.4 m × Height 28.7 m ×Length 11.4 m • Pump House & Control Room : RC Structure	Reuse	—
	Raw Water Pump & Motor	• Vertical Turbine Selfwater Lubricated Pump : 19.685 m^3/min × 94.559 m × 410 kW × 8 Units (2-Standby) • One System : 4 Pumps (1-Standby)	Replace	• The Same Specifications of the Existing
		• Check Valve × 8 Units • Gate Valve with Motor-Drive × 8 Units	Replace	• The Same Specifi-cations of the Existing
	Inlet Gate	• □1.60 m × 1.25 m × 3 Units × 2 Stage	Reuse	—
	Crane Equipment	• 10 Ton Semi-Electric Operated Travelling Crane × 1 Unit	Reuse	—
	Level Meter	• Not Provided	Improve	• Float Type
	Electrical Equipment	• Incommers Panel : 3 Units, • Motor Control Panel : 8 Units • Bus Coupler : 3 Units • L.T. Panel : 1 Unit • Capacitors : 8 Units	Replace	• The Same Specifications of the Existing
Power Substation	Transformer	• Outdoor Type : 33 kV / 3.3 kV – 2,000 kVA × 3 Units • Outdoor Type : 33 kV / 440 V – 250 kVA × 1 Unit • Outdoor Type : 33 kV / 440 V – 160 kVA × 1 Uni	Replace	• The Same Specifications of the Existing
	Electrical Equipment	• Outdoor Vaccuum Circuit Breaker : 3 Units • Current Transformer : 6 Units • Potencial Transformer : 6 Units • Lighting Arrester : 5 Units • Battery Charger : • Oil Filtration Plant : 1 Unit	Replace	• The Same Specifications of the Existing

Name of Facility / Equipment		Component of Existing	Component of Rehabilitation Work	
Raw Water Transmission Facilities (Rising Main)	Raw Water Transmission Main	• MS Pipe with Gunniting : D1,000 mm × 450 m × 1 Line • MS Pipe with Gunniting : D1,000 mm × 550 m × 1 Line	Reuse	—
	By-Pass Pipe & Valve	• Not Provided	Improve	• By-Pass pipe : D1,000 • By-Pass Valve : D1,000 mm × 2 Units
	Zero Valve	• D1,000 mm × 2 Units (1 Unit / System)	Replace	• The Same Specifi-cations of the Existing
	Air Chamber	• 2 Units (1 Unit / System)	Remove	—
	Flow Meter	• Electromagnetic Type: 2 Units (1 Unit / System)	Replace	• Ultrasonic Type : 2 Units (1 Unit / System)
	Flow Control Valve	• Not Provided	Improve	• D1,000 mm × Butterfly Valve with Motor-Drive Type × 2 Units (1 Unit / System))
Aerator & Mixing Facilities	Aerator	• RC Structure • 2 Basins (1 Basin / System)、Diameter = 5.5 m	Reuse	—
	Parshal Flume	• RC Structure、2 Basins (1 Basin / System)、	Reuse	—
	Flow Meter	• Flow Meter : 2 Units (1 Basin / System) – Not Working	Replace	• The Same Specifi-cations of the Existing
	Mixing Chamber	• RC Structure、4 Basins (2 Basins / System)、 • Inlet Gate : Steel Fabricate - 4 Units (2 Units / System)	Reuse	—
	Flash Mixer	• Vertical Suspended Type : 4 Units (2 Units / System)	Replace	• The Same Specifi-cations of the Existing
	By-Pass Channel	• RC Structure、2 Units (1 Unit / System)、	Reuse	—
	By-Pass Gate	• MS Fabricate、2 Units (1 Unit / System)、	Replace	• The Same Specifi-cations of the Existing
Flocculation & Sedimentation Facilities	Clariflocculator	• RC Structure、4 Basins (2 Basins / System)、 - Overall Diameter = 40.0 m • Flocculation Zone : Vertical Flocculator Type、 - Diameter = 17.6 m - Detention Time = 28.8 min. • Sedimentation Zone : Inclined Up-Flow Type - Diameter = 17.6 m ～ 40.0 m • Detention Time = 2.0 hrs.	Reuse	—
	Inlet Pipe	• D1,000 mm HP × 4 Lines (2 Lines / System)	Reuse	—
	Desludging Equipment	• Desludgeing Pipe : D300 mm × 4 Lines (2 Lines / System)	Reuse	—
	Flocculator	• MS Fabricate、 • Peripheral Type : 1.5 kW × 750 rpm × 4 Units / Basin	Replace	• The Same Specifi-cations of the Existing
	Drive Arrangement of Bridge	• MS Fabricate • 1.5 kW × 750 rpm × 4 Units	Replace	• The Same Specifi-cations of the Existing
	Outlet Channel	• RC Structure、2 Units (1 Unit / System)	Reuse	—
	By-Pass Gate	• MS Fabricate、4 Units (2 Units / System)	Replace	• The Same Specifi-cations of the Existing

Name of Facility / Equipment		Component of Existing	Component of Rehabilitation Work	
Filtration Facilities	Rapid Sand Filtration basin	• RC Structure、12 Basins (2 Cells / Unit) • Filtration Type : Rapid Sand Filtration – Air Scouring Wash & Backwash Water System、 • Filtered Area = 63.78 m^2/Basin (Dimension : Width 6.70 m × Length 9.52 m), 2 Cells / Basin • Filtration Rate = 213.2 m/d	Reuse	—
	Washing Rate	• Backwash Rate = 0.50 m^3/min/m^2 (per 1 Cell) • Air Scouring Rate = 0.85 m^3/min/m^2 (per 1 Cell)		—
	Under Drain System	• Under Drain System : D100 mm × CIP Laterals Type - Grit : Size 2.5 mm ～ 6.0 mm × Depth 175 mm - Gravel : Size 6 mm ～ 12 mm × Depth 100 mm - Gravel : Size 12 mm ～ 38 mm × Depth 100 mm - Pebble : Size 38 mm ～ 50 mm × Depth 150 mm	Replace	• The Same Specifications of the Existing
	Filter Sand	• Effective Size of Sand = 0.70 mm、 • Depth of Sand ＝0.835 m	Replace	• The Same Specifi-cations of the Existing
	Wash Water Troughs	• Width 0.38 m × Depth 0.38 m × Length 3.35 m × 8 Units / Basin	Reuse	—
	Operating Valves & Piping	• Inlet Gate : D600 mm Sluice Gate with Air-Pneumatic Operating Stand × 12 Units (1 Unit / Basin)	Replace	• The Same Specifications of the Existing
		• Filtered Water Valve : D300 mm Sluice Valve with Air-Pneumatic Operating Stand × 24 Units (2 Units / Basin)	Replace	• The Same Specifications of the Existing
	Operating Valves & Piping	• Wash Water Drain Gate : D400 mm Sluice Gate with Air-Pneumatic Operating Stand × 12 Units (1 Unit / Basin)	Replace	• The Same Specifications of the Existing
		• Back Wash Valve : D300 mm Sluice Valve with Air-Pneumatic Operating Stand × 24 Units (2 Units / Basin)	Replace	• The Same Specifications of the Existing
		• Air Scouring Wash Valve : D150 mm Sluice Valve with Air-Pneumatic Operating Stand × 24 Units (2 Units / Basin)	Replace	• The Same Specifications of the Existing
		• Control Valve Set : D400 mm Control Valve with Controller Float (D760 mm) × 12 Units (1 Unit / Basin)	Replace	• The Same Specifications of the Existing
		• Drain Valve : D80 mm Sluice Valve with Manual Operating Stand × 12 Units (1 Unit / Basin)	Replace	• The Same Specifi-cations of the Existing
Back Washing Equipment	Back Wash Pumping Equipment	• Backwash Pump : Vertical Turbine Selfwater Lubricated Pump 7.92 m^3/min × 17.1 m × 28.2 kW × 4 Units (1-Standby)	Replace	• The Same Specifications of the Existing
	Back Wash Pump Sump	• Capacity = 40 m^3	Reuse	—
	Backwash Flow Control Valve	• Not Provided	Improve	• Flow Control Valve : D400 mm Air-Pneumatic Operate Butterfly Valve × 1 Unit
	Back Wash Flow Meter	• Not Provided	Improve	• D400 mm Orifice Type × 1 Unit

Name of Facility / Equipment		Component of Existing	Component of Rehabilitation Work	
Air Scouring Equipment	Air Blower	• Air Blower : Roots-type 13.6 m^3/min × 3,500 mmWG × 37 kW × 3 Units (1-Stand-by)	Replace	• The Same Specifi-cations of the Existing
	Air Scouring Flow Meter	• Not Provided	Improve	• D150 mm Orifice Type × 1 Unit
	Air Scouring Flow Control Valve	• Not Provided	Improve	• Utilizing D150 mm Air Scouring Valve × 12 Units
Transmission Facilities	Filtered Water Outlet Channel	• RC Structure、2 Lines - 1 Line for Clear Water Reservoir (1) - 1 Line for Clear Water Reservoir (2)	Reuse	―
	Parshal Flume & Flow Meter	• RC Structure、1 Basin for Filtered Water Channel (1)	Reuse	―
		• Flow Meter for Filtered Water Channel (1) : 1 Unit - Not Working	Replace	• The Same Specifi-cations of the Existing
	Clear Water Reservoir	• RC Structure、2 Basins • Effective Capacity = 6,745 m^3 - (1) Basin : Capacity = 3,370 m^3 (Dimension : Width 31.2 m × Length 24.0 m × Depth 4.50 m) - (2) Basin : Capacity = 3,375 m^3 (Dimension : Width 50.0 m × Length15.0 m × Depth 4.50 m) • Detention Time = 1.0 hr	Reuse	―
	Maintenance Valve Equipment	• Inlet Gate (1) : MS Fabricate □1,500 mm × 1,200 mm Sluice Gate with Manual Operating Stand × 2 Units	Reuse	―
		• Inlet Gate (2) : MS Fabricate □1,200 mm × 1,200 mm Sluice Gate with Manual Operating Stand × 1 Unit	Reuse	―
		• Outlet Gate (1) : MS Fabricated D1,200 mm Sluice Gate with Manual Operating Stand × 2 Units	Reuse	―
		• Outlet Gate (2) : MS Fabricated D1,200 mm Sluice Gate with Manual Operating Stand × 1 Unit	Reuse	―
	Utility Water Pump	• 2 Units	Replace	• The Same Specifi-cations of the Existing
Chemical Feeding Facilities	Chemical & Administration Building	• Chemical Feeding Room for Aluminum Sulfate, Lime & Chlorine, Chemical Storage, Chlorination & Chlorine Tonner Room, Laboratory & Office	Reuse	―
	Solution Tank	• Aluminium Sulfate : 4 Units • Lime : 4 Units • Chlorine : 1 Ton (Net : 900 kg) Container	Reuse	• Reuse after Renovation of the Existing
	Chemical Feeding Equipment	• Aluminium Sulfate : Mixer : 4 Units • Lime : Mixer : 4 Units • Chlorine : 7.0 kg / hr × 5 Units (3 Units for Pre-Cl, 2 Units for Post-Cl)	Replace	• The Same Specifications of the Existing
	Neutralization Facility	• Neutralization Tank with Caustic Soda Solution : Not Available	Improve	• Reuse after Improvement and Renovation of the Existing
		• Safty Measures (Protection Masks : Inappropriate Location)		
Laboratory	Laboratory Room	• Located in Administration Building	Reuse	―
	Laboratory Equipment		Replace	• The Same Specifi-cations of the Existing

3.5.2 Rehabilitation of Transmission Mains

(1) Rehabilitation of Transmission Mains from Margao to Verna Pumping Station

Rehabilitation of the existing transmission mains from the existing Salaulim WTP to Verna Pumping Station which is prestressed concrete (PSC) pipe has been identified as a high priority for securing the sustainable and continuous supply of treated water from both the existing and proposed treatment plants, since pipe break accidents have occurred frequently because of deteriorated quality of the pipes. According to available breakdown records of the route from the Salaulim WTP to Margao between December 1989 and December 2001, the breakdowns occurred at 49 locations. During the study period, some breakdowns also occurred and the water supply to Margao, Verna and Vasco da Gama were suspended.

The PWD is, therefore, replacing the PSC pipes of a diameter of 1,400 mm, which are laid from the Salaulim WTP to Margao with mild steel (MS) pipes. The PWD has replaced about 10 km PSC pipes with MS pipes as of July 2006. The replacement of the remaining 11.3 km PSC pipes are under implementation and will complete within the year 2007 according to the PWD's information.

Therefore, the priority projects include the replacement of the remaining transmission lines of PSC pipes which is about 13.8 km of 1,200 mm from Margao to Verna Pumping Station as shown in Figure 35.1.

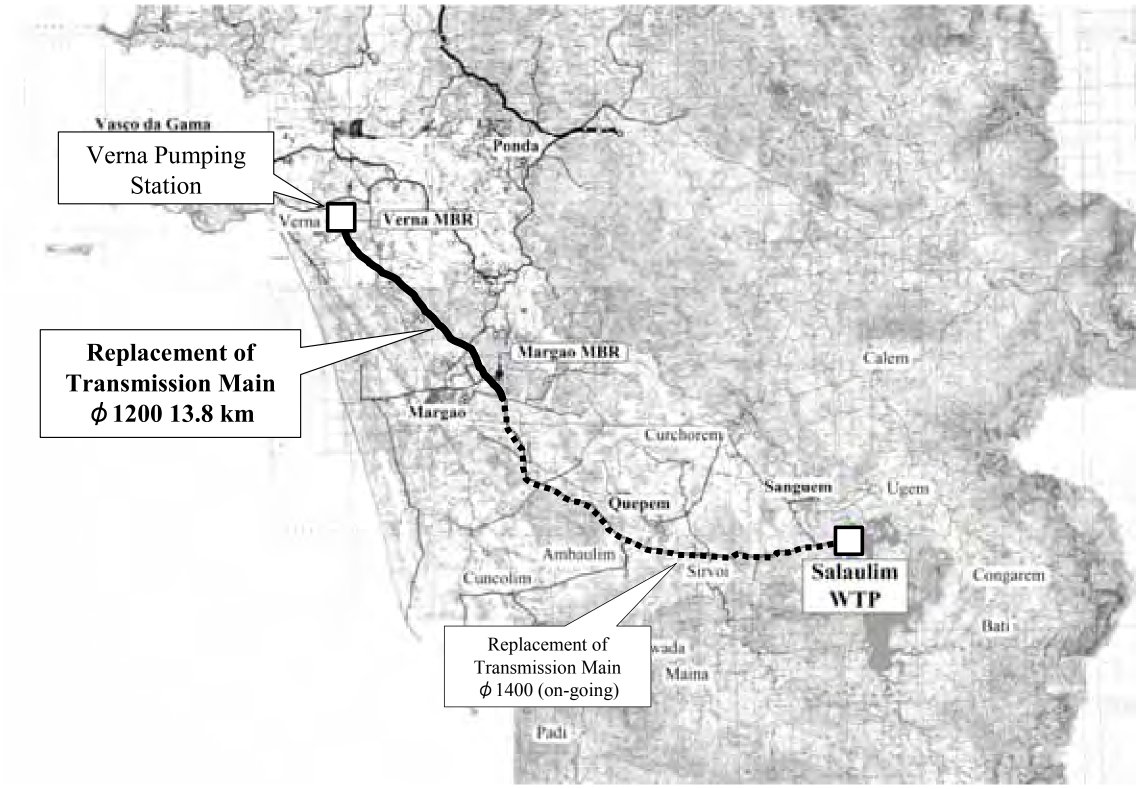


Figure 35.1 Route of Transmission Main to be Replaced in the Priority Project

(2) Rehabilitation of Other Transmission Mains

The Salaulim WSS has a total length of 71.81 km asbestos cement (AC) pipelines installed before 1990 (Sector Status Study – WSS Goa, 2004) as the tapping pipelines from transmission mains to reservoirs. The Study proposes that the existing 71.81 km of AC pipelines will be replaced with ductile iron pipes.

In addition the study proposes the rehabilitation of about 4.2 km of PSC pipes, which represents 30 % of the PSC pipelines with diameters greater than 600 mm.

It is noted that these rehabilitation works are not only for the Stage I projects but also for the Stage II projects until the year 2025 then the PWD should conduct these rehabilitation works every year as a routine works as well as the installations and rehabilitations of distribution networks and house connections. The Stage I will include about 50 % of the total rehabilitation works.

3.5.3 Replacement of Pumping Equipment

(1) Replacement of Pumping Equipment at Verna Pumping Station

The existing Verna Pumping Station has six pumps which are used to pump water to the Verna Master Balancing Reservoir. The outline of the existing Verna Pumping Station is listed in Table 35.2.

