No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NATIONAL WATER SUPPLY AND DRAINAGE BOARD
MINISTRY OF HOUSING AND PLANTATION INFRASTRUCTURE
DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

THE DETAILED DESIGN STUDY ON GREATER KANDY WATER SUPPLY AUGMENTATION PROJECT IN THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FINAL REPORT

VOLUME II-2

MAIN REPORT (2)

MAY 2002

NJS CONSULTANTS CO., LTD.
NIHON SUIDO CONSULTANTS CO., LTD.

Executive Summary

The Final Report, Volume II-2, Main Report (2) provides a study result of the detailed design for the Kandy Water Supply Augmentation Project in succession to the design concepts established in the Interim Report (2). Major equipment and plant designed is summarised as shown in the proposed scope of works attached hereunder.

1.0 Introduction

The detailed design of Greater Kandy Water Supply Augmentation Project was initiated by the Government of Japan (GOJ) upon a request made by the Government of Sri Lanka (GOSL) for technical assistance. The agreement for this assignment was signed between the Ministry of Urban Development, Construction, and Public Utilities, and National Water Supply and Drainage Board on behalf of GOSL, and Japan International Cooperation Agency on behalf of GOJ on 19th September 2000. This study is an extension of the original "Master Plan Study on the Greater Kandy and Nuwara Eliya Water Supply and Environmental Improvement Plan" (JICA F/S) conducted by JICA from February 1998 to February 1999, under a similar agreement between GOJ and GOSL.

The need for this study has arisen as the rapid development of Kandy City and its suburban areas had rendered the existing water supply systems highly inadequate to meet the current demands, and was in a dire need for augmentation in order to give impetus for the continued development, which was hindered by water shortage. This situation was foreseen before by a comprehensive Master Plan prepared by the NWSDB through the financial assistance provided by the Finnish International Development Agency (FINNIDA) in 1994, but the implementation of the proposals was aborted due to FINNIDA funding coming to an end.

At the commencement of the detailed design, a review of the original JICA Feasibility Study (JICA F/S) was carried out, which had already prepared the preliminary designs, and set out the extent of funding, with a view to updating the records and to make any changes necessary, which may have taken place during the ensuing period after completion of the JICA F/S in 1999.

In addition, studies were carried out to determine the effects of the discharge of untreated wastewater from the Kandy Municipal Council (KMC) area and other water sheds upstream on the raw water quality of the proposed Intake at Gohagoda on the Mahaweli River, and concluded that the proposed intake site is safe for use. On completion of Phase 1, the review of previous JICA F/S in April 2001, the basic design for the Project was prepared to set up the design concept for the Project. This Main Report (2) encompasses a result of detailed design of the comprehensive water supply systems including raw water intake, water treatment plant, clear water transmission pipelines, service reservoirs, and distribution networks.

2.0 Water Demand and Supply

Greater Kandy includes KMC area and parts of ten adjoining Pradeshiya Sabahs, namely Kandy Four Gravets, Akurana, Harispattuwa, Pujapitiya, Kundasale, Patha Dumbara, Patha Hewaheta, Udunuwara, Uda Palatha and Yatinuwara. This area covers about 460 km^2.

The 1999 JICA F/S determined the proposed service areas on the basis of population density, water demand, present status of the existing supply and service level, areas where there were applications for new service connections but not yet fulfilled, potential new areas which were currently served by individual wells etc. The existing systems covered about 20 percent of the geographical area of Greater Kandy, which was expected to be extended up to about 50 percent in the target year of 2015.

Together with these data, appropriate unit consumption rates also have been evolved, by comparison of the previous consumption rates and the increase in consumption that could be expected due to the improvement of service level to 24 hours of adequate supply, water losses etc.

The projected total population, the projected service population and the water demands are tabulated in the following table.

Description	2000	2005	2010	2015
Total Population	672,400	717,600	762,900	810,100
Coverage (%)	85.4	85.8	86.4	86.9
Served Population	574,200	615,800	659,400	703,600
Water Demand (m^3/d)	119,474	122,900	133,400	141,600

From above analysis it is seen that the current water demand is 119,474 m^3/d, whereas the current total production is estimated to be approximately 94,000 m^3/d, indicating already a 20 percent short production, which will aggravate as some of the existing systems will have to be abandoned in the near future due to their unreliable nature of water sources.

The proposed augmentation is scheduled to be implemented in 3 phases, in steps of 36,670 m^3/d in each Phase, and the water balance will be as follows.

Description (m^3/d)	2005	2010	2015
Daily average water demand	122,900	133,400	141,600
Daily max. water demand	147,430	160,040	169,980
Continued existing sources	64,960	64,960	64,040
Deficit over demand in ave.	56,940	67,440	77,560
Deficit over demand in max.	82,470	95,080	105,940
Augmented supply by new plant	36,670	73,330	110,000
Deficit over demand after augmentation in ave.	20,270	(5,890)	(33,440)
Deficit over demand after augmentation in max.	44,800	20,750	(5,060)

Thus, it is seen that in 2005 a significant short supply of water will prevail despite implementation of Phase 1 Project. This will be improved with the implementation of Phase 2 in year 2010 in the daily average demand basis. The full advantage of the Project will only be realised in year 2015 with the implementation of the Phase 3 Project. The water balance can be graphically represented as below.

3.0 Proposed Water Source

Greater Kandy has 33 existing water supply systems using surface water and ground water sources with a total production of approximately 90,000 m^3/d. The major source of surface water is Mahaweli River and its tributaries such as Nilambe Oya and Hulu ganga. There are also a number of other tributaries, which can be developed as water supply sources with proper water management, but not utilised to-date, as well as certain others, which are polluted and unsuitable as they dry up during the drought season.

The ground water sources are also associated with their own problems such as deteriorating yield of boreholes, drying up during the drought season, high hardness and iron content and lowering of water table in the surrounding area. The lowering of the yield in turn causes pumping problems as the pumps were designed for the originally determined safe production capacities, and in the present context these are mismatching.

The proposed source for the augmentation system is the Mahaweli River at Gohagoda is acceptable both quantitatively and qualitatively, located at 4.1 km upstream of the Polgolla Dam. The total designed capacity of the system is 110,000 m^3/d in Phase 3. The existing system based on the Mahaweli River is already drawing approximately 53,000 m^3/d, of which

KMC is a major consumer drawing 33,400 m^3/d.

According to the past records, the Mahaweli River Authority has set the minimum flow of the river at 180,000 m^3/d, except in extremely dry weather conditions. Furthermore, NWSDB has obtained water rights to use 180,000 m^3/d for water supply purposes. This quantity is quite feasible to supply by regulating the discharge at upstream of the Kothmale Reservoir. The augmentation proposal requires 110,000 m^3/d, and after adding the current abstraction of 53,000 m^3/d, there is still a surplus remaining of the total water rights for further use. However, under extremely dry weather conditions the restriction of the supply will become inevitable, as well as to preserve and re-activate the existing ground water systems, to supplement the supply.

The studies carried out during the current phase has confirmed that the raw water quality at the proposed intake site is safe, as the effect of the untreated waste water discharged from the KMC area and Gohagoda and Asgiriya watersheds upstream of the intake site is insignificant, as the quantity of river flow before these pollutant sources is more than 100 times that of major pollutant source. Studies have confirmed that the raw water could be treated by conventional water treatment process to satisfy the required drinking water quality standards.

4.0 Gohagoda Intake and Katugastota Water Treatment Plant

The experience gained in rehabilitation of the existing Ambatale Treatment Plant in 1992, and the field proven performance of other existing treatment plants in Kandy area has greatly inspired the design of intake and treatment plant of this project. This experience and the extensive studies carried out conclude that a conventional treatment plant is appropriate in this context, taking account for the following technical principle.

- To the maximum extent possible, the use of mechanical equipment should be limited for easy operation and low maintenance,
- Hydraulically based devices that use gravity for works such as rapid mixing, flocculation, and filter rate control are preferred over mechanised and/or automated equipment in consideration of the available favourable topography of the plant site,
- Mechanisation and automation are appropriate only where operations are not readily accomplished manually, or where they greatly improve the reliability assuring safe and stable water supply, and
- Indigenous materials and products that are easy and safe for use in construction should be used to reduce costs, and to bolster the local economy and expand industrial development.

The proposed intake is located 4.1 km upstream of the Polgolla Dam (max. flood water level 441 m AMSL). The intake installation will consist of two trains of coarse and fine screens, and grit chambers to remove particles larger than 0.1mm, with facilities to isolate grit chambers without interrupting the operation. Two pumps will be installed each with a capacity of 38,500 m^3/d in Phase 1, providing 100 percent standby capacity. The conveyance of raw water to the treatment plant is by a ductile iron pressure and gravity pipeline combination through a balancing tank which avoids negative pressure occurred along the pipeline.

At the treatment plant coagulation process will take place at the distribution chamber by rapid mixing of 10 percent alum solution through a hydraulic jump created inside the chamber. In the event the alkalinity of raw water is below 20 mg/1 pre lime will be added for pH adjustment using 10 percent lime solution. The maximum dosage of alum will be 30 mg/1, but provision will be made up to 60 mg/1. Similarly, the maximum dosage of lime will be 10 mg/1 but with provision for 30 mg/1. In addition pre chlorination will be applied using gas chlorinators. This is followed by hydraulic flocculation by making use of the gravity flow available. As the turbidity of raw water varies over a wide range horizontal flow sedimentation system is recommended for sedimentation process.

Rapid sand nitration is proposed for the filtration process with silica sand as the filter media, which is proved to be very effective in the past. The backwashing of the filter bed is by air scouring and backwash water obtained from the filtered water effluent tank. A constant rate filtration will be employed with influent and effluent control by weirs. The underdrain system will consist of nozzle type strainers where supporting gravel is none or minimal. Filtered water will introduce to the clear water reservoir designed in two compartments with provision for isolation of each compartment and with baffles to avoid dead zones.

The sludge generated in the sedimentation basins will be hydraulically withdrawn to sludge lagoons, dried and disposed of outside the plant periodically. All site pipe work as well as electrical distribution, grounding systems, and instrumentation wiring will be underground.

A two storey building is planned for administrative facilities as well as for storage, laboratory etc. More than 80 staff members will be accommodated in this building. In addition a single storey maintenance building will be constructed for maintenance purposes. The layout of the facilities has been done in the most prudent manner, making best use of the orientation and the difference in ground levels of the available land.

5.0 Transmission and Distribution System

After finalising the Phase 1 service areas, these were designated into 11 different service zones, to facilitate supply of water to the Greater Kandy area, namely KMC area and its suburbs to the south, east and west by KMC WTP, and to supplement the short production at KMC's northern boundary, from the proposed Katugastota plant. All the remaining areas are to be served from the Katugastota Plant.

The further studies during the detailed designs reaffirmed the basic concepts m JICA F/S, and also paved way to include far reaching improvements to certain proposals. This led to exploring more economical or effective alternatives with the maximum use of existing pipelines, and minimising the reinforcement of distribution system to meet future demands. Alternatives were considered for the staged laying of the transmission mains to choose the most appropriate cost effective sequence of construction in the three Phases. The availability of way leave on major roads and other likely problems to lay the pipes at different Phases was also analysed.

There are 21 service reservoirs outside KMC area and 8 within KMC under Phase 1 area, totaling 29 service reservoirs. The location of the 19 new service reservoirs including 6 for expansion was decided on the results of the topographic surveys. The respective service areas for each service reservoir was determined based on the pressure contours, with the widest possible coverage given for gravity flow. Where the ground elevations did not ensure proper coverage, elevated reservoirs were planned. Some reservoirs are proposed to supplement the existing ones. These are designed to retain about six hours maximum day demand of the respective service areas. The reservoirs will be designed according to the standard methods, and hence no maintenance or operational problems are expected, including auto-starting and auto-stopping of the pumps at the treatment plant. The necessary areas for the extension of the existing distribution systems have also been identified. Within KMC area six new service reservoirs are planned, of which one will be constructed by the KMC under ADB programme. These, with the other existing two reservoirs will cover the entire KMC area.

6.0 Mechanical Facilities

The raw intake pump from the Mahaweli River is planned for Phase 1. Vertical double suction volute pumps are proposed considering their less installation space, easy access and maintenance, and high efficiency as compared with horizontal double suction pumps, submersible pumps and wet well vertical mixed flow pumps. In order to accommodate the wide range of variation of the water level of Mahaweli River, variable speed pumping is recommended due to simple continuous setting, and low operating cost as against the valve control and operating pump number control system. The speed control can be automatically accomplished by signals transmitted by a flow meter installed on the raw water pumping main.

The sludge generated in the sedimentation basins will be scraped off by reciprocating flight sludge collector. This type is chosen for its low cost and easy maintenance, over other two major types of chain flight and travelling blade sludge collectors.

The pumping from the clear water pump station is planned for 3 zones for Phase 1. Dry well double suction volute pumps are recommended, similar to the raw intake pumps.

Booster stations are provided for nine transmission systems at seven service reservoirs. The pumps will be designed for Phase 3 requirement except for Kahawatte/Kurugoda and Asgiriya/Bahirawakanda lines as the increase in flow in Phase 3 is over 50 percent of Phase 1. Flows are relatively small and hence end suction volute pumps or multi-stage pumps are recommended.

It is necessary to stop pumping when the service reservoirs are full and the float valve is closed. This will be achieved by installing a flow meter to monitor no flow condition on the delivery main, which will then activate a control system to stop pumping at no flow. The pump will be subsequently re-started by a timer after the lapse of a certain predetermined period of time or manually.

7.0 Electrical Systems

The electrical system for the proposed intake, treatment plant and the booster pumping stations will be designed to comply with CEB, latest IEE (London), ISO, IEC, BS and J1S standards. In this connection, highest priority will be given for reliability, safety, economy, simplicity, easy and fault free control and operation, and easy maintenance aspects. The design will guarantee the operation of the full plant at any instant, with any fault arising in any component being isolated without affecting the overall operation, safeguarding the continuity of operations.

The main power supply will be obtained from CEB, supplemented by stand-by generators (stationary and mobile types) to use in the event of power failures, which are very common and frequent at present. The main transformer unit will consist of a minimum of two numbers, with each having capacity to operate 2/3 of the full facility, enabling the operation of the plant at a time one transformer is out of service. The power factor will be kept at 95 percent and will be adjusted automatically by APFC.

Although 3 kV is specified for motors above 300 kW, 400 V supply will be used to operate the high lift pumps (max. power output 450 kW), considering the ease of maintenance and economy. Also for efficient operation variable speed pumps will be used for the high lift pumps. All installations will be protected from lightening as per BS 6651: 1985, over current, grounding fault, lack of phase, and imbalance of three phases by suitable protective devices. The facilities will be designed for manual control at local control stations as well as central auto-controlling, by installing necessary local control switches at local stations.

There will be 24 hour monitoring of the operation of intake and treatment plant linked by a dedicated telecommunication line and the reservoirs by a general telecom line. Alarms will be provided to alert of any malfunctions of certain critical operations at the intake, treatment plant, and reservoirs. The incoming data will be stored in the server in the central monitoring room and processed simultaneously.

8.0 Construction Method

The construction methods for the works are to be decided on the results of surveys, tests and investigations carried out previously. It is of prime importance to maintain the traffic flow at a satisfactory level without causing a major breakdown and access shall be maintained to all properties where the construction works are in hand. When traffic breakdowns are inevitable night work should be planned for roads like A9 road.

The contractor is responsible to maintain all utilities intact without causing damages, and if there is an interruption of water supply he should arrange alternative ways of water supply to the affected consumers.

For the execution of the contract efficiently the contractor is expected to establish a central office at Katugastota WTP site and three other field offices at Gohagoda Intake site, nearby Kahawatte reservoir site and periphery of Asgiriya reservoir site to cover activities in central, northern and southern zones. The Katugastota office will accommodate the Engineer's and Consultant's staff as well who will supervise the works.