Table 35.2 Outline of the Existing Verna Pumping Station

Equipment / Facility		Specifications	
1. Pumps			
	Type	Horizontal Split Casing Centrifugal Pump	
	Size	300 × 250 mm, 1,060 m^3/h × H69m × 1,483 min^{-1} × 260 kW	
	Number	6 (4 duty + 2 stand by)	
2. Motors			
	Type	Squirrel Cage Totally Enclosed Tube Ventilated (TETV), IP55	
	Size	3 ϕ × 3.3 kV × 50 Hz × 1,483 min^{-1}, 260 kW	
	Number	6 (4 duty + 2 stand by)	
3. Transformer			
	Type	2,000 kVA (Oil filled), IP52	100 kVA (Dry type), IP52
	Size	3 ϕ × 33/3.3 kV × 50 Hz	3 ϕ × 3,300/433 V × 50 Hz
	Number	2	2
4. Switch Gear Board			
	Type	33 kV × 100 MVA	3.3 kV × 75 MVA

The proposal includes replacing four units of the existing pumping equipment (pumps and motors). This is required because water demand is expected to increase in the Mormugao Taluka (especially domestic demand in the Vasco da Gama Municipality and the industrial demand in the Verna Industrial Area); and because the design life of the existing pumping equipment has been exceeded. The specifications of the new pumps are as follows:

28.16m^3/min × H69m × 456kW × 4 units (pumps and motors)

Remaining other 2 units are proposed to be replaced at the Stage II.

(2) Replacement of Pumping Equipment for Other Pumping Stations

The life span of the pumping equipment is assumed to be 15 years. Therefore, the pumping equipment in all the existing pumping stations should be replaced by 2025. Details are shown in Table 35.3. It is noted that these replacement works are not only for the Stage I projects but also for the Stage II projects until the year 2025 then the PWD should conduct these replacement works every year as a routine works depend on the life span of each pumping equipment.

Table 35.3 Pumping Equipment Replacement Details until 2025

Name of Station	Pumping Unit (pump and motor)		Name of Station	Pumping Unit (pump and motor)	
	Rated Output (kW)	No. of Units		Rated Output (kW)	No. of Units
Margao	214.2	3	Loutoulim	2.0	3
Verna	455.3	6	Raia	3.7	3
Balli	31.3	3	Nuvem	15.7	3
Baida	5.9	3	Dabolim	2.6	3
Curtorim	16.5	3	Head Land Sada	16.9	3
Borda	2.3	2	Chicalim	2.8	3
Gavli Wada	10.4	3	New Vaddem	3.4	3
Camurlim	3.2	3	Mangor	14.0	3

3.5.4 Rehabilitation of Reservoirs, Distribution Pipelines and House Connections

(1) Reservoirs

The Salaulim WSS has 85 reservoirs except reservoirs at Salaulim WTP, Margao MBR and Verna MBR, as summarised in Table 35.4. A detailed list of the reservoirs is attached in Volume IV Appendix M31 Existing Water Supply System. The study identifies the reservoirs that need to be rehabilitated as shown in Table 35.4. Although the design life of the concrete structure is 50 years as mentioned in Section 3.2, this master plan assumes that about 20 percent of the existing reservoirs will be rehabilitated by 2025. This is because the data of construction years of all reservoirs was not available. The PWD should conduct these rehabilitation works (reconstruction) every year as a routine works depend on the life time of each reservoir.

Table 35.4 Number of Existing Reservoirs

Reservoir Volume (m^3)	Number of Reservoirs	
	Existing	to be rehabilitated
800 and above	27	5
500 - 650	8	2
400	6	1
300	24	6
200	3	1
150	11	2
100 and less	6	1
Total	85	18

Note: does not include the reservoirs at Salaulim WTP, Margao MBR and Verna MBR

(2) Distribution Pipelines and House Connections

The life span of the distribution pipelines is assumed to be 50 years. It is planned that 2 % of the existing 1,425 km of distribution pipelines will be replaced every year. This will total 24 % from 2007 to 2018. As a result the existing 340 km of distribution pipelines should be replaced with new pipelines during the Stage I from 2007 to 2018.

The life span of house connections is assumed to be 10 years. It is planned that all 105,700 existing house connections will be replaced within 10 years. As a result about 133,000 house connections will be replaced during the Stage I from 2007 to 2018.

These rehabilitation work of the distribution pipeline and house connections will also contribute to the reduction of NRW.

3.6 Improvement of Operation and Maintenance

3.6.1 Installations of Flow Meters at Reservoirs and WTPs

The study proposes to install the flow meters at all existing reservoirs for all the 7 WSSs in order to understand the flow rate into the distribution system belonged to the respective reservoirs as well as float valves to avoid unnecessary overflow from the reservoirs. Also the installations of flow meters at all WTPs are included in the priority projects to control and understand the flow discharged from the WTPs. Numbers of flow meters are listed in Table 36.1.

Table 36.1 Number of Flow Meters at Reservoirs and WTPs

WSS	for small diameter	for large diameter		Total
		Reservoir	WTP	
Salaulim	81	4	3	88
Opa	80	1	4	85
Chandel	33	0	2	35
Assonora	85	0	7	92
Sanquelim	26	0	5	31
Dabose	26	0	1	27
Canacona	12	0	1	13
Total	343	5	23	371

3.6.2 Installations of Flow Meters and Flow Control Valves at Transmission Mains

As the priority projects, the flow meters are proposed to be installed at major points of the existing and proposed transmission mains for all the 7 WSSs in order to understand the flow rate through the transmission mains. In addition, the control valves are recommended to be provided upstream or downstream of proposed flow meters for controlling the transmission flow appropriately. Numbers of flow meters and control valves for 7 WSSs are listed in Table 36.2. For the Salaulim WSS the locations of flow meters at the transmission mains are shown in Figure 34.15.

Table 36.2 Number of Flow Meters and Control Valves at Transmission Mains

WSS	Flow Meters			Flow Control Valves				
	for small diameter	for large diameter	Total	1400	1200	900	600 and less	Total
Salaulim	-	5	5	2	2	1	-	5
Opa	-	3	3	-	-	3	-	3
Chandel	-	3	3	-	-	-	3	3
Assonora	3	2	5	-	-	2	3	5
Sanquelim	2	1	3	-	-	1	2	3
Dabose	4	0	4	-	-	-	4	4
Canacona	7	0	7	-	-	-	7	7
Total	16	14	30	2	2	7	19	30

3.6.3 Improvement of Safety Standards at WTPs

The existing WTPs are operating and maintaining under the poor safety standards. The priority projects include the following safety improvement works for the operation and maintenance of all WTPs.

- Improvement of chlorine facilities such as isolation and ventilation of chlorine room, replacement of piping from chlorine gas cylinder to chlorinator with copper pipes, installation of gas detector, etc.
- Improvement of other plant safety such as railing of open channels, guarding of moving equipment/shaft, etc.

3.6.4 Establishment of Central Laboratory

Main functions of the PHE are to supply potable water and treat collected sewage to avoid contamination of public water bodies. To achieve the mission of the PHE, water quality, drinking water and treated sewage, should be monitored to confirm conformity of these quality with water quality guidelines.

Currently, the PHE water quality laboratory is established at Tonka, however, the water quality parameters which can be analyzed at the laboratory are limited and can not analyze all the parameters which are defined by the Indian water quality guidelines included in CPHEEO Manual.

Not only for water supply but also for sanitation, PHE should have enough capacity to monitor water quality by itself to be an accountable service provider. To achieve this target and to improve the PHE capacity, it is proposed to establish central laboratory to monitor water qualities at one laboratory owned and operated by the PHE.

The drinking water quality parameters are shown in Volume V Appendix F35 Drinking Water Quality Parameters and Frequency of Analysis to be conducted by the Central Laboratory together with frequencies of analysis recommended in short, medium, and long term. These parameters comply with the recommended guidelines in India. Currently all drinking water quality parameters are not measured. The central laboratory that can measure all the required parameters will be established. The central laboratory will be responsible for drinking water quality at all the water treatment plants. Samples will be taken monthly. In the short term the central laboratory will analyze only those parameters that are classified in the Indian guidelines that are also listed in the WHO guidelines as 'Health Significant Aspects'. In the long term all parameters in the Indian guidelines will be measured. Until the central laboratory is established, the parameters that cannot be measured in the existing Tonca laboratory will be measured at private laboratories.

The central laboratory will monitor drinking water quality and treated sewerage water quality in all water supply schemes and all sewerage systems. The roles of the central laboratory are shown in Figure 36.1. The central laboratory will conduct monthly analysis of treated water, daily analysis of distributed water, and monthly analysis of treated sewerage.

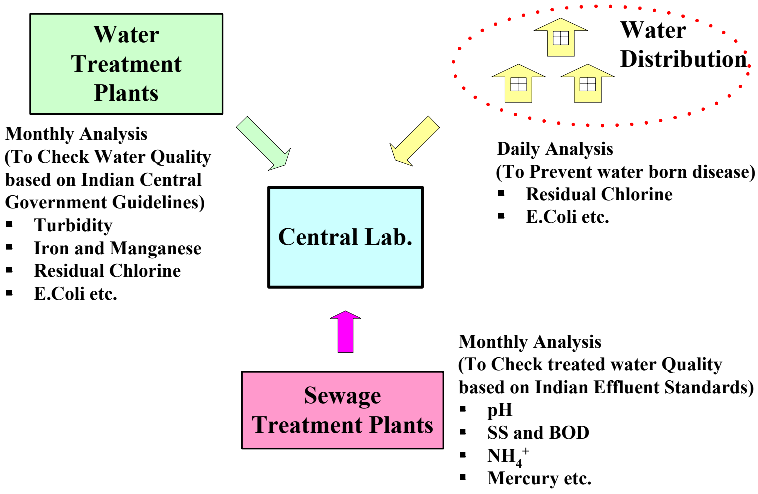


Figure 36.1 Roles of the Central Laboratory

The water treatment process monitoring parameters which are indispensable information for adequate plant operation are shown in Table 36.3. These parameters will be measured in on-site laboratories at the water treatment plants except for Trihalomethane formation potentials which will be measured in the central laboratory.

Table 36.3 Parameters and Frequency of Analysis for Monitoring Water Treatment Plant Processes

Monitoring Place (Lab.)	Parameters	Frequency of Analysis			
		Recommended	Present	Short Term	Long Term
Water Treatment Plant (Each WTP Lab.)	Turbidity	Daily	Daily	Daily	Daily
	Colour	Daily		Daily	Daily
	pH	Daily	Daily	Daily	Daily
	Odour	Daily		Daily	Daily
	Alkalinity	Daily	Daily	Daily	Daily
	Residual chlorine	Daily	Daily	Daily	Daily
	Iron	Daily	Daily	Daily	Daily
	Manganese	Daily	Daily	Daily	Daily
	Ammonia-Nitrogen	Daily		Daily	Daily
	Trihalomethane formation potential	Monthly or Quarterly			Monthly or Quarterly
	Hardness		Daily	Daily	Daily
	DO		Daily	Daily	Daily

Water quality in the transmission and distribution system must be sufficient to ensure public safety because once the water is released from this system people will be accessing the water. The parameters used to check the water quality in the transmission and distribution system were selected to allow monitoring of issues related to public health and customer perceptions. The parameters used to monitor the transmission and distribution system are shown in Table 36.4. These parameters will be measured daily in the central laboratory. In the longer term, Trihalomethanes will be measured to ensure further drinking water quality improvements in India.

Table 36.4 Parameters and Frequency of Analysis for Monitoring Water Quality in the Transmission and Distribution System

Monitoring Place (Lab.)	Parameters	Frequency of Analysis			
		Recommended	Present	Short Term	Long Term
Transmission & Distribution (Central Lab.)	Residual chlorine	Daily	Daily	Daily	Daily
	pH	Daily	Daily	Daily	Daily
	Conductivity	Daily		Daily	Daily
	Odour	Daily	Daily	Daily	Daily
	Taste	Daily	Daily	Daily	Daily
	Colour	Daily	Daily	Daily	Daily
	Turbidity	Daily	Daily	Daily	Daily
	Lead	Monthly			Monthly
	Iron	Monthly		Monthly	Monthly
	Manganese	Monthly		Monthly	Monthly
	Zinc	Monthly			Monthly
	E.coli	Daily	Daily	Daily	Daily
	Standard plate count bacteria	Daily	Daily	Daily	Daily
	Nitrate as N and Nitrite as N	Monthly			Monthly
	Chloride ion (Cl-)	Monthly			Monthly
	COD Oxygen consumed by $KMnO_4$	Monthly			Monthly
	Trihalomethanes	Monthly or Quarterly			Monthly or Quarterly
	Chloroform	Monthly or Quarterly			Monthly or Quarterly
	Bromodichloromethane	Monthly or Quarterly			Monthly or Quarterly
	Dibromochloromethane	Monthly or Quarterly			Monthly or Quarterly
	Bromoform	Monthly or Quarterly			Monthly or Quarterly
	Dichloroacetic acid	Monthly or Quarterly			Monthly or Quarterly
	Trichloroacetic acid	Monthly or Quarterly			Monthly or Quarterly
	Chloral hydrate	Monthly or Quarterly			Monthly or Quarterly

Responsibility should be assigned to an ‘effluent quality process owner’ for ensuring that control parameters are set and measured to ensure compliance with the appropriate effluent quality standards in force from time to time across the state.

Parameters that require specialist equipment or analysis should be agreed, sampled and analysed at a central laboratory that is fully equipped to ensure compliance with the appropriate standards in force from time to time. The central laboratory should take responsibility for setting sampling procedures, transport of samples for central analysis, record keeping and reporting to PWD and other government agencies as required. Table 36.5 shows Monitoring Parameters on Sanitation System.

Table 36.5 Monitoring Parameters on Sanitation System

No.	Parameters	Indian Standards	Operation Purpose	Frequency: Present in Panaji	Frequency: Proposed Short Term	Frequency: Proposed Long Term	Place of Analysis: STP	Place of Analysis: Central Labo.	Sample*
1	Colour	○	○	Alternate days	Daily		○	-	1,2,3
2	Odour	○	○	-	Daily		○	-	1,2,3
3	Suspended Solids (SS)	○	○	Alternate days		Daily	○	○	1,2,3
4	Particle size of Suspended solid	○	○	-	Once a year		-	○	2
5	pH	○	○	Alternate days	Daily		△	○	1,2,3
6	Temperature	○	○	Alternate days	Daily		○	-	1,2,3
7	Oil and grease	○	○	Monthly			-	○	1,2
8	Residual Chlorine	○	○	Daily			△	○	2
9	Ammonical Nitrogen (NH_4-N)	○	○	Weekly			-	○	1,2
10	Total Kjeldahl Nitrogen	○	○	Weekly			-	○	1,2,4
11	B.O.D.	○	○	Alternate days		Daily	-	○	1,2
12	C.O.D (Cr)	○	○	Alternate days		Daily	-	○	1,2
13	Arsenic as As	○		-	Frequency stipulated in the statute		-	○	2,4
14	Mercury as Hg	○		-	Frequency stipulated in the statute		-	○	2,4
15	Lead as Pb	○		-	Frequency stipulated in the statute		-	○	2,4
16	Cadmium as Cd	○		-	Frequency stipulated in the statute		-	○	2,4
17	Chromium as Cr^{6+}	○		-	Frequency stipulated in the statute		-	○	2,4
18	Total Chromium (Cr)	○		-	Frequency stipulated in the statute		-	○	2,4
19	Copper as Cu	○		-	Frequency stipulated in the statute		-	○	2,4
20	Zinc as Zn	○		-	Frequency stipulated in the statute		-	○	2,4
21	Selenium as Se	○		-	Frequency stipulated in the statute		-	○	2,4
22	Nickel (Ni)	○		-	Frequency stipulated in the statute		-	○	2,4
23	Cyanide as CN	○		-	Frequency stipulated in the statute		-	○	2,4
24	Fluorides as F	○		-	Frequency stipulated in the statute		-	○	2,4
25	Dissolved phosphates (P)	○	○	Weekly			-	○	1,2,4
26	Sulphide (S)	○		-	Frequency stipulated in the statute		-	○	2,4
27	Phenolic compound as C_6H_5OH	○		-	Frequency stipulated in the statute		-	○	2,4
28	Gross Alpha activity	○		-	Frequency stipulated in the statute		-	○	2,4
29	Gross Beta activity	○		-	Frequency stipulated in the statute		-	○	2,4
30	Bio-assay Test	○		-	Frequency stipulated in the statute		-	○	2,4
31	Managanese as Mn	○		-	Frequency stipulated in the statute		-	○	2,4
32	Iron as Fe	○		-	Frequency stipulated in the statute		-	○	2,4
33	Nitrate as N	○	○	Weekly			-	○	1,2
34	E.Coli		○	Weekly			-	○	1,2
35	Total Coliforms		○	Weekly			-	○	1,2
36	Total Soloids		○	Alternate days		Weekly	-	○	1,2
37	Dissolved Substance		○	Alternate days		Weekly	-	○	1,2
38	Coliform Bacteria		○	Weekly			-	○	1,2
39	Dissolved Oxygen (DO)		○	-	Daily		△	-	3
40	Volatile Solids(VS)		○	-	Daily		-	○	1,2,4
41	Sludge Volume(SV)		○	-	Daily		○	-	3

Note: ○ Examined by stipulated in the statute
△ Simple Test
* Sample 1: Raw sewage
2: Discharging point
3: Reactor tank
4: Slugde

The central laboratory will be established at the existing Tonka laboratory premises and costs required for buildings and water quality analysis equipment required for water quality parameters recommended are included in O/M improvement costs.

3.7 Summary of Stage I Projects

In conclusion Table 37.1 shows a summary of Stage I projects which will be implemented from 2007 to 2018. Among these projects, some projects which will be conducted from 2010 to 2012 as the priority projects have been selected.