The most difficult and complicated works are involved at intake and treatment plant sites where access roads, bulk earthwork, diversion of existing waterways, coffer damming, sheet piling, and dewatering, construction of huge concrete structures and installation of mechanical and electrical equipments etc. are involved. Other works also require careful studies and planning and therefore basic guidelines have been furnished in this main body to assist the Contractor to plan his work. The site conditions, and the design requirements have been very closely studied in the preparation of these guidelines. Furthermore, all works are expected to be tested, disinfected and approved by the Engineer before commissioning and taking over.

9.0 Operation and Maintenance Programme

The objective of a water supply system is to ensure an uninterrupted supply of adequate and safe water at a reasonable cost to the consumers. This can be achieved by proper operation and maintenance procedure, to maximise the functions of the equipment/facilities, extend the useful life and avoid the costly repairs. For this, it is vital to maintain a close liaison among the different individual parties handling the operation, maintenance, material control and procurement activities. Notwithstanding, there should be adequate provisions in the O & M budget to procure the necessary maintenance resources to work at an optimum level.

Regular patrol/inspection are required for each equipment/facility and the findings should be relayed to the maintenance crew for appropriate action. The measurement of the intake and treated water quantities, and water levels of reservoirs is also a principal activity to meet demand fluctuations. The procedures and methods for regular maintenance also should be standardised and systematised to make them more effective and efficient. Some equipment, facilities and processes need daily inspections, whereas some others need at longer intervals and these have been identified.

When the useful lifetime of equipment/facility is expired the efficiency will be declined though it had been properly maintained, and repairs must have to be planned. The previous maintenance records will give some insight into the timing of the repairs.

To guarantee proper water quality, measures have to be taken to maintain the source of water as clean as possible and to prevent contamination through the transmission and distribution systems. There are certain identified extreme situations causing the water unsafe at the source of water or at the treatment plant, whereby the water supply will have to be immediately stopped until the cause is eliminated.

In order to operate and maintain this Project, a Manager in the rank of an AGM will be appointed under whom 5 sections namely, production, transmission, water quality, maintenance and administration will function with a total staff strength of 80 personnel.

A total of 80 million Rupees is estimated for operation and maintenance annually, including such expenses as personnel, electricity, chemical, repair, etc.

10.0 Implementation Plan and Project Cost

The cost of implementation of this Project is to be met by a credit from JBIC in Japanese Yen currency. NWSDB will be the agency responsible for the implementation under the supervision of the Ministry of Housing and Plantation Infrastructure.

The same Project Director who headed the PIU during detailed design should continue to supervise the construction works with the assistance of the consultants. The role of the PIU will consist of the management of project, coordination with other divisions of NWSDB and concerned organisations of GOSL, coordination of tendering procedure and implementation of examinations and investigations which may become necessary.

A consultancy contract for contract supervision and a construction contract with selected Japanese companies are to be concluded by NWSDB, with JBIC concurrence. The roles of various organizations connected with the implementation are set out in the Implementation Organization.

The selected construction contractor shall be an individual Japanese company with civil, mechanical and electrical capabilities, a joint venture or partnership of Japanese companies qualified in the three fields, a Japanese civil or mechanical/electrical contractor with Japanese or a Sri Lankan mechanical/electrical or civil sub contractor.

The construction period is determined to be 33 months of which 3 months are allocated for operation and maintenance assistance after completion of construction works. The adverse weather conditions have also been taken into consideration in determining this period. Thus the works are scheduled to be commenced in early 2003 and completed in late 2005.

Since none of these facilities can be put into operation by itself or ahead of the other connected structures, the responsibility to complete on schedule should remain with a single contract.

However, RDA schedules to renovate the Wattegama Road under financed by ADB, along which part of the transmission main with diameters of 300 and 600 mm is to be laid. RDA has planned to rehabilitate shortly and advised the NWSDB that this pipeline should be laid before their rehabilitation.

The construction contract packages are, therefore:

- Package 1: Construction Work for Greater Kandy Water Supply Augmentation Project
- Package 2: Construction Work for Water Transmission Main Along Wattegama Road

Package 1 and pipe procurement of Package 2 will be contracted under the JBTC Special Yen Loan. Pipe laying may be implemented under local competitive tender procedure, using NWSDB’s counterpart fund.

A total of Project budget founded by JBIC for Package 1 and 2 is 4,732 million Japanese Yen including the Civil Works and contingencies the estimated cost is approximately 4,995 million Japanese Yen which exceeds the budget by approximately 263 million Japanese Yen or 5.56 percent. A total cost of the estimated Japanese goods and services is 3,123 million Japanese Yen, which is 58.53 percent of the Project Cost and fulfil the requirements of Procurement Procedure of the JBIC Special Yen Loan.

The cost estimates still include 58.53 percent of Japanese services and goods. There is a possibility that during competitive tendering this difference may be levelled off at some certain percentage and the budgetary allocation would not be disturbed, provided that the Tenderer puts considerable efforts into reducing the price by optimising the procurement rate of Japanese goods to be 50 percent. One example shows that the total project cost estimated is approximately 4,728 million Japanese Yen and 50 percent of Japanese services and goods in assuming lower cost of small pipes and imported reinforcement.

11.0 Recommendation Towards Project Implementation

The overall construction period is estimated to be approximately 30 months after the award of contract. There are several factors causing for critical delays for the implementation programme such as land acquisition, approvals required from various authorities for buildings, structures and pipe laying, CEB power supply, securing of borrow areas. Hence, these issues need to be resolved expeditiously for the timely completion of the Project.

During the pre-construction phase it is mainly the liaison with the concerned authorities namely RDA, CEA, UDA, Police, KMC and PSs to procure particular building/structure and pipe laying approvals necessary. Liaison with JBIC is necessary both before and after prequalification and tendering with the necessary documentations to receive its concurrence.

NWSDB will have to secure its budget to meet the expenses, which are essential, but left out in the Loan Agreement. These include general administration costs, taxes and duties, land acquisition, compensation and other expenses. In addition, securing of borrow fill areas, sludge disposal sites, garbage removal from the Gohagoda site are as well priority requirements.

Dependent on the Tender result, NWSDB may secure additional budget for the overrun portion for the Civil Works, which covers the balance between the bid price and JBIC funded budget, unless otherwise the scope of work may not be adjusted.

It should also not be forgotten that although the water quality of the Mahaweli River is currently acceptable as the source of water with the type of treatment proposed, there is a potential risk that the quality of water deteriorating in the future due to enhancement of various activities causing pollution, which will further aggravate during the dry seasons when the flow drops very low.

During the Construction Phase NWSDB has to finalise its organisation set up for the operation and maintenance of the Project after completion. This includes procurement of well experienced and responsible 0 & M staff, and training them not only in operation of the plant but also in preventive maintenance to guarantee the smooth, efficient and trouble free operation over its full designed lifetime. Apart from it, NWSDB will have to secure the budget necessary to meet the 0 & M cost after commissioning.

During post construction phase preventive maintenance will play the major role to guarantee the full life span of the Project. The 0 & M manuals prepared by the consultants and the training given to the staff during pre-construction period will be of immense benefit to achieve the desired objectives. Nevertheless, despite enforcement of proper preventive maintenance procedures, after long years of operation of equipment, facilities and integrated systems may deteriorate, and may require large scale rehabilitation/improvement programmes in order to restore them to their original condition or to upgrade their efficiency. Thus, NWSDB must secure the depreciation budget to meet such costs in future.

(Continued)

Scope of Works of Detailed Design

No.	Description	Original Scope of Works		Proposed Scope of Works	
		Specifications	Nos.	Specifications	Nos.
1.	**Construction of Intake facilities and Raw Water Transmission facilities**			←(no change)	
1)	- Intake structure	38,500 m³/day	L.S.	←	←
2)	- Pumping station	Q=446 l/s, H=50m	2 sets	←, H=44m	←
3)	- Water conveyance pipeline	DCIP ø 800	2.200m	ø 800, ø 1000	1049, 442 m
2.	**Construction of Water Treatment Plant**				
	(Coagulation and rapid sand filtering system)	36,670 m³/d	L.S.	←	←
3.	**Construction of Water Transmission Facilities**				
	- Pump facilities (including one stand by each)				
1)	KMC WTP – Primrose	Q=23 l/s, H=168m	3 sets	Cancelled	
2)	Heerassagala low – Heerassagala middle	Q=12 l/s, H=63m	2 sets	Q=31.7 l/s, H=68 m	←
3)	Heerassagala middle – Heerassagala upper	Q=12 l/s, H=73m	2 sets	Q=8.1 l/s, H=77 m	←
4)	Ampitiya – Elhena	Q=12 l/s, H=55m	2 sets	Q=13.8 l/s, H=45 m	←
5)	Ampitiya – Mullepihilla low	Q=8 l/s, H=78m	2 sets	Q=11.3 l/s, H=145 m	←
6)	Ampitiya – Meekanuwa	Q=9 l/s, H=66m	2 sets	Q=24.8 l/s, H=73 m	←
7)	Kahawatta – Kurugoda	Q=32 l/s, H=75m	2 sets	Q=49.0 l/s, H=65 m	←
8)	Kondadeniya sump – Kondadeniya (augmentation)	Q=45 l/s, H=145m	2 sets	Combined with Upland system	
9)	Kondadeniya – Kulugammana			Q=18.5 l/s, H=64 m	2 sets
10)	Asgiriya Bahirawakanda	Q=78 l/s, H=45m	2 sets	Q=26.3 l/s, H=68m	←
11)	R2 – Hantana Place	Q=18 l/s, H=94 m	3 sets	Q=22.6 l/s, H=102 m	2 sets
12)	Katugastota WTP – Kahawatta	Q=238l/s, H=103m	2 sets	Q=166.5 l/s, H=93m	←
13)	Katugastota WTP – Kondadeniya sump	Q=45 l/s, H=5m	2 sets	Combined with Upland system	
14)	Katugastota WTP – Gohagoda	Q=30 l/s, H=112m	3 sets	Q=68.0 l/s, H=104 m	2 sets
	Katugastota WTP – Upland	Q=282 l/s, H=160m	3 sets	Q=203.71l/s, H=137 m	2 sets
	-Transmission pipelines				
	Service area of Proposed Katugastota Plant	DI ø 150	0 m		0 m
		ø 200	0 m		3,940 m
		ø 250	0 m		4,624 m

(Continued)

		ø 300	4,150 m		4,605 m
		ø 350	700 m		4,309 m
		ø 400	1,400 m		2,020 m
		ø 500	6,350 m		4,390 m
		ø 600	3,080 m		3,272 m
		ø 700	2,950 m		1,850 m
		ø 800	0 m		415 m
		PVC ø 110	1,750 m		0
		ø 225	15,500 m		492 m
		Sub Total Length	**35,880 m**		**29,917 m**
	Service area of KMC	DI ø 150	0 m		1,972 m
		ø 200	1,200 m		4,539 m
		ø 300	0 m		1,782 m
		ø 350	0 m		1,002 m
		PVC ø 90	0 m		149 m
		ø 140	900 m		0 m
		ø 160	8,335 m		767 m
		ø 225	2,280 m		1,457 m
			12,715 m		**11,668 m**
		Total Length	**48,595 m**		**41,586 m**
	- Distribution Pipelines	**Total Length**	**24,000 m**		**27,687 m**
4.	**Construction of Distribution Facilities**				
	- Reservoirs				
1)	Kahalla		323 m^3		600 m^3
2)	Bangalawatta		298 m^3		300 m^3
3)	Pihilladeniya		248 m^3		200 m^3
4)	Kahawatta		1,174 m^3		600 m^3
5)	Kurugoda		535 m^3		600 m^3
6)	Telambugahawatta		124 m^3		500 m^3
7)	Kulugammana (augmentation)		111 m^3		100 m^3
8)	Kondadeniya (augmentation)		384 m^3		200 m^3
9)	Gohagoda		207 m^3		200 m^3
10)	Bahirawakanda (augmentation)		1,595 m^3		600 m^3
11)	Upland		2,728 m^3		2,960 m^3

(Continued)

12)	Primrose (augmentation)		315 m^3	Cancelled	
13)	Heerassagala low		198 m^3		200 m^3
14)	Heerassagala middle		248 m^3		250 m^3
15)	Heerassagala upper		248 m^3		200 m^3
16)	Dangolla (augmentation)		254 m^3		500 m^3
17)	Hantana place		248 m^3		200 m^3
18)	Asgiriya		3,059 m^3		4,100 m^3
19)	Elhena		248m^3		300 m^3
20)	Mullepihilla low (augmentation)		79 m^3		100 m^3
	-Total Volume		**12,624 m^3**		**12,710 m^3**
	- Appropriate distribution networks		L.S.		←
5.	**Procurement of maintenance equipment**				
1)	Water quality analysis equipment		L.S.	←	←
2)	Leakage detection equipment		L.S.	←	←
3)	Truck with loading crane etc.		L.S.	Backhoe	←

THE DETAILED DESIGN STUDY
ON
GREATER KANDY WATER SUPPLY AUGMENTATION PROJECT
IN
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FINAL REPORT
VOLUME II-2
MAIN REPORT (2)

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

Abbreviations and Acronyms

1. Unit

cm	centimeter
ft.	foot
g	gram
gpcd	gram per capita per day
ha	hectare (1 ha = 10,000m^2)
hr	hour
kg	kilogram
km	kilometer
km^2, or sq.km	square kilometer
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
l, or L	liter
l/day, or l/d	liter per day
l/sec, or l/s	liter per second
lpcd, or Lpcd	liter per capita per day
m	meter
m/s, or m/sec	meters per second
m^2, or sq.m	square meter
m^3, or cu.m	cubic meter
m^3/d, or cu.m/day	cubic meter per day
m^3/min	cubic meter per minute
m^3/s, or cu.m/sec	cubic meter per second
MCM	million cubic meter
mgd	million gallons per day
mg/l	milligram per liter
mm	millimeter
Mpa	megapascal
ppm	parts per million
Rs.	Sri Lankan Rupee
V	volt

2. Water Quality

BOD_5	Biochemical Oxygen Demand (20^{o}C, 5 days)
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
pH	Hydrogen ion potential
SS	Suspended Solids
TS	Total Solids

3. Organizations

ADB	Asian Development Bank
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CPC	Central Provincial Council
FINNIDA	Finnish International Development Agency
GS	Gramasevaka Divison (local administrative unit)
IBRD	International Bank for Reconstruction and Development (World Bank)

ICC	Interagency Co-ordinating Committee
IDA	International Development Association (soft loan facility of IBRD)
IMF	International Monetary Fund
JBIC	Japan Bank for International Cooperation (Japan)
JICA	Japan International Cooperation Agency (Japan)
KMC	Kandy Municipal Council
MASL	Mahaweli Authority of Sri Lanka
MHUD	Ministry of Housing and Urban Development
MOF	Ministry of Finance
MSL	Mean Sea Level
NJS	Nippon Jogesuido Sekkei Co., Ltd.
NSC	Nihon Suido Consultants Co., Ltd.
NWSDB, or NWS&DB	National Water Supply and Drainage Board
OECD	Organization for Economic Cooperation and Development
PS	Pradeshiya Sabha (local administrative unit)
RDA	Road Development Authority
RSC	Regional Support Center, NWSDB
UC	Urban Council
UDA	Urban Development Authority

4. Others

BOT	Build - Operate - Transfer
BWL	Bottom Water Level
CED	Central Environmental Division
CPI	Consumer Price Index
EAC	Environmental auditing Commission
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
FY	Fiscal Year
GDP	Gross Domestic Product
GL	Ground Level
GNP	Gross National Product
GST	Government Sales Tax
HWL	High Water Level
HH	Household
IEE	Initial Environmental Examination
LWL	Low Water Level
L/S	Lift Station
NGO	Non-Governmental Organization
NRW	Non-revenue Water
ODA	Official Development Assistance
PEU	Project Environmental Unit
P/S	Pumping Station
SLS	Sri Lankan Standards
STP	Sewage Treatment Plant
T.A	Technical Assistance
TWL	Top Water Level
UFW	Unaccounted-For-Water
VAT	Value Added Tax
WID	Women in Development
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant (=STP)

CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Project Background

The total volume of water produced and supplied by over 30 different systems in the study area of Greater Kandy is approximately 94,000 m^3/d. Total population served is about 550,000 with an average per capita consumption rate more than 1501, while the total population in the service area covering about 460 km^2 was 650,000 in 1997. Apart from the Kandy Municipal Council (hereinafter referred to as "KMC") water supply system there are several other major water supply systems operated by the National Water Supply and Drainage Board (hereinafter referred to as “NWDSDB”) in the study area.