Table 37.1 Summary of Stage I Projects

Work Component		Description	Implementation Period	
			as the Priority Projects	as the Routine Works of PHE
1. Expansion Works (for Salaulim WSS)				
	Salaulim WTP	100 MLD	2010 - 2012	
	Transmission Mains	73.65 km, 150 – 1,400 mm	2010 – 2012	
	Reservoirs	Sirvoi MBR, 20,000 m^3	2010 – 2012	
		6 reservoirs, 100 – 800 m^3	2010 – 2012	
	Pumping Stations	5 stations	2010 - 2012	
	Distribution Pipelines	550 km		2007 - 2018
	House Connections	39,000 nos		2007 - 2018
2. Rehabilitation Works (for Salaulim WSS)				
	Salaulim WTP	160 MLD	2010 - 2012	
	Transmission Mains,	Margao to Verna, 13.8 km, 1,200 mm	2010 - 2012	
		Others, 38 km		2013 - 2018
	Pumping Equipment	Verna Pumping Station	2010 - 2012	
		Others, 10 of 16 stations until 2025		2007 - 2018
	Reservoirs	6 of 18 reservoirs until 2025		2013 - 2015
	Distribution Pipelines	340 km		2007 - 2018
	House Connections	133,000 nos		2007 - 2018
3. Improvement of Operation and Maintenance (for all 7 WSSs)				
	Installation of Flow Meters	23 nos at WTPs	2010 - 2012	
		348 nos at reservoirs with float valve	2010 - 2012	
		30 nos at transmission mains with flow control valve	2010 - 2012	
	Safety Standards for WTPs	Chlorination Facility and others	2010 - 2012	
	Central Laboratory	established at Tonca, Panaji	2010 - 2012	

3.8 Strategies for Continuous Water Supply

3.8.1 Necessary Measures/Actions to provide for Continuous Water Supply

The public awareness survey indicated that the public would like a continuous or "stable water supply". Sufficient water quantity and pressure, and water quality were the second and third most populate requests during the public awareness survey. Approximately 82% of the sampled households (who have a house connection) responded with the comment that the water supply service should meet international standards, which includes a 24 hour potable supply. This would also help to improve tourism in Goa.

These results demonstrate that consumers in Goa would like to have a continuous water supply 24 hours a day, 7 days a week. The Master Plan therefore seeks to achieve continuous water supply by designing the water supply facilities to achieve continuous water supply. Continuous water supply is possible within the known financial constraints.

Strategies that need to be implemented to achieve the continuous water supply are discussed in this section. To change the existing system from providing an intermittent water supply to providing a continuous supply, facility improvements and other measures/actions need to be implemented. These measures are shown on Figure 38.1.

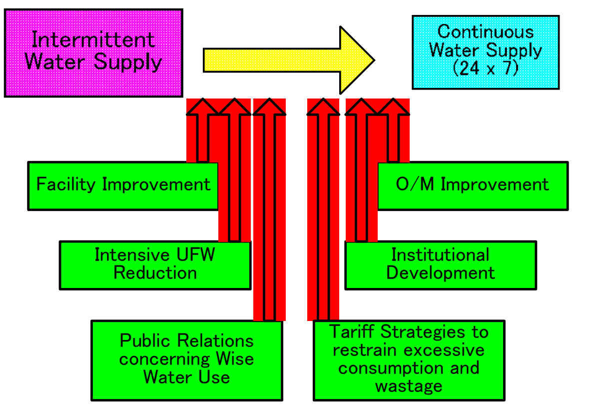


Figure 38.1 Measures for Achieving Continuous Water Supply

(1) Facility Improvement.

The water treatment plant and water distribution pipelines have sufficient capacity to meet the water demand continuously. Water reservoirs have sufficient capacity to absorb any water consumption fluctuation meaning a stable water supply is possible. Therefore, if the facilities are improved, a continuous water supply can be achieved. Other measures and actions to support the continuous water supply should be implemented simultaneously, as shown in Figure38.1.

(2) O/M improvement

The facilities must be maintained after the improvement works are complete.

Without maintenance, the efficiency of the facilities may decline or they may malfunction. Adequate, timely, and preventative maintenance must be carried out to ensure continuous water supply.

(3) Institutional Development

Institutional improvement and capacity building of the PHE (as the service provider) is required to improve the water supply service. The billing and bill collection system should also be improved.

(4) Raising Public Awareness with regards to Efficient Water Use

It is difficult to generate water efficient use consciousness for the customers because the existing water supply is intermittent. The results of the public awareness survey indicate that 80 % of households that have water connections also have a water tank. The tap to supply water to the individual tanks is usually kept open and unattended, so that the tank can be filled when the water service is available. However, because the taps are unattended, water overflows once the tank is full, which wastes water. When the continuous water supply is achieved, it will be important to change this habit. A public awareness program is therefore required.

(5) Tariff Strategies to Restrain Excessive Water Consumption and to Avoid Water Wastage

The above section explains that it is important to raise public awareness in relation to efficient water use. Tariff strategies should also be introduced to help restrain excessive water use and to avoid water wastage. The current water tariff level is low when compared to the average income level. This means people do not seriously consider their water usage.

(6) Intensive UFW/NRW Reduction

The intermittent water supply means that water flows only for limited hours in the pipelines. When the water supply is upgraded so that flow is continuous, water will always flow. this means water leakage will increase (i.e. the UFW will increase). Therefore, before the system is upgraded, the leakage points should be repaired, where possible. Leakage detection and repair must become part of the maintenance program.

To reduce UFW and NRW it is recommended that the PWD implement the "NRW Reduction Roll-out Plan". This plan is described in Chapter 4 NRW Reduction Roll-out Plan.

3.8.2 Preparatory Measures/Actions to provide for Continuous Water Supply

The measures and actions needed to achieve a continuous water supply are shown in Figure 38.2. The system consists of a branch pipe from the transmission pipeline, a reservoir, and a distribution network.

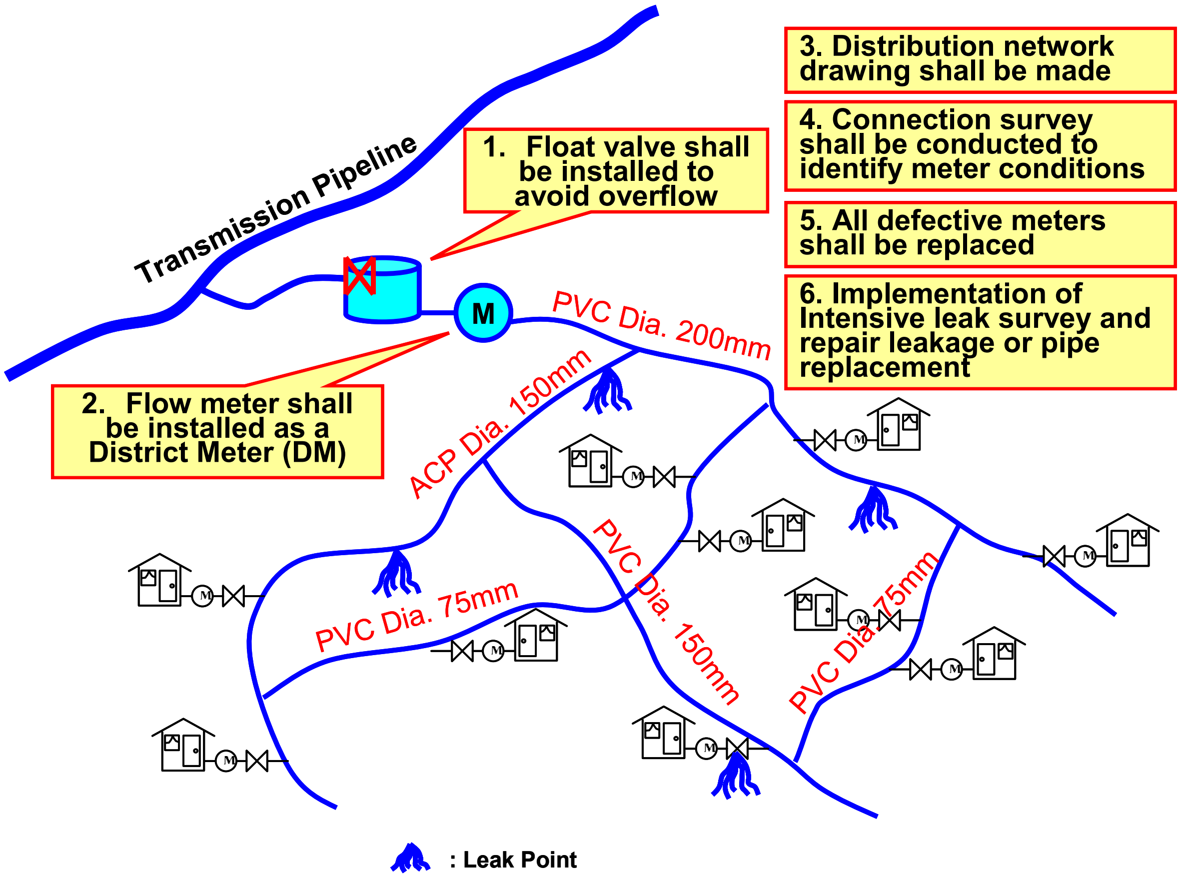


Figure 38.2 Required Works to achieve a Continuous Water Supply

(1) Installation of Float Valve

The distribution reservoir supplies water to the distribution network. The reservoir needs to be equipped with a float valve to automatically prevent water inflow once the reservoir is full. A survey of the condition of the existing equipment revealed that most of the float valves are faulty and that the inlet valves require manual adjustment. Manual valve operation is not suitable for a continuous water supply. It is recommended that a float valve be installed to avoid unnecessary overflow and wastage.

(2) Installation of flow metering at the reservoir outlet

To measure the quantity of water distributed from the reservoir, outlet water flow meters should be installed. This will allow the PWD to evaluate NRW in the distribution area by comparing the quantity of water that is distributed, with the sum of water consumed. Based on this assessment the PWD can prioritize areas where intensive leakage control is required.

(3) Preparation of Distribution Network Drawings

Distribution network drawings are not available at the relevant division or sub-division offices. Lack of drawings hider operation and maintenance of the distribution network and flow / pressure control, and will make it difficult to undertake the intensive leakage survey. The location, material and diameter of all the distribution pipelines should be confirmed, as was done during the pilot study stage of this project.

(4) Undertaking a House Connection Survey

Once the distribution network drawings are prepared a house connection survey should be undertaken. This will involve checking each house connection individually. During the pilot project a significant number of illegal and unregistered connections were found. The house connection survey means that an accurate customer list can be prepared. Also, during the house connection survey the condition of every water meter at each house connection should be checked.

(5) Replacement of Defective Meters

All defective meters should be replaced with working meters. The defective meters will be identified during the house connection survey. The water meters that are difficult for the PWD meter reader to access should be replaced to provide for easier access. Currently, if a meter is not working a flat rate is applied to that connection. This does not encourage efficient water use and therefore results in water wastage. Efficient water use will not be possible using flat rates. Malfunctioning water meters will also cause difficulties when the PWD is trying to evaluate the NRW in the distribution area.

(6) Implementation of an Intensive Leakage Survey

Before the continuous water supply is introduced, every water leakage point should be repaired. An intensive leakage survey should be implemented to identify these leakage points.

Once actions (1) to (6) (listed above) are completed, the PWD can announce that the area is ready to receive a continuous water supply. At this time, the customers in the distribution area should be notified that:

- Continuous water supply will be soon be implemented.
- Water consumption will be measured using water meters and that the water tariff will be based on the meter reading. It should be explained that these measures will mean that leakage or wastage within the household will result in an increased water bill.
- In the future, the volume of water that needs to be stored in the customer's house will only be required for emergency situations because water will now be available 24 hours a day.
- Customers should inform the PWD of any leaking or malfunctioning meter. The PWD can then arrange repair.

These activities should be implemented starting at the upstream end of the transmission pipeline, and progress in a downstream direction. In this way the area that can receive continuous water supply will be gradually expanded.

This section has indicated that it is important to reduce NRW when introducing the continuous water supply.

CHAPTER 4

NRW REDUCTION ROLL-OUT PLAN

CHAPTER 4 NRW REDUCTION ROLL-OUT PLAN

4.1 Introduction and Assumptions

This roll-out plan has been formulated based on the experiences gained from the NRW reduction pilot project conducted by the joint JICA/PWD Study Team during April/May 2006 and the review of current PWD NRW performance and practices during the first and second phases of the study. During the pilot project, not only leakages but also illegal or unregistered connections were found.

The premise on which this plan is based is as follows:

- NRW is at an unacceptable level and will need to be reduced by adopting a more proactive approach to NRW reduction
- The NRW reduction pilot project was a success in demonstrating the benefits to be gained in reducing NRW by taking and 'active' approach and PWD are keen to build on the transfer of knowledge and technology gained during the project
- PWD would benefit from gaining additional assistance in developing and delivering the roll-out plan to ensure it's success and to maximise benefits and sustainability
- A number of actions, resources and investments are required to bring NRW under control and to sustain it at economic levels. This may include the need to let external contracts as well as to enhance in-house efforts
- NRW reduction activities will need to become 'a way of life' as opposed to a series of adhoc or one-off exercises

4.2 Outline of the NRW Reduction Pilot Project and Key Findings

The 'NRW Pilot Project' was conducted in the Santa Cruz area (suburban residential area), approx 6km south-east of Panaji city which receives a 24 hour supply. The project area contains approximately 2,000 connections (including public taps) and 12 km of distribution pipelines (ranging from 50-200mm; consisting of AC, CI and GS pipes).

The project area was selected based on the following:

- Discussions with PHE
- High priority water shortage area
- Suspected high leakage area
- Minimal enabling works required
- 24 hour supply available
- Relative ease of isolation of the study area

The project was conducted between 25 April to 01 June 2006, involving classroom lecture as well as practical training and a variety of 'field work', topographic surveys (mapping of assets, connections, boundaries etc.), household surveys, water balance calculations and 'active' leakage control measures. The project team consisted of 26 PWD staff and 6 JICA team members. All necessary equipment such as flow/pressure measuring devices, data loggers, acoustic leak detection equipment etc. was provided by the JICA study team.

Objectives

The key objectives of the NRW reduction pilot project were to:

- Transfer knowledge and technology through training and active participation of PWD staff in the pilot program
- Demonstrate the benefits of an 'active' leakage approach in reducing the levels of NRW in the pilot area through adoption of leakage mitigation measures
- Impart training to broaden the understanding of the components of NRW and how to mitigate their effects
- Impart training on the use of leak detection equipment
- Set up a discrete zone within the pilot area for accurate measurement of leakage and to implement leakage reduction measures
- Reduce NRW through accurate determination of NRW ratios for the project area and use of practical measures to reduce the key elements
- Provide data, experience and knowledge for the development and implementation of a state wide NRW reduction and control program

Methodology

The methodology adopted included the need for household surveys, topographical surveys, water audits and leak detection surveys to be carried out. The complete 'workflow' was as follows:

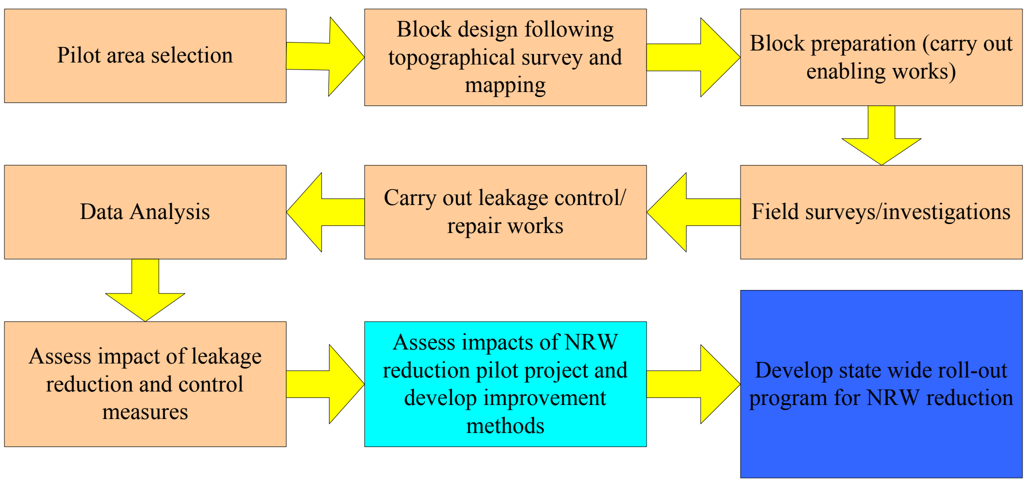


Figure 42.1 NRW Reduction Pilot Project Workflow

Detailed Tasks

Based on the objectives of the pilot project, the key tasks carried out included the following:

- Prepareation of detailed drawings of the project area, including pipe location, type, diameter, length, existing valves, connections etc.
- Preparation of a plan for flow measurement and location of isolation valves
- Conducting enabling works such as installation of meters, valves and flow/pressure monitoring devices etc.
- Collecting information on house connections, sources of water supply, water supply period, household composition, status of water meters, condition of service pipes etc.
- Flow/pressure measurement in the project area at designated points including customer taps on a 24 hour basis
- Reading of consumer water meters
- Assessment of water consumption by public street taps and/or other consumption (un-metered, faulty meters, illegal connections)
- Hands-on training for use of acoustic leak detection equipment and NRW reduction methodology
- Conducting leakage surveys (by acoustic methods) in the study area; finding and fixing leaks
- Identifying causes and types of leakage
- Assessment of NRW by component and savings resulting from the project

A schematic of the project area is shown as follows:

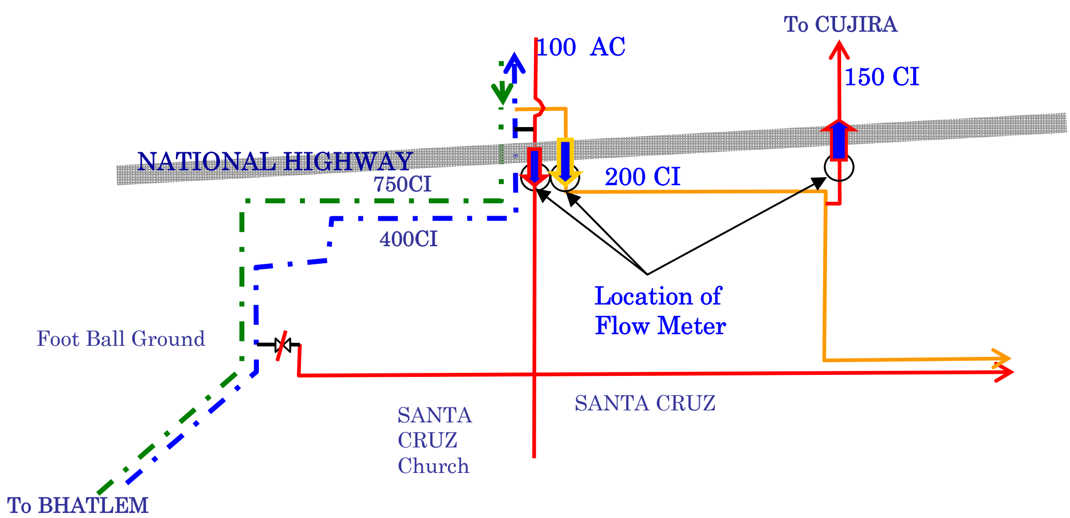


Figure 42.2 Schematic of the Project Area

Key findings, outputs and results of the NRW reduction pilot project

- Of the 1958 houses surveyed in the project area, 1746 had a PWD supply connection, of which 99 were not registered and 35 were illegal connections
- Of the 1647 registered (metered) connections, 262 (16%) could not be checked due to lack of access, 699 (42%) were working, although the accuracy was not determined and 686 (42%) were not readable/not working
- Of the 80 leaks detected, 40 (50%) were on service connections
- Leaks resulted from either poor installations/workmanship, use of inferior repair materials, or through making poor/temporary repairs
- As a result of the project, it was determined that NRW was reduced from 56% of water into the project area to 49% over a short period of time, through leak detection/repair alone. Refer to Figure 42.3 below:
- Further savings can be made through replacement of non readable/non working meters and in tackling other 'apparent losses' such as unregistered/unbilled accounts
- The NRW reduction pilot project was successful in transferring knowledge and technology to PWD and for gaining understanding and enthusiasm to continue with 'active' NRW reduction methods. The experience gained from the project has been used in formulating the NRW roll-out plan as detailed in this chapter
- PWD understands the importance in continuing with 'active' leakage control measures and the effects this can have on reduction NRW
- The NRW reduction pilot project has demonstrated the benefits to be gained through 'institutionalising' NRW reduction methods across the State

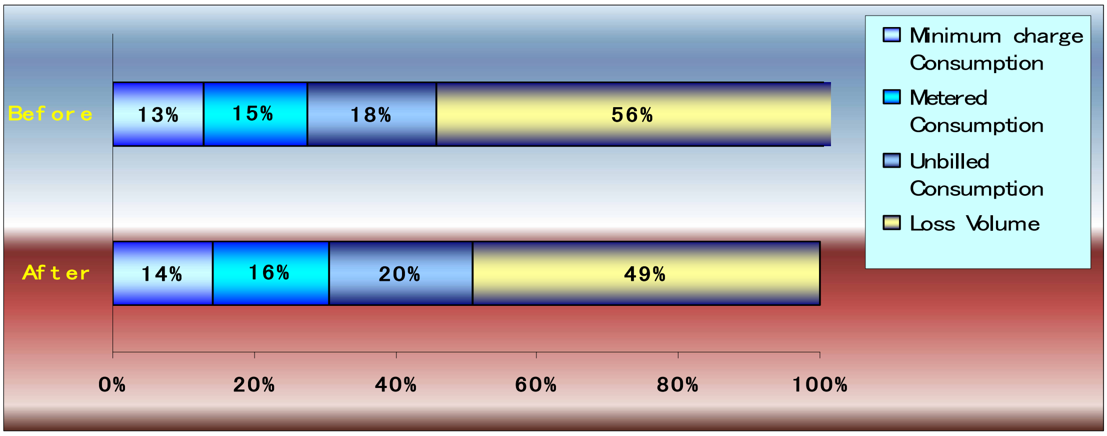


Figure 42.3 Effects of Leakage Repairs on NRW

4.3 Actions to be addressed by the NRW Reduction Roll-out Plan

A successful NRW reduction roll-out plan will need:

Leadership – From the top of the organisation, there must be a "Champion" to ensure that the whole organisation concentrates upon the basics of increasing income and reducing the physical leakage

Commitment – Throughout the organisation there must be a determination to follow through the processes that reduce NRW.

Resources – Significant resources are required to make the step change necessary to reduce NRW. Once NRW is under control and efficient and effective processes are in place then the resource can be reduced to a lower level. It must be recognised that NRW control is an ongoing operation.

Based on the experience gained from the NRW reduction pilot project, the following actions will need to be addressed:

- Improve network management practices
- Establish standards for new connections and repairs including standard specifications for materials, fittings, meters, layout, non-return valves, sealing, testing, calibration etc
- Introduce leakage policy and improved methods
- Replace all defective (leaking) house connections
- Repair all existing visible leaks
- Introduce metering policy and improved practices
- Replace all defective meters
- Conduct enabling works and leakage control measures
- Set up Active Leakage Teams within each Division or Region with appropriate tools to find and fix leaks. It may also be prudent to establish a 'centrol coordinating' role to collate and share Regional performance across the State
- Institutionalise NRW management measures and tackle 'apparent' as well as 'real' losses
- Ensure 100% billing and improve revenue collection practices

It should be noted that the premis on which the feasibility study for water supply is based, emphasises the provision of 24 x 7 supplies in future. This brings with it the challenges of ensuring that leakage control measures are put in place to keep leakage 'in-check', as potentially, increasing the hours of supply could increase the level of water lost as a result of leaks if the current 'passive' approach to leakage management is not changed.

The provision of 24 hour supplies also presents challenges for network management practices in terms of ensuring that the use of reservoirs is optimised in order to minimise pressures and flows throughout the network as customers become accustomed to the availability of continuous supplies as opposed to the current intermitent supplies. Research by the Asian Development Bank and the International Water Association in South Asia shows that provision of 24 hour supplies can often result in less consumption per capita as consumers do not have to revert to storing water and subsequently wasting water through 'refreshing' supplies when water is only available intermittently. Source: "Asian Water Supplies; ADB/IWA, October 2000. Chapter 5; Intermittent Water Supply". The research aslo stresses the need to address NRW, to enforce strict metering and collection and to introduce higher tariffs for 24 hour supply zones. These are some of the challenges that will have to be resolved by PWD and the GOG if their vision of 24 hour supply systems are to be achieved.

4.4 Outline of the Roll-out Plan

Detailed recommendations and actions needed to reduce NRW water and to maintain it at economic levels are shown at Volume III Chapter 11 Section 2 NRW Reduction; however, the key elements of the Roll-out Plan are as follows:

Table 44.1 Outline of the NRW Reduction Roll-out Plan

NO.	DESCRIPTION	PRIORITY	COMMENT
NRW Reduction roll-out Plan			
1	Agree ownership for roll-out program.	Urgent	Suggest CE I is 'owner' and places responsibility on the SE's to 'champion' within each region. PWD Secretary to 'sponsor' efforts.
2	Agree terms of reference for the roll-out programme.	Urgent	This will specify objectives, targets, procedures, resources, budgets and responsibilities for all involved with the roll-out programme.
3	Identify staff to be involved within each region, provide training, equipment and identify a 'pilot area' within each region to gain experience.	Urgent	SE's to form teams. Training to be provided by the Santa Cruz study team.

NO.	DESCRIPTION	PRIORITY	COMMENT
4	Determine if 'Assistance' is required to build capacity.	Urgent	Rolling-out the pilot will require planning, management and supervisory expertise. There are a number of benefits to be gained in securing additional assistance to ensure maximise success, benefits and sustainability of the roll-out programme. Refer to 4.5.2 below.
5	Procure equipment for each pilot and conduct pilot reduction programme within each region. Tackle 'apparent' (commercial) losses as well as 'real' (physical) losses.	Short term	SE's to 'champion' supported by Santa Cruz team 'Commercial' teams to be established to resolve metering/meter reading problems, eliminate illegal connections and ensure 100% billing and revenue collection.
6	Benefits of pilots to be identified and shared state-wide.	Short term	SE's to organise regional and central presentations of findings.
7	Identify further areas that would benefit from an 'active' NRW reduction approach and roll-out within each region across all supply schemes.	Short to medium term	SE's to 'champion' and share benefits state-wide.
8	Institutionalise NRW reduction strategy and mitigation measures within each region as detailed in Table 44.2 below.	Medium term	PWD Secretary to 'sponsor', CE I 'owns' and Regional SE's 'champion'. Decide if external assistance is required. It is becoming common practice to let contracts for enabling works such as installation of DMA's and to bring UFW within acceptable limits and then to continue the effort in-house. Refer to 4.5.3 below.

Table 44.2 Detailed NRW Reduction Action Plan

NO	DESCRIPTION	PRIORITY	COMMENT
INCOME GENERATION			
1	Replace all defective meters	Urgent	Use good quality class 'B' or 'C' meters that comply with international standards
2	Replace all defective (leaking) house connections	Urgent	Use improved materials instead of galvanised pipes and fittings
3	Agree standards for new connections including standard specifications for materials, fittings, meters, layout, non-return valves, sealing, testing, calibration etc.	Urgent	Introduce a 'metering policy' that specifies materials and equipment to be used with specified periods for calibration, maintenance, replacement etc.
4	Set up a 'Meter Inspection Team' in each division to improve management, supervision and control.	Urgent	Carry out a random audit of 1% of meter readings per reading cycle and provide training to meter readers where needed. Ensure that suspected or actual fraudulent activity is dealt with
5	Audit the billing system to ensure 100% billing	Urgent	Conduct surveys to ensure that all who have a connection receive a bill
6	Improve debt collection	Urgent	Conduct audits to ensure that divisions have the resource to economically chase debt
7	Review Commercial/industrial meter sizing	Short term	Ensure that all meters are sized correctly, calibrated and tested for accuracy
'FIRST AID'			
1	Repair all existing visible leaks	Urgent	Use existing manpower resource or works contracts already in place or introduce new incentivised contracts

NO	DESCRIPTION	PRIORITY	COMMENT
2	Ensure that all leaks are repaired only once	Short term	Ensure that the correct materials are in stock to avoid making temporary repairs and that good quality repair materials such as clamps and other fittings are specified and use
3	Set up a monitoring system to ensure that 80% of all leaks are repaired within 24hours and all leaks are repaired within 5 working days	Short term	Will need to implement a database for recording and tracking repairs, materials used, burst data etc. (preferably a computerised system)
4	Stop all reservoirs and water towers from overflowing by means of inlet controls or indicators back to the pump control or treatment facility	Short term	Set up a project team within each Region to investigate and implement appropriate solutions
Prevention			
1	Ensure that all Contractors are 'qualified' (certified) to work on PHE networks both existing and new	Medium term	Introduce a system of contractor certification or accreditation, set appropriate standards of repair and enforce standards
2	Ensure that all materials used on installations and repairs are in accordance with agreed standard specifications	Medium term	Introduce a system of new improved standard specifications for pipes, materials, fittings and equipment and ensure compliance by staff and contractors
3	Consider adopting suitable "Byelaws" to prevent waste and preserve water quality	Medium term	Review existing bylaws and ensure that these are 'policed'
4	Prepare Strategic mains plans	Medium term	Digitise all networks starting with the strategic mains
5	Exercise "key" valves	Medium term	To ensure operability in times of need

NO	DESCRIPTION	PRIORITY	COMMENT
6	Set up an emergency store in each Division of all appropriate repair materials and equipment and ensure it is available to PHE staff and Contractors	Short term	Ensure that staff and contractors are equipped to get the job done without delay and that H&S issues are taken into account

ENABLING WORKS			
1	Ensure that all Source works have reliable and accurate metering	Urgent	This is mandatory in many countries. This provides the knowledge of the basic supply of product to the customer and will help improve network management including service delivery and control of UFW
2	All Source meters are checked for accuracy every two years	Short term	Carried out by clamp on ultrasonic or insertion type flow meter
3	Consider the introduction of a system to capture spatial information	Medium term	As part of the IS strategy, consider introduction of a Geographical Information System (GIS) as well as other systems for asset management such as a computerised maintenance management system (CMMS)
4	Ensure networks are analysed for optimum flows/pressures	Medium term	Introduce appropriate software and train staff on network analysis. This will require installation of flow and pressure measuring devises at 'critical control points'
5	Design Zones and DMA's for 24 hour supply systems	Medium term	Where networks are supplying on a 24 hour basis, installation of district meters will aid the management and control of the network as well as aid the monitoring and control of UFW
6	Evaluate each DMA or supply zone for potential pressure reduction	Medium term	The potential for pressure management is substantial due to its topography. Minimising pressures will help reduce leakage
7	Install Telemetry for DMA meters and pressure transducers	Long term	This will help to optimise network performance and service delivery
8	Conduct a pilot UFW reduction program	Short term	This is to be completed during the feasibility study phase. Will need to decide if this is conducted in-house or by contract; or a combination of the two
9	Roll-out UFW reduction across all networks	Medium term	Will need to decide if this is conducted in-house or by contract. It is preferable to let a contract for enabling works such as installation of DMA's and to bring UFW within acceptable limits and then to continue the effort in-house

ACTIVE LEKAGE DETECTION			
1	Set up Active Leakage Teams within each Division or Region with appropriate tools to do the job to **find and fix leaks**	Short term	Introduce targets and monitoring system to ensure that UFW is brought within and maintained at economic levels. For 24 hour systems, teams will need to work at night
2	Provide training and equipment for each team	Short term	Initial training was provided as part of the pilot UFW reduction program. Equipment will include: pipe locators, listening rods, leak noise correlators, basic tools, vehicles, pressure and flow measuring devices, data loggers etc.
3	Introduce a 'leakage database' to monitor leakage activities and performance	Short term	The database (preferably computerised) will record and track detection team performance, repair team performance, locations, failure types, repairs, materials used, burst data etc. as well as parameters necessary to maintain UFW within economic limits
4	Introduce a system of key performance measures	Short term	Monitor performance against agreed targets for each team/division/region
5	Set up a dedicated 'leak line' to enable customers to report leaks	Short term	This should be toll-free
6	Introduce new technology to improve leakage detection/reduction	Medium term	Including the use of: Noise Loggers, Hydrogen Gas Injection, ground Penetrating Radar.

4.5 Strategies for Setting up and Running NRW Reduction Activities

There are a number of options available to PWD in tackling the current levels of NRW and for putting measures in place to firstly bring it within acceptable limits and then to maintain it at economic levels.

4.5.1 In-house Approach

Considerable experience and knowledge has been gained by a group of PWD staff as a result of conducting the NRW Reduction Pilot Project. The demonstrable benefit in adopting an 'active' approach to leakage reduction has generated enthusiasm for continuing the in-house effort. The roll-out plan that PWD should consider adopting is outlined above, however, the amount of time, effort and resource necessary to make this approach a success should not be underestimated. Assuming an in-house approach was adopted, PWD would need to consider the following:

Setting up NRW Reduction Units (organisational arrangements)

The roll-out programme requires that staff are identified and trained within each Region and equipped with the tools and methods to bring NRW under control. Initially within a pilot area, followed with further areas that would benefit from an 'active' approach, this method would systematically apply 'active' leakage mitigation measures across the entire network within each Region. The amount of training imparted and manpower needed in this approach is paramount to success and places a major burden on staff who are already tasked with their 'day-jobs'. Consequently, for best results, an in-house approach is best achieved through providing a dedicated resource to NRW reduction activities. This would require that staff directly involved with the NRW reduction activities are redeployed into dedicated 'NRW reduction units' or additional staff are employed specifically for this purpose. The NRW reduction units would act as a catalyst to ensure that 'active' NRW mitigation measures are adopted State-wide.

Schedule of Activities and Required Resources

Building on the experience of the NRW reduction pilot project, it is recommended that each pilot area consists of a discrete area of the supply network containing approximately 2000 connections. This builds on the concept of the 'caretaker' approach whereby a small area is 'patrolled' by a small number of staff under the control of a single 'caretaker'. To allow sufficient time for the setting up and training of staff as well as for conducting the tasks detailed in table 45.1 below, it is recommended that NRW reduction activities established within the Regions are conducted over a three month period as a minimum until permanent systems are put in place for continuous NRW reduction activities.