Tie development in the Kandy City and its suburban area is so rapid that the capacity of existing water supply systems is not sufficient to cater for the present as well as anticipated future demands. Extensive expansion of existing water supply systems is therefore an urgent need for NWSDB, for the furtherance of the development of Greater Kandy area.

Furthermore, NWSDB had already prepared a comprehensive Water Supply Master Plan for Greater Kandy highlighting the future developments necessitated, and the possible alternative solutions, under the financial assistance of the Finnish International Development Agency (hereinafter referred to as “FINNIDA Master Plan”) in 1994. However, its implementation had been withheld due to financial constraints caused by FINNIDA funding coming to an end.

In consequence of this situation, the Government of Sri Lanka (hereinafter referred to as “GOSL”), requested the Government of Japan (hereinafter referred to as “GOJ”) to grant technical co-operation to conduct a study on Greater Kandy and Nuwara Eliya Water Supply and Environmental Improvement Plan (hereinafter referred to as “JICA Master Plan”). In response to this request by GOSL, GOJ agreed to conduct a study to formulate a comprehensive master plan for Water Supply and Sewerage system up to the target year of 2015 for Greater Kandy by reviewing the FINNIDA Master Plan, inter-alia, as one component of this study. In fulfilment of this agreement, JICA started the Master Plan Study in February 1998, in close collaboration with the concerned authorities of GOSL, and submitted the Final Report in February 1999.

In the light of the recommendations made in this JICA Master Plan, GOSL made a further request to extend the assistance to conduct the Detailed Design Study on Greater Kandy Water Supply Augmentation Project (hereinafter referred to as the “Project”), encompassing KMC and surrounding ten Pradeshiya Sabahs (hereinafter referred to as "PS") or Divisional Secretary areas as shown in Figure 1.1.

1.2 Component of Main Report (2)

This Main Report (2) deals with the results of the study carried out for Phase 3, detailed design as proposed in the "Inception Report" submitted by the Study Team in January 2001. The detailed designs include a comprehensive evaluation of the overall project feasibility and detailed designs for the intake, water treatment plant, clearwater transmission, service reservoirs, and distribution systems.

This Main Report (2) comprises of 17 chapters and 4 appendices as follows:

Chapters		Contents
Chapter 1	:	Introduction to the Study
Chapter 2	:	Confirmation of capacity of the existing water supply systems
Chapter 3	:	Water demand allocation to the Study areas
Chapter 4	:	Available water source for the Project
Chapter 5	:	Scope of works for the Study
Chapter 6	:	Analysis for the proposed treatment processes
Chapter 7	:	Analysis for the proposed transmission and distribution systems
Chapter 8	:	Analysis for the proposed civil and structural works
Chapter 9	:	Analysis for the proposed mechanical systems
Chapter 10	:	Analysis for the proposed electrical systems
Chapter 11	:	Analysis for the proposed construction methods
Chapter 12	:	Analysis for contract package
Chapter 13	:	Analysis for procurement procedures
Chapter 14	:	Analysis for operation and maintenance
Chapter 15	:	Analysis for project cost
Chapter 16	:	Project implementation programme
Chapter 17	:	Recommendation for Project implementation
Appendix 1	:	KMC WTP Operation in the Year 2000
Appendix 2	:	Analysis on polyethylene pipe
Appendix 3	:	Proposed mechanical equipment
Appendix 4	:	A tentative construction schedule

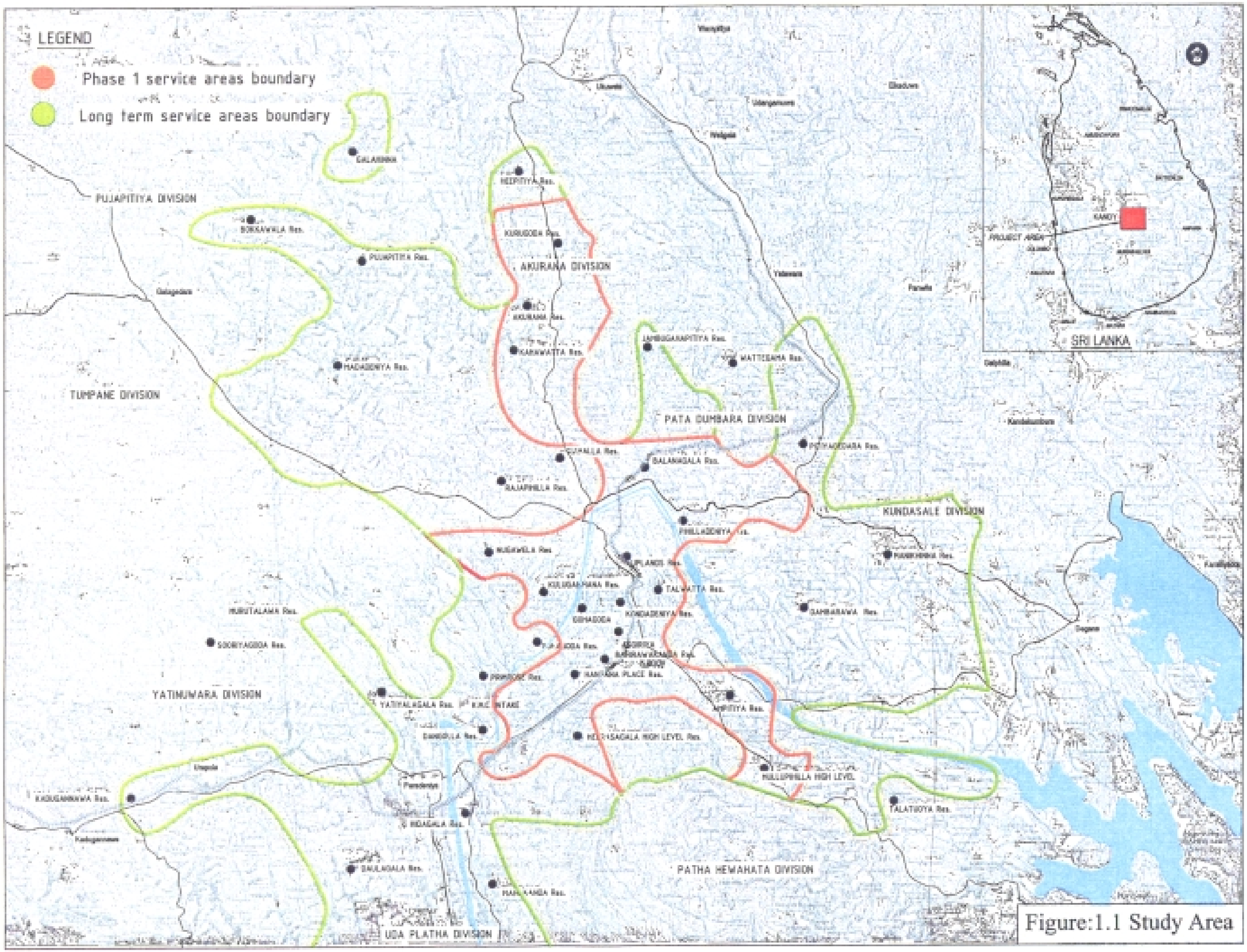


Figure:1.1 Study Area

CHAPTER 2
REVIEW OF REGIONAL WATER SUPPLY

CHAPTER 2 REVIEW OF REGIONAL WATER SUPPLY

2.1 General

The term Greater Kandy was not an officially recognized administrative entity, until it started gaining wide usage among planners and policy makers after the NWSDB introduced it in its “ Water Supply Master Plan for Greater Kandy” prepared by FINNIDA in 1994 under Kandy District Water Supply and Sanitation Project. Subsequently, the Urban Development Authority re-defined Greater Kandy area to refer to the Kandy Municipal Council area and other 10 adjoining PS areas.

Consequently, whatever study carried out before 1994 period was either related to the Kandy District as a whole, or to the individual PS areas. Extensive studies in water supply sector commenced after the arrival of FINNIDA in late seventies and completed their first report titled “The Kandy District Water Resources Potential Study” in 1982. This report focused on the available water resources inventory, the possible water supply feasible areas, water demand projections, demarcation of service areas based on surface water and ground water sources, alternative proposals to cover the proposed areas and an assessment of the capital investments required. However, these proposals had been overlooked and ground- water based systems had been implemented even in areas recommended for surface water sources.

In 1989, FINNIDA prepared “The Water Supply and Sanitation District Report” for the Kandy District to review the prevailing situation, and submit fresh proposals for water supply strategies to cover Kandy District. This report encompassed five Divisional Secretary Divisions, whereby the existing groundwater potential and surface water potential had been evaluated for the identified pipe borne feasible areas. It has also highlighted the serious operational difficulties and reliability problems associated with the ground water systems, which were experienced from the existing systems, and made recommendations on the advantage of the use of surface water sources over ground water sources. The potential and reliable surface water sources thus identified were Mahaweli River, Nillambe Oya, and Hulu Ganga

There were 11 water supply systems in Harispattuwa electorate with a grave need for expansion and as an effort to augment or to expand them, there is a record of NWSDB preparing a report titled “ Harispattuwa Integrated Water Supply Project – Identification Report” in which the pipe borne feasible areas had been identified for the Harispattuwa electorate, and the respective water demands had been evaluated. The source of supply of the proposed service area had been chosen as Mahaweli River at Gohagoda complete with a large-scale treatment plant.

These studies have however, overlooked KMC area and Kandy Four Gravets PS area.

The study next in line was the “Water Supply Master Plan for Greater Kandy” prepared by FINNIDA in 1994 (1994 FINNIDA Master Plan). This report focused on the evaluation of the prevailing status of the existing systems in respect of the improvements required on the quality and quantity, water demand projections for the existing areas, as well as the proposed extension areas for the target year of 2015, status of the available ground water resources and their reliability to continue to use them as future supplementary sources in an alternative surface water system, potential of the surface water resources in relation to their quality and quantity, type of treatment process, technical difficulties encountered with the method of abstraction, location of intake(s), treatment plant(s), additional service reservoirs and their capacities, transmission and distribution systems, cost estimates and phasing out of the implementation programme, and augmentation of existing large scale water supply systems.

In addition, 1994 FINNIDA Master Plan identified short-term rehabilitation programmes including the need for further feasibility study requirements where necessary, and the tentative cost estimates. It also reviewed on the optimum utilization of the on-going major systems, and identified the immediate investment requirements, and areas where further detailed studies were required.

The final proposal envisaged by 1994 FINNIDA Master Plan was to augment KMC intake at Getambe to feed KMC area and Central and Western Zones of Greater Kandy, and to construct a new intake and a treatment plant at Polgolla to serve Northern and Eastern Zones, both using Mahaweli River as the source of supply. Nillambe Oya was another source recommended, and the construction works to serve Uda Palatha was already in hand at the time the report was under preparation. It has also recommended the upward revision of NWSDB tariff structure, administrative changes for the operation of KMC head-works by NWSDB and distribution of water by the relevant local authority, and improvements in the disposal of wastewater to prevent pollution of water sources.

The KMC system, which is the largest water supply system in operation within Greater Kandy area, is managed by KMC, which supplies water to its own areas of jurisdiction and provides a bulk supply to the neighbouring Ampitiya area in Kandy Four Gravets PS. The present existing system was originally commissioned in 1966, and the plant capacity was upgraded in 1983 with the assistance of the Government of France from 22,267 m^3/d (5 mgd) to 33,400 m^3/d (7.5 mgd). In 1992 rehabilitation work was carried out to the Intake and Treatment Plant with a grant in aid from the Japanese Government, and since then no major improvement has been carried out, other than addition of small pumping stations, and reservoirs with insignificant extensions to the distribution systems.

There is a significant wastage of the water in the form of Non Revenue Water (hereinafter referred to as “NRW”). The city is badly affected by an inadequate water supply system, impeding the development of the city to its full potential. Therefore, in response to a request made by KMC, the Ministry of Urban Development, Housing and Construction decided to conduct a “Feasibility Study on Water Supply Augmentation and Distribution at Kandy” with the assistance of the Asian Development Bank (hereinafter referred to as "ADB"). This report was completed in October 2000 fulfilling its obligations of drafting proposals to meet the following objectives.

- Rehabilitate the existing system to meet the demand in the year 2020
- Reduce the present NRW to a much more acceptable level.
- Develop conceptual designs to meet the overall objectives
- Establish a cost viability or develop proposals to achieve the cost viability of the proposed improvements
- The findings/conclusions of this study such as current production capacity, consumption data, population projections, water demand projections, NRW, locations and conditions of service reservoirs etc., are also of considerable importance as references in the detailed design.

2.2 Service Area

2.2.1 Composition of Service Area

1999 JICA Master Plan has identified the service areas of the Greater Kandy as comprising of the entire administrative area of Kandy Municipality, and parts of ten adjacent PSs namely: i) Akurana (98 percent), ii) Harispattuwa (93 percent), iii) Pujapitiya (72 percent), iv) Patha Dumbara (80 percent), v) Kundasale (90 percent), vi) Yatinuwara (60 percent), vii) Kandy Four Gravets (98 percent) , viii) Patha Hewaheta (20 percent), ix) Udunuwara (75 percent), and x) Uda Palatha (3 percent) and as shown in Figure 1.1. The numbers within parenthesis indicate the percentage of population included in the study area. This area covered about 460 km^2. Kandy District has a land area of about 1,900 km^2, and hence the Greater Kandy study area covers geographically about 24% of the land area of the entire Kandy District.

This selection is justified by the recommendations made in 1994 FINNIDA Master Plan, which identified the service areas on the basis of the following criteria.

- The Population Density exceeding 1500/km^2 along a stretch of 150 m on either side of the roads,
- Water Demand exceeding 70m^3/d/km^2, and
- Where existing water supply is inadequate to meet the prevailing demand.

The potential areas identified by 1994 FINNIDA Master Plan on the above basis were identical with JICA F/S proposed service areas, with some minor differences on the boundaries of the proposed areas.

1999 JICA Master Plan included some new areas where there were applications pending for service connections but not accomplished due to shortage of water, and some potential areas, which were presently served by groundwater from individual wells. Due to this divergence in approach, the feasible populations in individual systems varied up to about 20 percent, but notwithstanding the projected total population in year 2000 was in close agreement within 2.5 percent.

The implementation of the JICA Master Plan proposals has been spread over 3 phases due to cost and funding constraints. The Phase 1 is expected to be completed in the year 2005 and the final Phase 3 in 2015. Hence, the highest priority areas have been chosen for implementation in Phase 1. The long-term coverage area is fixed, but the Phase 2 and Phase 3 service areas are to be determined at the appropriate time in the future as and when funding is available

2.2.2 Phase 1 Service Areas

The 1999 JICA Study Team conducted a survey on the current water supply situation, including information such as service level, duration of water supply and interruptions. KMC, Udunuwara and Yatinuwara areas enjoyed a water supply for approximately 20 hours a day, while other eight areas received a restricted supply for 12 hours or less. In a qualitative analysis, taking account of the population and water supply hours, KMC, Kandy Four Gravets, Harispattuwa, and Kundasale were found to be mostly affected due to lack of water supply, and was ranked as first priority areas (rank “A”) and Akurana and Patha Dumbara were ranked as second priority areas (rank “B”).