It is recommended that each NRW reduction team consists of the following appropriately trained and experienced staff:

Table 45.1 NRW Reduction Unit Responsibilities

Task	Number of Staff	Assignment
Team Leader	1	Organisational set-up and management of the project. Agree pilot area within each supply scheme. Agree and procure leakage equipment and provide other resources such as vehicles, survey equipment etc. to tackle 'real' losses. Agree staff required to tackle 'apparent' losses within the same pilot area. Act on the results of the NRW reduction Unit findings to tackle NRW levels in other parts of the Region.
Block Preparation and Mapping	3	Map pipe network, existing valves, connections etc. Prepare detailed drawings of the study block(s). Prepare plan for flow measurement and location of isolation valves. Conduct enabling works such as installation of meters, valves and flow/pressure monitoring devices etc.
Household Surveys	2	Collect information on house connections, sources of water supply, water supply period, household composition, status of water meters, condition of service pipes etc. Provide data to teams tackling both 'real' and 'apparent' losses.

Task	Number of Staff	Assignment
Water Audit and 'active' leakage detection	5	Flow/pressure measurement in the transmission pipelines. 24-hr flow/pressure measurement in the study block(s). Reading of consumer water meters. Assessment of water consumption by public street taps and/or other consumption (un-metered, faulty meters, illegal connections). Assessment of water meter errors. Conduct leakage survey (by acoustic methods).
Leakage mitigation	5	Repair all visible leaks. Replace all defective meters. Repair/replace all defective house connections. Repair all leaks detected by 'active' leak detection methods.
Meter Reading, Billing and Revenue Collection	3	Ensure 100% billing in the pilot area. Ensure all illegal connections are registered and billed. Ensure outstanding debt is collected.

The following equipment is the minimum requirement to equip each NRW Reduction Unit to conduct active leakage reduction measures. As equipment for the NRW reduction pilot was imported from Japan, indicative costs are shown in US$ (1US$=112JYn). The vehicle costs, however, are shown in local currency (Rs.) as these would be procured (or hired) locally. It will be necessary to establish a minimum of three NRW Reduction Units (one per Region) later to be expanded to at least on Unit per water supply scheme, until an 'active' approach to NRW reduction becomes institutionalised:

Table 45.2 Leak Detection Equipment Requirements for Each NRW Reduction Unit

Equipment	Indicative Unit Cost US$	Quantity Required	Indicative Total Cost US$
Mechanical listening stick	165	5	825
Leak detector with ground microphone	3,780	2	7,560
Metal pipe locator	6,450	2	12,900
Metal detector	1,410	2	2,820
Portable ultrasonic flow meter with data logger	8,920	2	17,840
Pressure logger	1,125	2	2,250
Vehicles to transport leak detection and leak repair staff	180,000 Rs.	2	360,000 Rs.

Based on the foregoing, there is considerable scope for additional technical assistance to be provided in order to help PWD 'equip' themselves for the tasks described in terms of capacity building measures such as strengthening PWD's management, supervisory and technical capacity to apply the required skills and techniques associated with an 'active' approach to NRW reduction. This is described in section 4.5.2 below.

4.5.2 External Technical Assistance Approach

Even with the enthusiasm generated from the success of the NRW reduction pilot project, it will be difficult to get the roll-out programme 'off the ground' by using entirely PWD staff with out additional external technical assistance. External technical assistance will provide the expertise and 'driving force' to formulate and initiate roll-out so that PWD can implement the plan successful following a thorough planning phase. In short, external technical assistance would:

- Help PWD in planning a successful roll-out program
- Help PWD in developing capacity to implement the programme
- Help start-up of the State wide roll-out programme
- Support PWD during implementation of the programme
- Support PWD in analysing the benefits of the programme

Based on the number and complexity of water supply schemes, it would be preferable to seek external technical assistance by means of a Technical Cooperation Project rather than arbitrary assignment of technical experts' per-se. The tentative skill requirements for a successful technical cooperation project would be as follows:

Table 45.3 Functional Expertise Required for Technical Cooperation

Title	Assignment
Team Leader	Organisational set-up and management of the project
NRW Reduction Specialist	Planning and development of detailed practical strategies for the state wide roll-out programme
Pipe Network Specialist	Evaluation of supply networks to 'stabilise' the networks and to eliminate excessive pressures.
Leak Detection Specialist	To train staff in the use of techniques and equipment to find and fix leaks and in tackling all aspects of 'real' losses
Mapping Specialist	Preparation of digitised maps of all networks in the project area
Customer Relations Specialist	Customer relations and household surveys
Billing/Accounting Specialist	Planning and development of detailed practical strategies for improvement of metering, meter reading, billing and revenue collection through tackling 'apparent' losses

Required input from PWD

PWD would need to provide sufficient counterpart staff to implement the roll-out programme. Making use of the original NRW Reduction Pilot Project participants to help train staff within each Region as well as help implement the roll-out programme would be invaluable to ensuring success of the programme. Additionally PWD would need to:

- Establish NRW Reduction Units for each supply scheme or within each Region
- Provide counterpart staff to conduct mapping, household surveys, find and fix leaks
- Provide equipment, materials, vehicles and other resources to conduct field work, effect repairs
- Provide materials for replacing defective house connections and defective meters

Expected Outputs of a Technical Cooperation Project

The expected outcomes of such as technical cooperation project would include the following benefits:

- Improved efficiency of water supply schemes
- Establishment of NRW reduction units capable of reducing NRW initially and then maintaining it at economic levels
- Implementation of the state-wide roll-out programme via the NRW reduction units
- Reduce NRW in the project area
- Improve customer relations/PWD image
- Increase water availability/sales through reduction of 'real' losses
- Reduce operating costs through reduction of 'real' losses
- Increase revenues through reduction of 'apparent' losses

4.5.3 Outsourcing Leakage Reduction and Mitigation Measures

It is becoming common place for water utilities to let contracts for the reduction of NRW down to a target level and to provide mitigation measures such as design and set-up of DMA's, installation of flow and pressure regulating and measuring devices, leak detection equipment etc. for the monitoring, control and reduction of 'real' losses associated with NRW. Contracts of this nature require the contractor to bring investment and expertise in return for demonstrable savings resulting from NRW reduction. This is one of the areas along with Asset Management Planning, for example, that would come under the auspices of a 'Management Contract' type arrangement. Refer to Chapter 7.

It should be noted however, in adopting this approach, PWD would have to ensure that 'ownership' for NRW reduction would still rest with PWD and as such would need to ensure that mechanisms are in place within the Contract to ensure the transfer of knowledge as well as technology. This can only be effectively achieved if PWD staff actively work alongside contractor staff during the life of the Contract.

If PWD decide to outsource leakage reduction and mitigation measures to a third party contractor, this does not negate the need for PWD to establish in-house capabilities or the need for technical assistance as combining the effects of all three approaches simultaneously will have a cumulative positive effect on reducing NRW over time.

4.6 Priority of Implementation

Implementation of NRW reduction measures will need to be prioritized regardless of whether the approach to tackling NRW is conducted in-house or by a combination of the three approaches described above. Prioritization will need to be based on the following:

Areas wise: Areas suffering severe water shortages/intermittent supplies should be tackled as a priority as savings in water resulting from NRW reduction measures will make more water available to existing customers and provide supplies to those that currently do not receive a supply. This will improve supply coverage, increase revenues and improve service delivery and public image.

Scheme wise: The water supply schemes that provide the largest volume of water or supply the largest amount of customers or contributes the largest amount of revenue should be tackled as a priority as these will return the greatest benefits in the short term. However, it should be noted that the larger schemes will present the biggest challenges as these are likely to contain longer transmission/piped distribution lines and more reservoirs. The current lack of reservoir level control and flow measuring devices will need to be rectified accordingly.

Salaulim Water Supply Scheme: In accordance with the feasibility study, the Salaulim water supply scheme will be refurbished and expanded in order to provide 24 hour water supplies in the scheme area. Accordingly, it will be crucial to prioritise NRW reduction measures for the Salaulim supply area. Refer to section 4.3 for challenges presented in providing 24 x7 supplies from existing intermittent supply conditions.

CHAPTER 5

SEWERAGE SYSTEM

CHAPTER 5 SEWERAGE SYSTEM

5.1 General Conditions for Feasibility Study

5.1.1 Target Area and Target year

The three (3) areas selected as priority project in the Master Plan, such as Margao, Mapusa and North Coastal Belt (Calangute and Baga areas), are the objective for the Feasibility Study (hereinafter as F/S) for sewerage system improvement.

5.1.2 Collection System

A separate system is adopted for sewage collection as planned in the master plan.

5.1.3 Per Capita Sewage Flow and Pollution Load

The per capita sewage flow and pollution load area are determined in Volume II Chapter 6 and are shown in Table 51.1.

Table 51.1 Per Capita Sewage Flow and Pollution Loads

Per capita sewage flow for resident	150 ℓ/day/capita
Sewerage return rate	80 %
Groundwater infiltration	20 %
Per capita sewage flow for tourist	260 ℓ/day/capita
Per capita BOD	45 g/day/capita
Per capita SS	38 g/day/capita

5.1.4 Design Criteria for Sewerage Facilities

The design criteria for sewerage facilities are adopted from CPHEEO manual, and main items are shown in Table 51.2.

5.1.5 Facilities to be Designed Preliminary in the F/S Stage

Main facilities such as trunk sewers, pumping stations and treatment plants are designed preliminary in F/S. Sewer with diameter of 200 mm or larger are categorized as trunk sewer in this F/S, and the pumping stations located on the trunk sewers are designed in this F/S. Other sewers are not designed but their lengths are measured and their costs are included in the cost estimation. Main facilities and equipment for treatment plants are designed.

Table 51.2 Main Design Criteria for Sewers and Pumping Stations

Item	Criteria	
(1) Design flow	Peak flow for both sewer and pumping station	
	Population	Peak Factor
	Up to 20,000	3.0
	20,000 to 50,000	2.5
	50,000 to 750,000	2.25
	Above 750,000	2.0
(2) Flow velocity formula		
Gravity flow	Manning's formula (Concrete pipe: n=0.015)	
Pressure flow	Hazen-William's formula (Cast iron: C=100)	
(3) Minimum diameter of sewer	150 mm	
(4) Design flow for standby pump	50% of peak flow	
(5) Types of pumping stations	Manhole type (design flow ≦ 3.0 m^3/min)	
	Conventional type (design flow > 3.0 m^3/min)	

5.1.6 Summary of Basic Features of Sewerage System

The population, sewage flow and other main features are summarized in Table 51.3 and breakdown of figures are shown in Volume V Appendix F51.1 Population and Sewage flow in the Master Plan Area for F/S Target Cities.

Table 51.3 Summary of Basic Values of Sewerage System in F/S Stage

Location	Unit	Margao		Mapusa		North Coastal Belt Calangute & Candolim	
Stage		Stage I	M/P	Stage I	M/P	Stage I	M/P
Target year		2015	2025	2015	2025	2015	2025
Covered population	Person	80,680	118,193	34,260	68,255	19,772	39,358
Sewage flow	m^3/day	13,678	20,861	5,354	10,782	5,090	11,172
Sewage treatment plant							
Capacity (New)	m^3/day	6,700	13,400	5,400	10,800	5,600	11,200
(Existing)	m^3/day	7,500	7,500	-	-	-	-
(Total)	m^3/day	14,200	20,900	5,400	10,800	5,600	11,200
Treatment method		Activated sludge method					
		Conventional + (Sand filtration)		OD + (Sand filtration)		OD + Sand filtration	
Location		Margao		Mapusa		Calangute	
Discharge river		Sal River		Tributary of Mandovi R.		Baga River	
Sewage quality		In	Out	In	Out	In	Out
BOD	mg/ℓ	300	30	300	30	240	10
SS	mg/ℓ	250	100/50	250	100/50	200	100/50(10)

Notes: (Sand filtration): Sand filtration is proposed for Margao and Mapusa ,if necessary.
Treated sewage quality of SS : Effluent quality standard/ expected effluent quality (with sand filtration)

5.2 Margao

5.2.1 Population and Sewage Flow Projection

The sewerage network in Margao has been developed in North and Central zones, the objective area of F/S is a part of south zone. Many urban facilities such as railway station or main markets are located in this South zone and 48 % of the Margao population is distributed in this area.

To collect sewage from these high density area including railway station and markets is the main objective of this F/S, adjacent areas to be collected by gravity are also be covered.

By developing these areas, more than 80 % of the Margao population will be covered including by the existing facilities. The general layout plan is shown in Figure 52.1 and the coverage area, planned population, sewage flow and pollution load are presented in Table 52.1.

Table 52.1 Coverage Area, Population, Sewage Flow and Pollution Load

Item		Unit	Stage I	M/P
Area	Developed Area (North & Central)	ha	-	548
	Expansion Area (South)	ha	392	511
	Total	ha	-	1,059
Population	Developed Area (North & Central)	person	(43,899)	61,286
	Expansion Area (South)	person	4 36,781	56,907
	Total	person	(80,680)	118,193
Sewage Flow		m^3/day	13,687	20,859
Pollution load	BOD	kg/day	4,007	6,078
	SS	kg/day	3,384	5,135

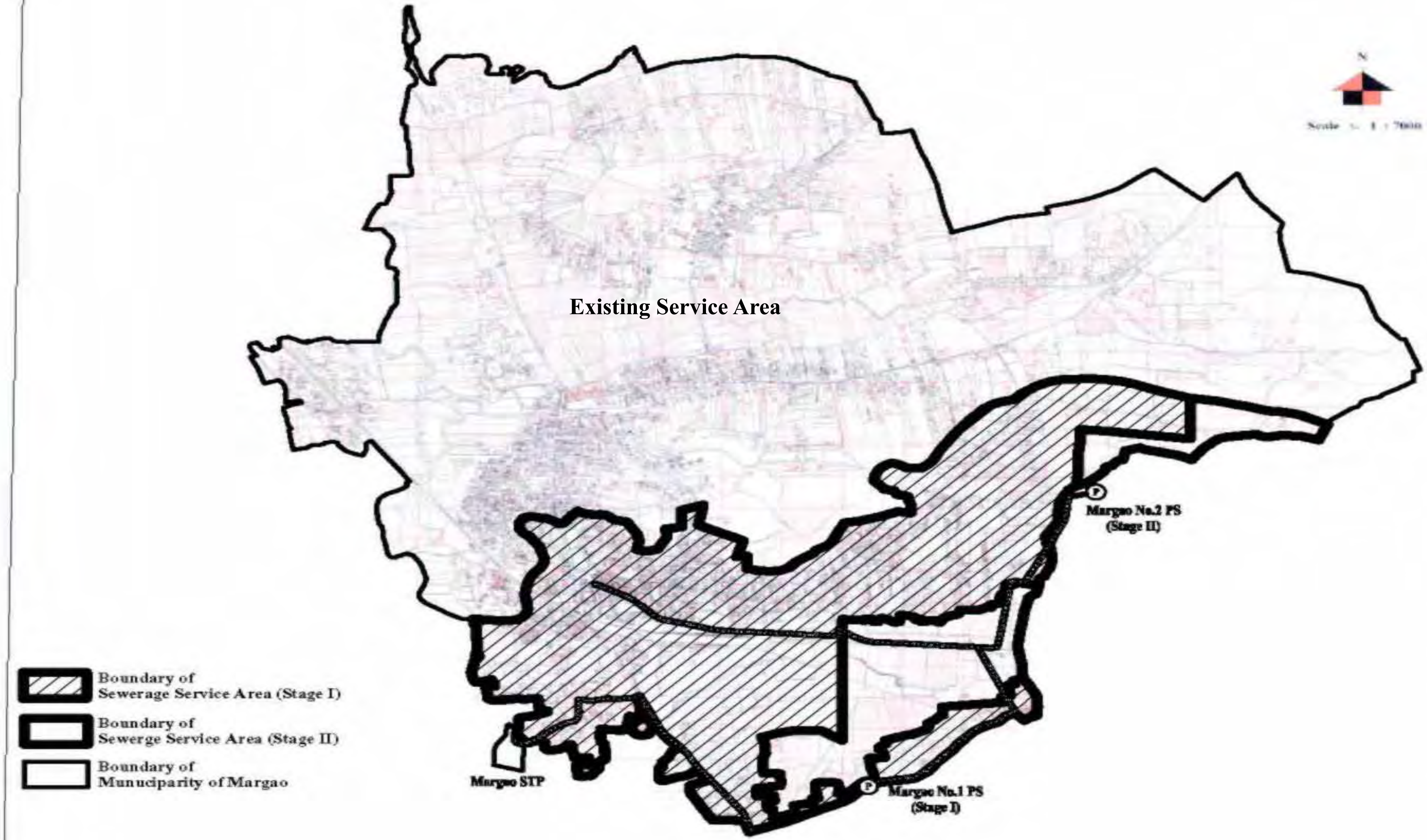


Figure 52.1 General Layout Plan of Margao

5.2.2 Sewage Collection System

Wastewater generated in North and Central Zones of Margao has been collected through existing North Main Sewer and sub trunk sewers, and it is treated at existing Margao STP. The study area of this F/S is remaining South Sewerage Zone.

Proposed main trunk sewer starting at the north east end of the service area runs toward south receiving sub trunk sewer from the city center. After receiving sub main sewer, the trunk sewer crosses railway track, then it turns to west and reaches at Margao No.1 Pumping Station. Pressure main from the pumping station discharges wastewater into outfall manhole located at south end of the service area. Trunk sewer restarting at the outfall manhole runs toward north then reaches existing Margao STP.

Main points to be consider regarding the South Zone are,

(1) Method of trunk sewer laying at congested street in the city market area
(2) Method of trunk sewer crossing railway track and the its location
(3) Site of Margao No.1 Pumping Station in association with railway track crossing.

There were two options for railway crossing point, one is near New Margao Station and the other is at east-end of Margao Municipality area near a flyover and a station of new transportation system.

Trenchless method is recommended to be adopted for a part of congested street in the main market area, because

- There is no alternative route for the trunk sewer
- The trunk sewer route will be constructed beneath the congested and very narrow main street of the market

Also, trenchless method is recommended for crossing the railway track. The crossing point is selected at east-end of Margao Municipality area because less cost than the other.

The results of geographical survey shows the service area is covered with common soil or hard soil. Therefore, sewers are supposed to be laid with no difficulty, but hard lock layer is observed at about 5 meters in depth or more at the proposed site of Margao No.1 Pumping Station. Rock drill machine will be necessary for excavation for deep part of wet sump of the pumping station.

The list of trunk sewer is shown in Table 52.2. Also refer to flow calculation sheet and longitudinal profile of trunk sewer in Volume V Appendix F52.1 Flow Calculation Sheet and Volume VI respectively.

Table 52.2 List of Sewers in Margao

Category	Diameter (mm)	Length (m)
Trunk Sewer	200	0
	250	0
	300	287
	350	0
	400	806
	450	641
	500	544
	600	0
	700	3,179
	Total	6,406
Branch Sewer	150	36,145

5.2.3 Pumping Station

Proposed Margao No.1 Pumping Station of which capacity is 231.1 lps (13.9 m^3/min) with lifting head of 14.2m has four submersible type pumps. As ancillary facilities, fine screens, sand pits and power generator will be installed. General plan and structure of the pumping station are shown in drawings in Volume V Appendix F52.1 Flow Calculation Sheet. Also, capacity calculation of the pumping station is shown in Appendix F52.1 Flow Calculation Sheet in Volume V.

Table 52.3 Facility and Equipment List of Margao No.1 Pumping Station

Design Flow (peak) (lps)	Pump					Pressure Main	
	Capacity		Head (m)	Motor Power (kW)	Nos. of Pump	Diameter (mm)	Length (m)
	(lps)	(m^3/min)					
231.1	58 116	3.5 7.0	14.2	14.3 28.6	2 + (0-standby) 1 + (1-standby)	400	642
Ancillary facilities: Fine screen, sand pits, power generator							

5.2.4 Sewage Treatment Plant

(1) Basic Conditions for the design of Sewage Treatment Facilities

The basic conditions for the design of sewage treatment plant are presented in Table 52.4.

Table 52.4 Basic Conditions for the Design of Margao STP

Item	unit	Stage I	Master plan
Target year	-	2015	2025
Available land area	m^2	31,100	
Service population	person	80,700	118,200
Design Flow	m^3/day	13,700	20,900
Existing capacity	m^3/day	7,500	7,500
Additional capacity	m^3/day	**6,200**	**13,400**
Sewage quality		Raw	Treated
BOD	mg/l	300	30
SS	mg/l	250	50

(2) Effective Use of Existing Facilities

The existing STP facilities in Margao have operated without serious problems since year 2000 when it was commenced. The augmentation plan of STP capacity considers using the existing facilities effectively as much as possible and the facility expansion plan will cater for the balance between the design flow in the future and the existing treatment capacities. The outline of existing facilities is discussed in VolumeII Chapter3.2.3.

(3) Site Condition for Expansion Facilities

According to the layout, proposed facilities can be accommodated in the existing plant premises. The ground level for the new facilities is decided based on the results of site topographical survey conducted by the Study Team. The summary of the site condition for the new facilities is presented as below.

Required Land Area (m^2) : 31,080m^2 Ground Level (m): +2.90 m above sea level

(4) Plant Hydraulics

Hydraulic profiles are prepared in order;

- ✧ To ensure that the hydraulic gradient is adequate for the sewage to flow through the treatment facilities by gravity
- ✧ To reserve the head loss requirement for the pumps where pumping will be needed
- ✧ To ensure that the plant facilities will not be flooded by backwater during rainy seasons

Typical ranges of head losses through respective treatment units are given in Table 52.5.

Table 52.5 Typical Head Losses Across Various Units

Treatment Unit	Head Loss Range (m)
Bar Screen	0.15 – 0.30
Grit Chamber	0.45 – 0.90
Primary Settling Tank	0.45 – 0.90
Aeration Tank	0.21 – 0.60
Secondary Settling Tank	0.45 – 0.90
Disinfection Tank	0.21 – 1.80

Source: Wastewater engineering, Metcalf & Eddy, Third Edition, Page 513

Due to data unavailability of high water level of river at the effluent discharging point of Margao STP, the hydraulic study of proposed facilities is calculated taking into account the highest water level in the river section and the level of facilities are decided to be higher than the highest possible water level at the site. The drawing of hydraulic profile of Margao STP is shown in Volume IV.

(5) Facility Layout Plan

The layout plan of expansion facilities is studied considering the following factors.

- ✧ Available open area for expansion facilities locate at the west of the existing STP
- ✧ Location of proposed trunk sewer inlet from the South Zone of Margao locate at the north of the existing STP
- ✧ Location of existing effluent pipe
- ✧ Location of sewage and sludge treatment facilities which will be located at the central area to ensure the easy O&M

As the result of layout study, general layout plan of Margao STP is pland as shown in Figure 52.2.

(6) Odour Control Considerations

Odour nuisance in the vicinity of sewage treatment plant, particularly in the down-wind direction of prevailing winds, can have adverse impacts on land values, public health and well being. These factors have to be considered in selecting sites for location of sewage treatment plants and layout study of facilities in the proposed site.

The generation of offensive odour from the STP is impossible to stop completely. In the sewage treatment plant, the principal sources of odour are (1) screenings and unwashed grit, (2) scum on primary settling tanks, (3) organically overloaded biological treatment processes, (4) sludge thickening tanks, (5) sludge dewatering facilities, (6) sludge drying beds.

Where there are odour problems at treatment facilities, approaches to solve these problems may include (1) operational changes to the treatment process or plant upgrading to eliminate odour sources, (2) layout of the facilities as far from the residential areas as possible, (3) application of odour treatment (deodorant processes).

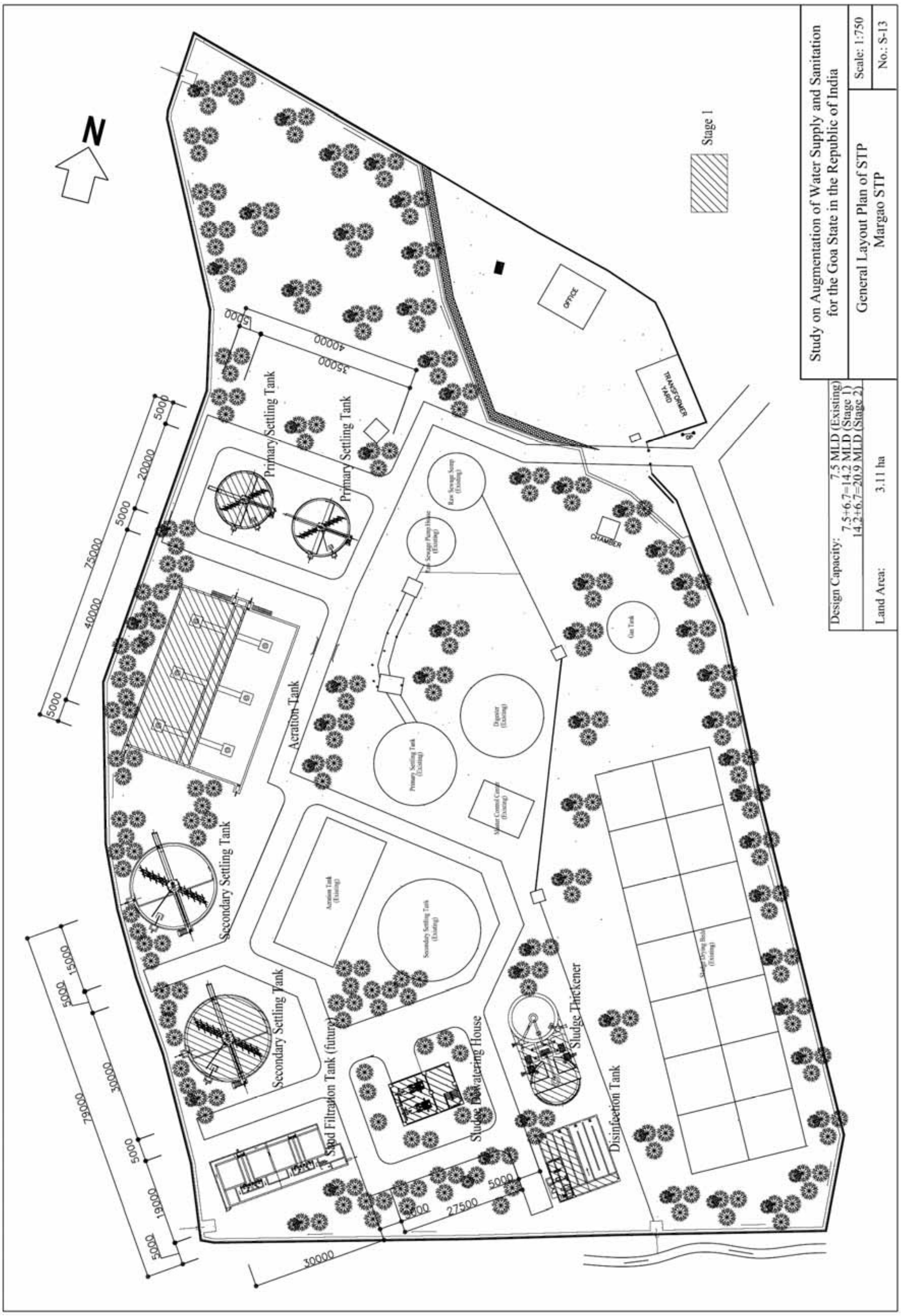


Figure 52.2 General Layout Plan of Margao STP

1) Odour Control in Feasibility Study (Stage I)

a. Operational Changes

Operational changes in order to mitigate odour problems can include the following:

- ✧ Increase the frequency of disposal of grit and screenings
- ✧ Reduce overloading on plant processes
- ✧ Increase the removal frequency of sludge and scum.

b. Layout of the Facilities

In the proposed facility layout, odour generating facilities are located as far from the residential areas as possible. Aforested buffer zone may also be effective in isolating odours from residential areas; examples of buffer distances used by New York State are presented in Table 52.6.

Table 52.6 Suggested Minimum Buffer Distances from Treatment Units

Treatment Unit	Buffer Distance (m)
1. Settling tank	120
2. Aeration tank	150
3. Sludge thickening tank	300
4. Sludge dewatering (Vacuum filter)	150
5. Sludge drying beds	150

Source: Wastewater engineering, Metcalf & Eddy, Third Edition, Page 513

2) Odour Control in the Future (when required)

In case where the treatment facilities are close to residential areas and could not maintain the above buffer distance, it may be necessary to cover some of the treatment units such as the primary clarifiers and sludge thickeners. Where covers are used, the trapped gas shall be collected and treated. The odour treatment methods may be classified as physical, biological, and chemical. The typical methods are summarized in Table 52.7. Two of the most common methods of odour treatment, chemical scrubbers and activated carbon, are illustrated in Figure 52.3 and 52.4.

Table 52.7 Methods to Control Odours Gases

Method	Description
Activated carbon	Odourous gases pass through beds of activated carbon to remove odours. Carbon regeneration can be used to reduce cost.
Soil absorption	Odourous gases pass through sand, soil or compost beds. Odourous gases from pumping stations may be vented to the surrounding soils or to specially designed beds containing sand or soils. Odourous gases collected from treatment units may be passed through compost beds.
Chemical deodorant	Odourous gases pass through specially designed scrubbing towers to remove odours. Some type of chemical or biological agent is usually used in the tower.
Biological deodorant	Specially designed towers use to strip odourous compounds. Typically, the towers are filled with plastic media of various types on which biological growths can be maintained.

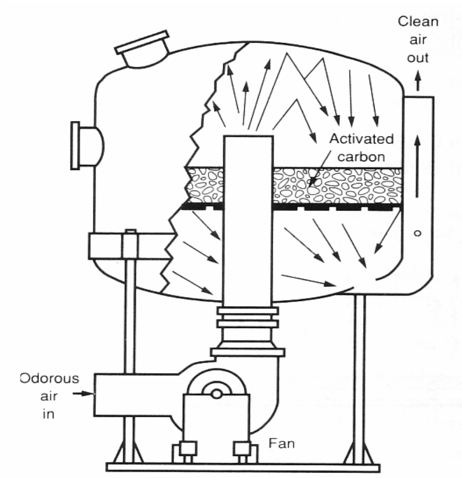


Figure 52.3 Activated Carbon System

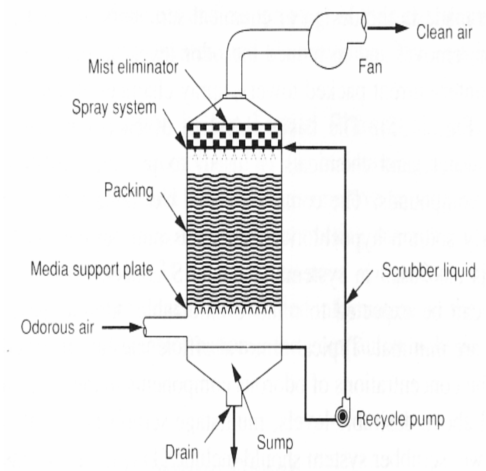


Figure 52.4 Chemical Scrubbers System

Although serious odour problems are not expected at the planned STPs, when the nuisance odour problems appears in the future, appropriate deodorization system will be selected and installed out of four processes as shown in Table 52.7 considering the features such as the type of odour, easy O&M, least cost for O&M and removal efficiency of odour.

(7) Proposed Facility Plan of Margao STP

The expansion facilities for the Margao STP are proposed considering the following aspects.

✧ The disinfection, sludge thickening and dewatering systems are designed for total design flow of the whole STP since the existing STP does not have these systems. On the other hand, the remaining facilities are designed for the additional flow to the existing treatment capacity.

- ✧ The existing administrative building is regarded sufficient for the expanded STP. Open area in the west of the existing house will be used for the future expansion of the building.
- ✧ The sand filters are adopted to reduce suspended solids in effluent in order to reuse it as gardening water. The proposed capacity of filters in the stage I is planned equal to the total water tanker volume for sprinkling. Additional filters could be installed in the future to treat all the effluent flow.
- ✧ Additional pumps for increasing design flow are to be installed in the open space in the existing pump house and it is no need to construct a new pumping house.
- ✧ According to the results of capacity evaluation (refer to the calculation in Volume V Appendix F53.1 Capacity Calculation of Sewage Treatment Plant (Margao)), the existing digestion tank has enough capacity to treat sludge not only for the Stage I but also for future till 2025.
- ✧ The existing sludge drying beds will be used as the stand-by process at the time of periodical maintenance and repair for the proposed dewatering equipment
- ✧ Generator to avoid the overflow of sewage and to ensure continuous operation during power outages will be considered.

The drawings of several proposed facilities are shown in Volume IV.

Since the stabilization of sludge quality suitable for agricultural reuse requires long time, generated sludge shall be temporarily dumped to the disposal site.

(8) Staged Construction Schedule

Out of the proposed facilities for the Master Plan (2025), the proposed expansion facilities are limited with the design flow for the Stage I and the remaining facilities will be constructed by the year 2025. The capacity calculations of the proposed facilities are presented in Volume V Appendix F53.1 Capacity Calculation of Sewage Treatment Plant (Margao). The summary of the proposed facilities for each stage is shown in Table 52.8.

Table 52.8 Summary of Expansion Facilities in Margao STP

Facility	Stage I		Future Expansion	
	Existing	New Facility	Existing	New Facility
Pump equipment	4 units	2 units	-	6 units
Mechanical screen	1 unit	1 unit	1 unit	1 unit
Primary settling tank	1 basin	1 basin	1 basin	2 basins
Aeration tank	1 basin	1 basin	1 basin	2 basins
Secondary settling tank	1 basin	1 basin	1 basin	2 basins
Sand filtration tank	-	-	-	4 basins
Disinfection tank	-	6 passes	-	8 passes
Sludge thickening tank	-	2 basins	-	2 basins
Sludge digestion tank	1 basin	-	1 basin	-
Gas tank	-	-	-	1 basin
Mechanical Dewatering	-	1 unit	-	2 units
Sludge drying bed	14 basins	-	14 basins	-

5.3 Mapusa

5.3.1 Population and Sewage Flow Projection

Mapusa is a major urban area with population about 40,000, though sewerage is undeveloped. To collect sewage from high density area located in the south east of municipality is the main objective of this priority projects, adjacent areas to be collected by gravity are also be covered. The general layout plan is shown in Figure 53.1 and the planned population, sewage flow and pollution load are presented in Table 53.1.

Developing these areas, approximately 63 % of the Mapusa population will be covered.