KMC was treated to be the highest priority area because of its strategic location, high level of development, urbanization, and the large population with a 25 % of the total population in the study area.

Kandy Four Gravets and Harispattuwa are fast developing as bed towns of KMC and continue to increase in population, but the development is somewhat hampered due to inadequate water supply, and hence prioritised as rank “A”. Though Akurana was ranked as “B”, the adjoining areas of Kahawatte and Kurugoda are affected by the lowering of the yield of the existing boreholes. Hence, Akurana was also prioritised.

Although Patha Dumbara was ranked as “B”, the ground water level is not stable. Moreover, Katugastota is fast developing as a commercial area and Kahalla, Balanagala, Bangalawatte and Pihilladeniya are earmarked to be developed as residential areas. Already, Kahalla and Balangala are experiencing water shortages. Hence, Patha Dumbara was also prioritised.

Despite the fact that Kundasale was ranked as “A”, the Hulu Ganga Project was under construction to serve this area, and hence it was deleted from the scope of this Project.

Therefore, eleven systems were incorporated in the Phase 1 Study for augmentation to meet projected demand in the year 2015 on the highest priority basis, and were assigned in different zones for ease of identification and analysis of hydraulics. These are KMC, Ampitiya, Mullepihilla and Hantana systems (KMC-R2/Kandy Four Gravets/Uda Peradeniya Zones), Alawathugoda and Akurana (Katugastota/Kahawatte Zone), Balanagala and Polgolla (Katugastota/Madawala Zone), Kulugammana and Kondadeniya (Katugastota/Uduwawala Zone), and Gohagoda (Polgolla/Gohagoda Zone) systems.

2.3 Existing Water Supply Systems

There are altogether 33 operating water supply systems in Greater Kandy area as shown in Table 2.1, which are based on both surface water as well as ground water sources, with prominence given for surface water, due to general availability and certain inherent problems associated with ground water resources. The total current production capacity is around 94,000 m^3/d. It is to be noted that Kundasale Agriculture Dept. Farm School, Penideniya TTC and Peradeniya University systems are institutional related, with no mutual benefit to Greater Kandy or vice versa.

There are four other systems using streams/springs as the source of supply, and these are operated as gravity systems, and some of which are very small. The reliability of some of these sources is poor, as during the dry seasons the yields of these sources would deplete significantly. The quality of the water produced has deteriorated in certain systems and these are intended to be abandoned by 2005. Some important Gravity systems are Wattegama water supply system using three streams, Punchimola Stream, Mangalagiriella Stream, and Rassaella Stream (2000 m^3/d, during drought season 800 – 1,400 m^3/d), Kadugannawa System using Damba Oya (800 m^3/d, during drought season 200 m^3/d)

Table 2.1 Existing Water Supply Systems in Greater Kandy

No.	Name	Admin. Area	Operating Body	Service Area	Source	Cap. (m^3/d)	Remarks
01	*Kandy Municipal Council*	KMC	KMC	KMC limits	Mahaweli River	*33,400*	Inadequate supply
02	Peradeniya University	Kandy Four Gravets & Udunuwara P.S	NWSDB (Headworks)	University Campus	Mahaweli River	9,000	Satisfactory operation quality and quantity wise
03	*Ampitiya*	Kandy Four Gravets	NWSDB	Ampitiya, Meekanuwa	Borehole	*1,300*	(N). High hardness
04	*Hantana*	-Ditto-	NWSDB	Hantana H/S	Stream	450 (*300*)	Low yield in dry season
05	Mullepihilla	-Ditto-	NWSDB	Mullepihilla	Stream	Small	No yield in dry period
06	Mahakanda	-Ditto-	Kandy For Gravets P.S	Univ. Quarters	Stream + borehole	Small	Low yield in dry season
07	Akurana	Akurana & Pujapitiya P.S	NWSDB	Akurana, Ambatenna	Boreholes	1,600	GWL lowering year by year. 8 Boreholes & 6 in service
08	*Alawathugode*	Akurana P.S	NWSDB	Alawathugoda/ Kurugoda/ Konakalagala	Boreholes (Vilana / Owissa)	640 (*500*)	High elevation and low yield
09	*Rajapihilla*	Harispattuwa P.S	NWSDB	Ranawana/ Uduwawala/ Hunnanoya	Boreholes	990 (*650*)	One low pumpage and the other good condition
10	Gohagoda	Harispattuwa P.S	NWSDB	Gohagoda	Boreholes	600	One to be abandoned as located at garbage dumping site, and the other receives protests due to lowering of water level of nearby shallow wells.
11	Kondadeniya	Harispattuwa P.S	NWSDB	Kondadeniya	Boreholes	1,440	2 wells dried, 1 corrupt. Large yield from others as ht river is close by. High iron content
12	*Yatihelagala*	Harispattuwa P.S	NWSDB	Haloluwa	Boreholes	1,850 (*1,920*)	One abandoned. Others good quality and quantity.
13	*Hedeniya*	Harispattuwa, Pujapitiya & Tumpane P.S	NWSDB	Hedeniya/ Madawala/ Pujapitiya	Boreholes	*840*	High iron content and low yield, 2015 abandoned
14	*Kulugammana*	Harispattuwa P.S	NWSDB	Heenagama/ Nugawela/ Kulugammana	Borehole	790 (*450*)	High iron, turbidity and colour

No.	Name	Admin. Area	Operating Body	Service Area	Source	Cap. (m^3/d)	Remarks
15	*Bokkawala*	Pujapitiya & Harispattuwa P.S	NWSDB	Bokkawala	Boreholes	1,000 *(600)*	Good quality
16	*Galhinna*	Pujapitiya P.S	NWSDB	Galhinna	Boreholes	*80*	Low production, 2015 abandoned
17	Menikhinna	Kundasale P.S	NWSDB (Headworks)	Menikhinna	Stream + Borehole	300	Very small yield at stream. High hardness and low yield of ground water. No stand by well
18	Kundasale	Kundasale P.S	NWSDB (Headworks)	Kundasale New Town	Borehole	576	(N). Low pumpage and high hardness in dry season
19	*Pallekele (Gam Udawa)*	Kundasale P.S	NWSDB (Headworks)	Gam Udawa/ Open Prison Camp/ Dodandolla Rd	Boreholes	1,200 *(720)*	High hardness
20	Pallekele	Kundasale P.S		Balagolla Settlement/ BOI/ Digana Village	Mahaweli River	2,000	Operation difficult due to fluctuation of water level by 20m
21	*Kundasale*	Kundasale P.S	NWSDB	Service areas in No. 18 -21	Hulu Ganga *Note 2	*13,000*	Under construction. 4000 m^3 allocated to BOI and the rest to service areas
22	Farm School, Kundasale	Kundasale P.S	Agriculture Dept.	Farm school premises	Mahaweli River	1,900	Difficulties due to fluctuation of water level at intake by about 20m.
23	Polgolla	Patha Dumbara P.S	NWSDB	Mahaweli A Qtrs., Uyanwatte TTC, Coop School, Open University	Mahaweli River	1,500	Civil structures deteriorating
24	Balanagala	Patha Dumbara P.S	NWSDB	Polgolla/ Balanagala	Borehole	1,000	Colour in the water
25	*Wattegama*	Patha Dumbara P.S	Wattegama U.C	Wattegama U.C	3 Streams	*1,400*	Treatment needed. 2 streams have very small yield. One stream fear of agrochemical contamination
26	Wattegama	Patha Dumbara P.S	Patha Dumbara P.S	Meegammana, Yatirawana			
27	Talatu Oya	Patha Hewaheta P.S	NWSDB	Talatu Oya	Borehole	200	Very poor yield
28	Udu/ Yatinuwara	Udunuwara, Yatinuwara & Kandy Four Gravets P.S	NWSDB	Daulagala/ Peradeniya/ Pilimatalawa/ Gelioya/ Uda Peradeniya	Mahaweli River	4,600	Direct riverbed filtration used. Cannot cope up with turbidity in rainy season.