Table 53.1 Coverage Area, Population, Sewage Flow and Pollution Load

		Unit	Stage I	M/P
Area		ha	193	322
Population		person	34,260	68,255
Sewage Flow		m^3/day	5,354	10,781
Pollution load	BOD	kg/day	1,582	3,178
	SS	kg/day	1,336	2,685

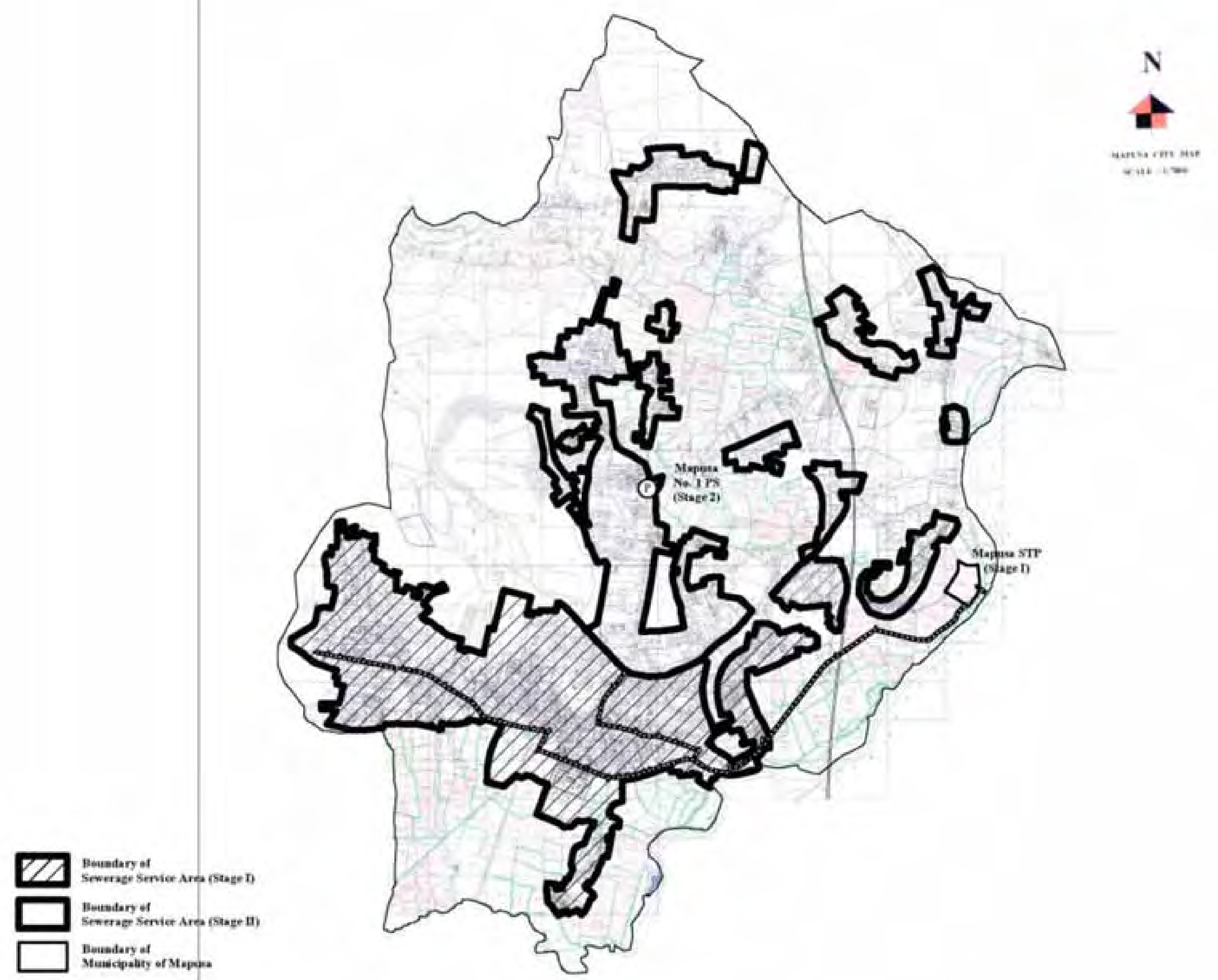


Figure 53.1 General Layout Plan of Mapusa

5.3.2 Sewage Collection System

Main trunk sewer will be laid in lowland of Mapusa city from west to east discharging into proposed Mapusa STP located at the east end of Mapusa Municipality. The sub main trunk sewer which starts at the ridge of the city center will be connected to the main trunk sewer. There is no pumping station for these main and sub-main trunk sewer, but there are some for branch sewers.

Geographical survey showed the target area is covered with common soil or hard soil. Therefore, sewers are supposed to be laid with no difficulty.

The list of trunk sewer is shown in Table 53.2. Also refer to flow calculation sheet and longitudinal profile of trunk sewer in Volume V Appendix F52.1 Flow Calculation Sheet and Volume VI, respectively.

Table 53.2 List of Sewers in Mapusa

Category	Diameter (mm)	Length (m)
Trunk Sewer	200	423
	250	35
	300	0
	350	497
	400	88
	450	1,226
	500	909
	600	0
	700	1,821
	Total	4,999
Branch Sewer	150	20,680

5.3.3 Pumping Station

No pumping station is required in Mapusa.

5.3.4 Sewage Treatment Plant

(1) Basic Conditions for the design of Sewage Treatment Facilities

The basic conditions for the design of sewage treatment plant for the Stage I are presented in

Table 53.3.

Table 53.3 Basic Conditions for the Design of Mapusa STP

Item	unit	Stage I	Master plan
Target year	-	2015	2025
Available land area	ha	2.57	
Service population	person	34,300	68,300
Design Flow	m^3/day	**5,400**	**10,800**
Sewage quality		In	Out
BOD	mg/l	300	30
SS	mg/l	250	50

(2) Site Condition for Proposed STP

The proposed STP site of Mapusa should satisfy the following conditions.

- ✧ Land is large enough to accommodate the proposed facilities adequately
- ✧ Proposed site locates close to the discharging river
- ✧ Least environmental impacts to the surrounding areas are expected
- ✧ Easy to acquire land for the proposed STP

In this Study, the selected STP site is the communal land near the river as shown in Figure 53.1 and it could be acquired at no cost. The ground level in the proposed STP is decided based on the result of site topographical survey. The summary of the proposed STP site condition is presented below.

Required land Area : 2.57 ha
Ground Level : +3.00 m above sea level

(3) Plant Hydraulics

Due to no data of high water level of river at the effluent discharging point of Mapusa STP, the hydraulic study of proposed facilities is calculated taking into account the highest water level in the discharging river section of tributary river of Mandovi and the level of facilities are decided to be higher than the highest possible water level at the site. The hydraulic profile of Mapusa STP is shown in Volume IV.

(4) Facility Layout Plan

The layout plan of the proposed facilities is prepared considering the following aspects.

- ✧ Proposed inlet trunk sewer locates at the south of the STP site
- ✧ Discharging river of treated water locates at the east along the boundary
- ✧ Nearest residents locate at the west of the site
- ✧ Trees should be planted along the perimeters of the proposed site
- ✧ Proposed sewage and sludge treatment facilities are placed at the central area to ensure the easy O&M

As the result, general layout plan of Mapusa STP is shown in Figure 53.2.

(5) Odour Control Considerations

In the study of Mapusa STP, mitigation measures for offensive odour should be same as those for the Margao STP discussed in Chapter 5.2.4.

(6) Proposed Facility Plan of Mapusa STP

The proposed facility plan of Mapusa STP is studied considering the following aspests.

- ✧ Each treatment process has two or more units in order to prevent discharging untreated sewage when one unit of treatment facility suddenly stops its operation.
- ✧ Disinfection facility is adopted to reduce the number of pathogens.
- ✧ The sand filters are adopted to reduce suspended solids in effluent in order to reuse it for gardening. The proposed capacity of filters in the Stage I will be planned equal to the total water tanker volume for sprinkling. Additional filters could be installed in the future to treat all the effluent flow.
- ✧ The civil structures of pumping house and sludge dewatering house are designed to meet future capacity in 2025. On the other hand, mechanical and electrical equipment are designed for the design flow of Stage I

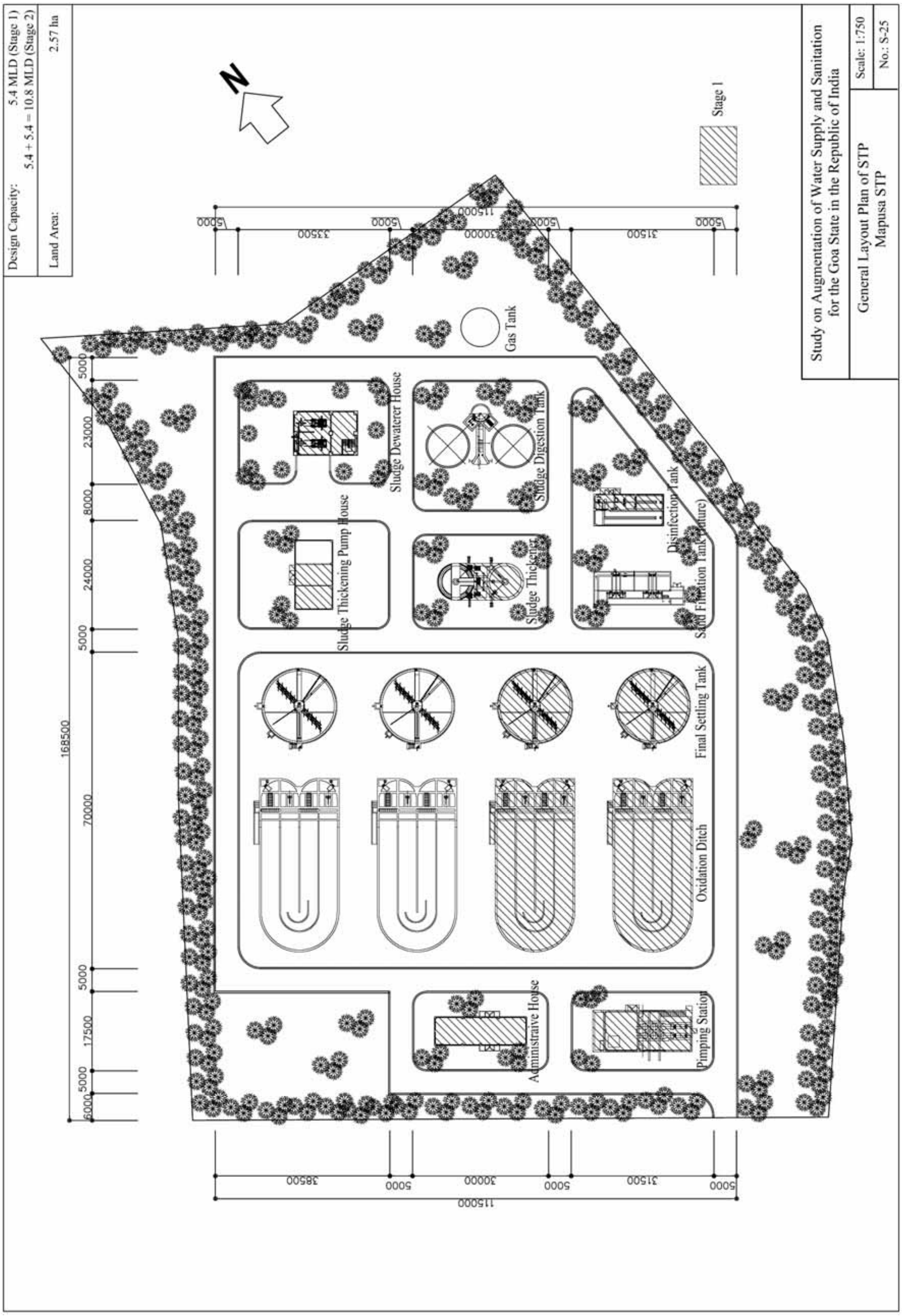


Figure 53.2 General Layout Plan of Mapusa STP

- ✧ Sludge digestion process will be installed in next stage, but not at the Stage I because sludge generation will be low at the start of operation
- ✧ Generator to avoid the overflow of sewage and to ensure continuous operation during power outages will be considered

The drawings of proposed facilities are shown in Volume IV.

(7) Staged Construction Schedule

Out of the proposed facilities in the Master Plan (2025), the proposed facilities are limited with the design flow for the first stage and the remaining facilities will be constructed by the year 2025. The capacity calculations of the proposed facilities are presented in Volume V Appendix F53.2 Capacity Calculation Sewage Treatment Plan (Mapusa). The summary of the proposed facilities are shown in Table 53.4.

Table 53.4 Summary of Expansion Facilities in Mapusa STP

Facility	Stage I	Future Expansion
Pump equipment	3 units	5 units
Mechanical screen	1 unit	2 units
Oxidation ditch tank	2 basin	4 basins
Final settling tank	2 basins	4 basins
Sand filtration tank	-	4 basins
Disinfection tank	2 passes	4 passes
Sludge thickening tank	1 basin	2 basins
Sludge digestion tank	-	2 basins
Gas tank	-	1 basin
Mechanical Dewatering	1 unit	2 units

5.4 North Coastal Belt

5.4.1 Population and Sewage Flow Projection

The Master Plan until 2025 proposed sewerage area of North Coastal Belt is composed with Calangute and Candolim, the STP is proposed in the northern end of the area named Baga. In this F/S, to collect sewage from main street of Calangute, which locates the northern half of this area, is the main objective, adjacent areas to be collected by Calangute No.1 pumping station are also be covered. Southern part of the north coastal area will be covered in the next stage.The general layout plan is shown in Figure 54.1 and the planned population, sewage flow and pollution load are presented in Table 54.1.

Table 54.1 Coverage Area, Population, sewage Flow and Pollution Load

		Unit	Stage I	M/P
Area	Calangute	ha	354	425
	Candolim	ha	47	200
	Total	ha	401	625
Population	Calangute	person	17,158	26,134
	Candolim	person	2,613	13,224
	Total	person	19,771	39,358
Sewage Flow		m^3/day	5,090	11,172
Pollution load	BOD	kg/day	1,258	1,061
	SS	kg/day	1,061	2,266

5.4.2 Sewage Collection System

Shape of North Coastal Belt area is long and thin in south and narrow. This area is rather flat topographically as a whole, but ground level of north and south ends is a little lower than the center of the area. Following two options are compared in Master Plan stage.

(Option 1) Two sewage treatment plants at north end and south end each
(Option 2) One sewage treatment plant at north end in Calangute

Option 2 was recommended because of easier and less operation and maintenance, in spite of higher initial costs than Option 1. Trunk sewer will be installed in the main street connecting Calangute Area of north and Candolim Area of south, collecting wastewater from resort area along the main street. Two pumping stations will be constructed for the trunk sewer. One is located at south end of Candolim; the other is at north in Calangute. Calangute No.1 Pumping Station, one of the two pumping stations will be constructed near the football stadium in lowland pocket of Calangute Area.

Some small pumping stations (manhole type) are necessary to carry wastewater generated in low land along coastline to the trunk sewer. At present, there are not enough local roads for branch sewers connected to the small pumping stations. Therefore, wastewater from the area along the trunk sewer should be collected by gravity for the time being. To collect more wastewater by gravity, earth covering of trunk sewer should be 3 m at least in Calangute area.

It is necessary to lay branch sewers under proposed roads or even in private land to reduce numbers of small pumping stations or initial costs.

Geographical survey showed the target area is covered with common soil or hard soil. Sewers suppose to be laid with no difficulty

The list of trunk sewer is shown in Table 54.2. Also refer to flow calculation sheet and longitudinal profile of trunk sewer in Volume V Appendix F52.1 Flow Calculation Sheet and Volume VI, respectively.

Table54.2 List of Sewers in North Coastal Belt

Category	Diameter (mm)	Length (m)
Trunk Sewer	200	515
	250	0
	300	0
	350	0
	400	0
	450	0
	500	409
	600	1,057
	700	1,613
	800	1,774
	Total	5,368
Branch Sewer	150	25,180

5.4.3 Pumping Station

Proposed Calangute No.1 Pumping Station of which capacity is 215.9 lps (13.0 m^3/min) with lifting head of 13.6 m has four submergible type pumps. As ancillary facilities, fine screens, sand pits and power generator will be installed. Plan of the Pumping Station is shown in Volume IV. General plan of the Pumping Station is shown in Volume IV. Also, capacity calculation of the pumping station is shown in Volume V Appendix F52.1 Flow Calculation Sheet.

Table 54.3 Facility and Equipment List of Calangute No.1 Pumping Station

Design Flow (peak) (lps)	Pump					Pressure Main	
	Capacity		Head (m)	Motor Power (kW)	Nos. of Pump	Diameter (mm)	Length (m)
	(lps)	(m^3/min)					
215.9	54 108	3.3 6.5	13.6	12.9 25.8	2 + (0-standby) 1 + (1-standby)	400	478
Ancillary facilities: Fine screen, sand pits, power generator							

5.4.4 Sewage Treatment Plant

(1) Basic Conditions for the Design of Sewage Treatment Facilities

The basic conditions for the design of sewage treatment plant in the Stage I are presented in Table 54.4.

Table 54.4 Basic Conditions for the Study of Baga STP

Item	unit	Stage I	Future Expansion
Target year	-	2015	2025
Available land area	ha	2.07	
Service population	person	21,000	39,400
Design Flow	m^3/day	**5,500**	**11,200**
Sewage quality		In	Out
BOD	mg/l	240	30
SS	mg/l	200	50

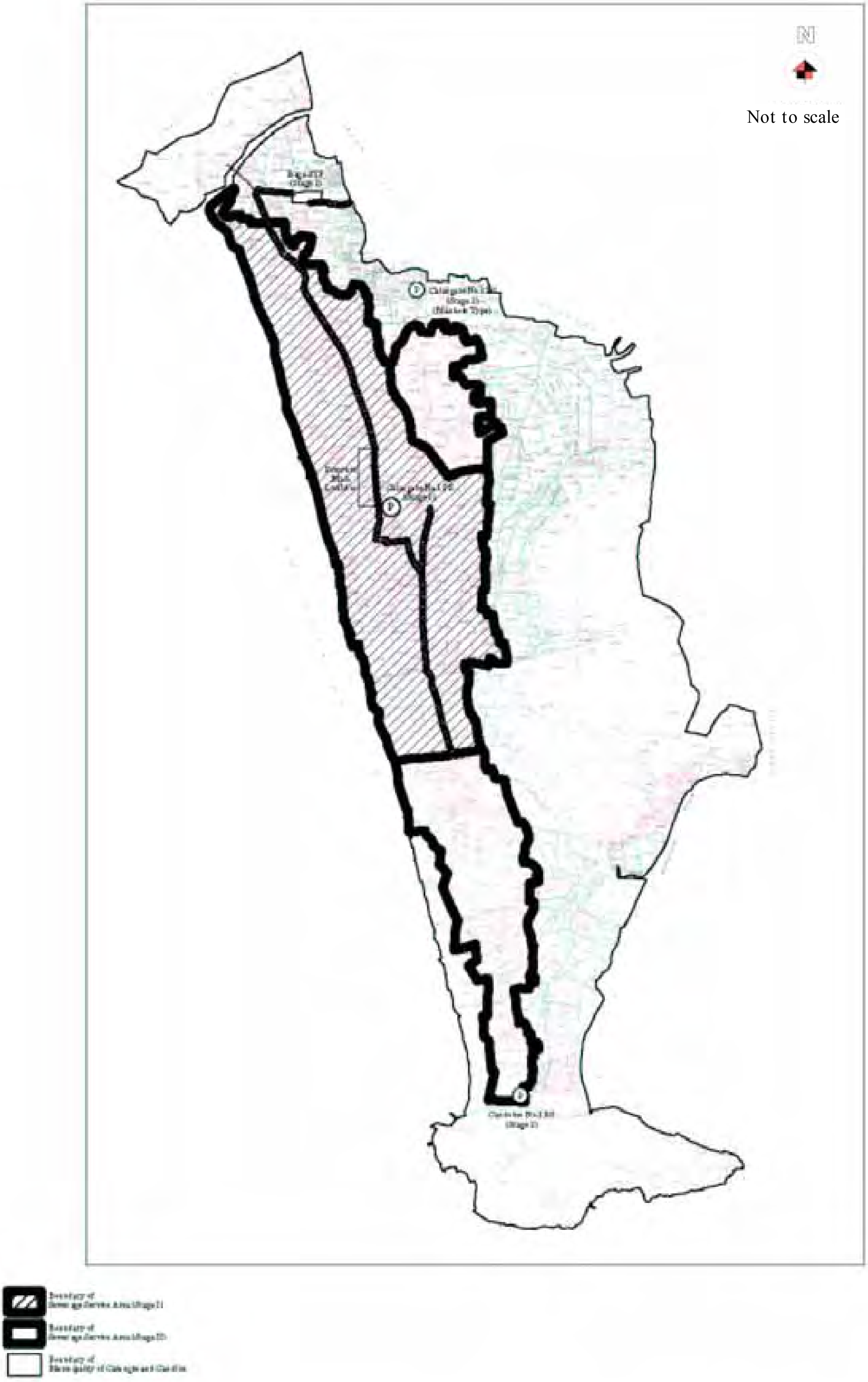


Figure 54.1 General Layout Plan of North Coastal Belt

(2) Site Condition for Proposed STP

The proposed STP site for North Coastal Belt should satisfy the following conditions.

- ✧ Land is large enough to accommodate the proposed facilities adequately
- ✧ Proposed site locates close to the discharging river
- ✧ Environmental least impacts to the surrounding areas are expected
- ✧ Easy to acquire land for the proposed STP

In this Study, the selected STP site is the governmental land near the river as shown in Figure 54.1 and it could be acquired at no cost. The ground level in the proposed STP is decided based on the result of site topographical survey. The summary of the proposed STP site condition is presented below.

Required land Area : 2.07 ha
Ground Level : +1.50 m above sea level

(3) Plant Hydraulics

Due to no data of high water level of river at the effluent discharging point of Baga STP, the hydraulic study of proposed facilities is calculated based on the highest discharging water level in the section of Baga river and the vertical level of facilities are decided to avoid no impact of backwater from river. The drawing of hydraulic profile of Baga STP is shown in Volume IV.

(4) Facility Layout Plan

The layout plan of the proposed facilities is prepared considering the following aspects.

- ✧ Proposed inlet trunk sewer locates at the west of the STP site
- ✧ Discharging river of treated water locate at the east
- ✧ Nearest residents locate at the west of site
- ✧ Trees should be planted along the perimeter of the new STP
- ✧ Proposed sewage and sludge treatment facilities are placed taking into account the easy O&M and staged construction

As the result, general layout plan of Baga STP is shown in Figure 54.2.

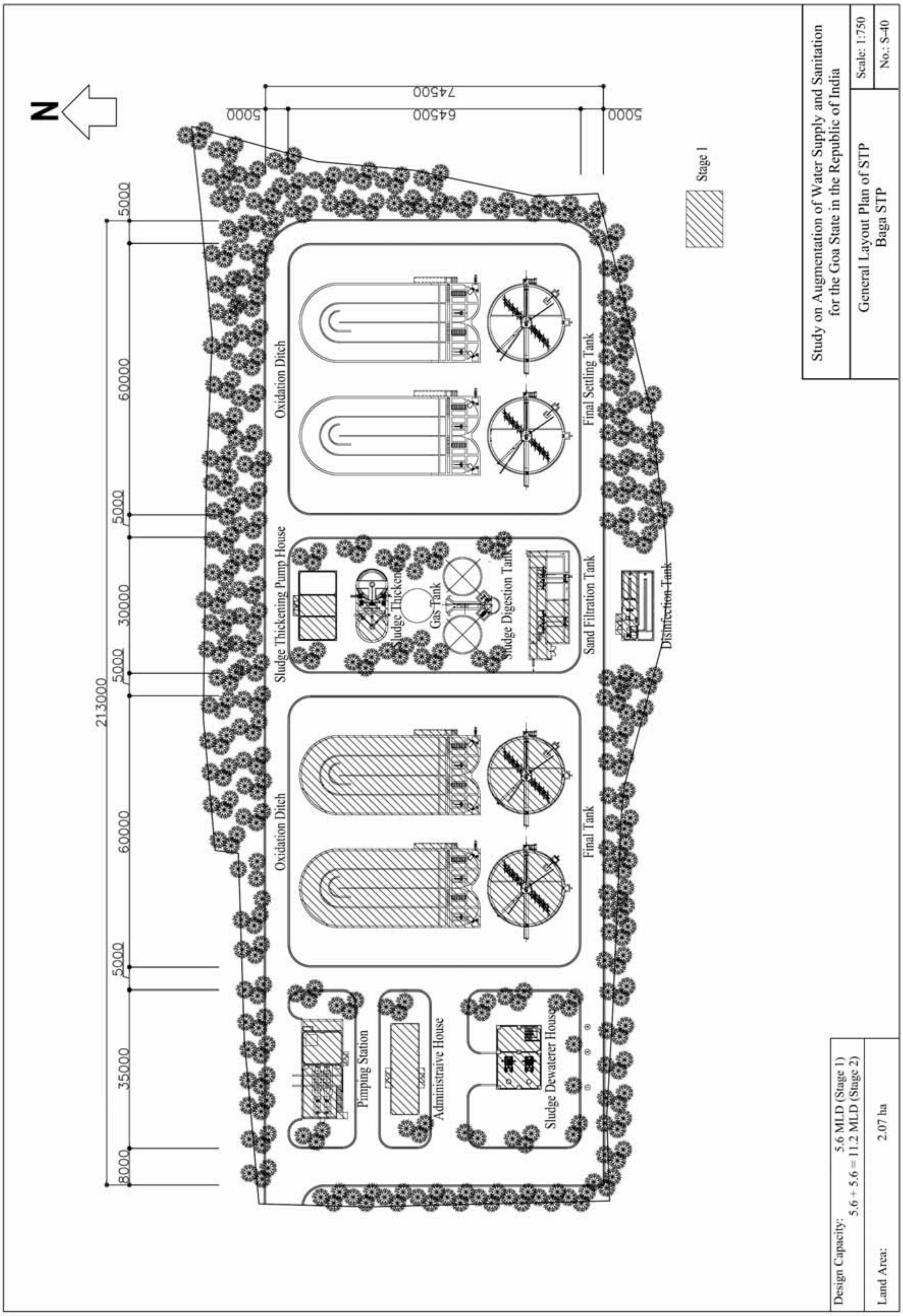


Figure 54.2 General Layout Plan of Baga STP

(5) Odour Control Considerations

In the study of Baga STP, mitigation measures for offensive odour should be same as those for the Margao STP discussed in Chapter 5.2.4.

(6) Proposed Facility Plan of Baga STP

The facility plan of Baga STP is proposed considering the following items.

- ✧ Each treatment process has two or more units in order to prevent discharging untreated sewage when one unit of treatment facility suddenly stops its operator.
- ✧ Disinfection facility is adopted to reduce the number of pathogens.
- ✧ The sand filters are adopted to reduce suspended solids in effluent in order to reuse it for gardening. The proposed capacity of filters in the Stage I will be planned equal to the total water tanker volume for sprinkling. Additional filters could be installed in the future to treat all the effluent flow.
- ✧ The civil structures of pumping house and sludge dewatering house are designed to meet future capacity in 2025. On the other hand, mechanical and electrical equipment is designed for design flow of Stage I
- ✧ Sludge digestion process will be installed in future because sludge generation will be few at the time of starting operation
- ✧ Generator to avoid the overflow of sewage and to ensure continuous operation during power outages will be considered
- ✧ A part of treated effluent is treated by sand filters for reuse as gardening water. The remaining treated effluent is also treated to reduce the suspended solids because it is discharged near to the world famous beach resorts.

The drawings of proposed facilities are shown in Volume IV.

(7) Staged Construction Schedule

Out of the proposed facilities in the Master Plan (2025), the proposed facilities are limited with the design flow of the Stage I and the remaining facilities will be constructed by the year 2025. The capacity calculations of the proposed facilities are presented in Volume V Appendix F53.3 Capacity Calculation of Sewage Treatment Plant (Baga). The summary of the proposed facilities is shown in Table 54.5.

Table 54.5 Summary of Expansion Facilities in Baga STP

Facility	Stage I	Future Expansion
Pump equipment	4 units	5 units
Mechanical screen	1 unit	2 units
Oxidation ditch tank	2 basin	4 basin
Final settling tank	2 basins	4 basins
Sand filtration tank	2 basins	4 basins
Disinfection tank	2 passes	4 passes
Sludge thickening tank	1 basin	2 basins
Sludge digestion tank	-	2 basins
Gas tank	-	1 basin
Mechanical Dewatering	1 unit	2 units

5.5 Operation and Maintenance Plan for Sewer Network

(1) Sewer

Sewer cleaning plan as the operation and maintenance for sewage collection system is discussed in Volume03Chapter06.

1) Inspection of Sewers

Besides the sewer cleaning activities, inspection of sewage collection system is also a very important activity as part of the operation and maintenance of sewers. Two major purposes of inspection are to prevent leaks from the sewage collection system and to identify existing leaks. The existence of leaks in a collection network is a serious and often expensive problem.

Closed-circuit television (CCTV) has been used for the inspection of sewers. A CCTV inspection consists of a special television camera passing through the sewer with the picture being observed on a monitor. This picture allows a visual inspection of the internal of sewers.

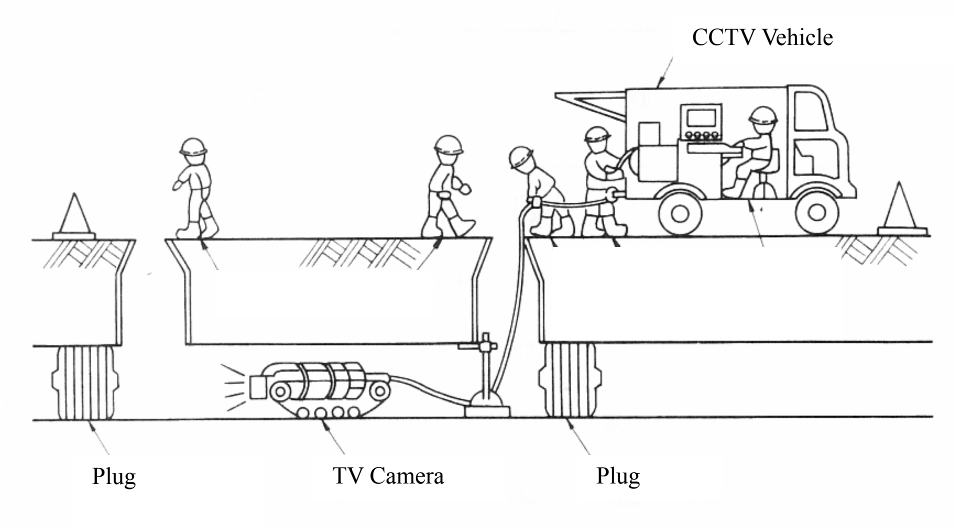


Figure 55.1 Inspection of Internal Sewers

2) Rehabilitation Method of Existing Sewers

Rehabilitating the existing collection system includes upgrading structural aspects of sewers. Structural rehabilitation can include repair and renovation or renewal of pipes. Over the past three decades, numerous methods have been developed to repair collection system. At present, various rehabilitation techniques are suited to solving particular performance problems and could enhance or adversely affect others. The applicable pipeline rehabilitation methods are shown in Table 55.1.

Table 55.1 Sewer Rehabilitation Methods

Rehabilitation Method	
1. Pipe linings	Slip lining
	Segmental linings
	Coatings
2. Pipe replacement	Open cut replacement
	Trenchless replacement
3. Mechanical sealing	

(2) Pumping Station

1) Emergency Maintenance

Emergency maintenance is a form of corrective maintenance that occurs when a piece of equipment or system fails, creating a threat to public health or equipment. This is a special case of corrective maintenance in which the unscheduled failure of a system or piece of equipment could have a severe or catastrophic effect.

2) Preventive Maintenance

Preventive maintenance is defined as routine, scheduled activities performed before equipment failure for the purpose of extending service life of equipment, reducing O&M costs and increasing reliability. Maintenance programs should devote appropriate level of resources to preventive maintenance. Recommended typical preventive maintenance tasks and frequency are shown in Table 55.2.

Table 55.2 Recommended Preventive Maintenance and Frequency

System	Daily	Weekly	Monthly	Semi-annual	Annual
Gates	○	-	○	-	-
Screens	○	-	○	-	-
Pumps	-	○	-	-	○
Motors	-	○	-	-	○
Valves	-	○	-	-	○
Electrical Equipment	-	○	-	-	○
Generator	○	-	-	○	-
Dredging tank	-	-	-	-	○

Source: Wastewater Collection Systems Management, Fifth Edition

(3) Sewage Treatment Plant

The operation and maintenance of STP is one of the most important subjects. The sewerage system quickly removes wastewater generated from the urban area, and prevents the pollution of public water bodies. These objects of the sewerage can, therefore, only be attained not only by constructing the facilities but also by carrying out sufficient operation and maintenance.

The operation and maintenance of STP is largely divided into three tasks, operation, maintenance, and ledger, daily/periodical report.

1) Operation Task

The operation task includes the following:

- ✧ Receive instructions from laboratory and adjust the operating conditions of specific treatment process (if necessary)
- ✧ Monitor the operating conditions of equipment and record the running conditions
- ✧ Apply immediate relief measures in abnormalities and break down of equipment

This work is relatively easy when the system operates without abnormalities, but it is of importance that training be given occasionally to assigned operators at the plant so as suitable relief measures can be taken in any emergency cases.

2) Maintenance Task

The maintenance task is an important work for keeping the mechanical and electrical equipment in proper conditions to prevent occurrence of any troubles and accidents. When the maintenance is properly done, it is also possible to expect the extension of service life of the equipment. The maintenance of machines and equipment can be classified according to the frequency of execution as follows:

a. Daily Inspection

The daily inspection is to check the existence of abnormality by inspecting facilities for the operating status, everyday at fixed time. The result of inspection is recorded in the daily inspection list.

b. Preventive Maintenance

The preventive maintenance is carried out in accordance with the maintenance procedure sheet. This maintenance is done to clarify the status such as deterioration of facilities, and to conduct repairs and improvement works as scheduled. If any defective part is found by this task, it is immediately replaced with suitable measures. Preventive maintenance is carried out in accordance with the yearly execution schedule.

3) Ledger, Daily/Periodical Report

a. Ledger

Since ledgers are the basis of the sewerage management, they should be arranged so as the whole sewerage system can be stored properly. Ledgers related to the operation and maintenance of the treatment plant are fixture ledger, facility ledger and work history ledger.

b. Daily and Monthly Report

The operation daily report is to briefly report the working conditions of the facilities to supervisors and others concerned.

The operation monthly report and annual report are to summarize the results of operating for each month and year, and are stored. These records will be reflected to the method of subsequent operation, and the improvement plans of facilities.