No.	Name	Admin. Area	Operating Body	Service Area	Source	Cap. (m^3/d)	Remarks
29	Udu/ Yatinuwara	Udunuwara, Yatinuwara & Kandy Four Gravets P.S	NWSDB	Daulagala/ Peradeniya/ Pilimatalawa/ Gelioya/ Uda Peradeniya	Nillambe Oya	11,500 *(9,000)*	9,000 m^3 to Greater Kandy and balance to other areas
30	Welamboda	Udunuwara P.S	NWSDB	Welamboda			Under construction
31	Penideniya Teacher Training College	Udunuwara P.S	Penideniya TTC	Penideniya TTC/ Quartets	Mahaweli River	545	During dry season River Intake is blocked with sand, gravel and sediments
32	*Kadugannawa*	Yatinuwara P.S	NWSDB	Kadugannawa Town and Suburbs	Stream (Damba Oya)	*800*	Low yield during dry season
33	Ankumbura	Pujapitiya P.S	NWSDB	Ankumbura	Borehole	300	-Ditto-
	Total for 2001					**94,201**	
	Total for 2005	**Note3*				**64,960**	
	Total for 2015					**64,040**	

Notes:
1. (N) – Bulk Water Supply by NWSDB
2. Total includes 13,000 m^3/d of Hulu hGanga Project which is still under construction.
3. *Italic* shows the capacity that will be retained till year 2005.

CHAPTER 3
WATER DEMAND

CHAPTER 3 WATER DEMAND

3.1 General

In the Interim Report (1) submitted by the Study Team in April 2001, the served population and water demand of the Project area under three Phases in 2005, 2010 and 2015 had been discussed. These proposals were in conformity with the recommendations made in the 1999 JICA F/S, on the basis of per capita consumptions, safe yield of available ground and surface water sources, and the proposed new Mahaweli River source at Gohagoda. This section, therefore, intends to review the water demand established in the 1999 JICA F/S for the Greater Kandy in the long term.

3.2 Served Population

For the proposed long-term development of Greater Kandy area, the entire KMC area and parts of 10 adjacent P.S. areas were included. Of these, 100 percent water supply coverage for KMC area, Kandy Four Gravets and Akurana P.S. areas in the year 2015 is planned, and for the rest of the areas only part coverage is allowed. For the whole of Greater Kandy, Table 3.1 adopted in the 1999 JICA F/S population projections will be considered as the basis for Project.

Table 3.1 Water Supply Service Population in Greater Kandy

Area	Projected Population			
	2000	2005	2010	2015
KMC	144,000	153,000	162,000	171,000
Kandy Four Gravets (part)	58,000	62,000	67,000	71,000
Harispattuwa, Akurana, & Pujapitiya (part)	138,000	150,000	161,000	173,000
Kundasale (part)	87,300	93,800	99,500	106,000
Patha Dumbara (part)	42,900	46,000	48,400	51,600
Patha Hewaheta (part)	8,600	9,400	10,600	12,000
Udunuwara, Yatinuwara, & Uda- Palatha (part)	95,400	101,600	110,900	119,000
Sub-total outside KMC	430,200	462,800	497,400	532,600
Total	**574,200**	**615,800**	**659,400**	**703,600**

Different population growth rates for different areas had been used for this evaluation depending on the present level of development, availability of land for further migration/ expansion, and the future development trends etc.

According to the past records from 1981 to 1990, KMC area recorded the highest growth rate of 1.9 percent and next was Kandy Four Gravets. Of the suburban areas Harispattuwa , Akurana, Pujapitiya and Kundasale recorded highest population growth rates of 1.6 percent. However, the long term future trend will be a gradual reduction of the growth rate down to about 1.1 to 1.2 percent within the period 2010/2020.

3.3 Water Demand

There are three factors governing the water demand of a particular water supply system, i.e. the water use pattern, water loss and peak ratio. For accurate assessment of these factors intensive studies involving previous production and consumption records are indispensable, together with some field studies/tests. Such accurate records are not available with any of Greater Kandy existing systems.

The water use pattern is identified by per capita consumption, and the water loss by Non-Revenue Water (NRW). The peak ratio is the factor used to evaluate the maximum day demand from the average day demand for a system. In the absence of accurate data, the results of certain studies carried out before by FINNIDA for Greater Kandy, and ADB for KMC area were further developed by the 1999 JICA F/S, and combined with the experience gained from the operation of other major systems elsewhere in the country, and in other countries and assigned some reasonable values to these factors. The JICA F/S estimated the present NRW at 42 percent and proposed this to be reduced to 25 percent in year 2015. On the above basis unit water consumption has been identified as given in the following Table 3.2.

Table 3.2 Per Capita Water Demand Rates and NRW Ratio for Greater Kandy

Description	Unit Rates (lpcd)			
	2000	2005	2010	2015
KMC Area				
Domestic	101	108	115	121
Non- domestic	58	61	65	69
NRW	115	95	81	63
Total	274	264	261	253
Outside KMC				
Domestic	78	82	90	98
Non- domestic	30	32	36	41
NRW	78	64	57	46
Total	186	178	183	185
Greater Kandy				
Domestic	85	89	96	104
Non- domestic	37	39	43	48
NRW	88	72	62	50
Total	210	200	201	202
NRW (%)	42	36	31	25

It is seen from the above analysis that though unit consumption rates have gradually increased over the years, the per capita consumption rates have dropped from 210 lpcd in 2000 to 202 lpcd in 2015 for Greater Kandy, due to the reduction of NRW from 42 to 25 percent.

On this basis the projected water demand for Greater Kandy has been determined as per the following Table 3.3.

Table 3.3 Projected Water Demand in Greater Kandy

Description	Water Demand (m^3/d)			
	2000	2005	2010	2015
KMC Area				
Domestic	14,570	16,500	18,610	20,730
Non Domestic	8,352	9,333	10,530	11,799
NRW	16,560	14,535	13,1222	10,773
Total	39,482	40,392	42,282	43,263
Outside KMC Area				
Domestic	33,556	38,156	44,766	52,253
Non Domestic	12,906	14,689	17,965	21,631
NRW	33,556	29,619	28,352	24,500
Total	80,018	82,464	91,083	98.,384
Total Greater Kandy				
Domestic	48,100	54,680	63,396	72,944
Non Domestic	21,258	24,022	28,495	33,430
NRW	50,116	44,154	41,474	35,273
Total	119,474	122,900	133,400	141,600

3.4 Water Demand and Production

As mentioned before, the water productions in the three Phases have been reviewed, and it is hereby intended to review as to how this production is going to meet the projected demands in Greater Kandy in future. It is to be noted that consideration has been given for continuation of production of certain existing systems up to the year 2015, and they also become part and parcel of this augmentation project. Some of the systems expected to be continued are KMC system, Nilambe Oya system, Hulu Ganga system etc.

Table 3.4 and

Figure 3.1 show water balance between demand and supply for various stages.

Table 3.4 Balance of Water Demand and Production in Greater Kandy in Three Phases

Description	Water Demand/ Production (m^3/d)		
	2005	2010	2015
Daily Average Water Demand	122,900	133,400	141,600
Daily Maximum Water Demand	147,430	160,040	169,980
Continued Existing Sources	64,960	64,960	64,040
Deficit of average demand without augmentation	56,940	67,440	77,560
Deficit of maximum demand without augmentation	82,470	95,080	105,940
Phased Production by Proposed Augmentation	36,670	73,330	110,000
Deficit to average demand	20,270	(5,890)	(33,440)
Deficit to maximum demand	44,800	20,750	(5,060)

Notes: The figures in parenthesis show deficit in water supply against demand.

From above, it is clear that the implementation of Phase 1 will not necessarily solve the water shortage problem in Greater Kandy in a satisfactory manner, as there is a significant short supply in terms of average demand and maximum day demand. With the implementation of Phase 2 in 2010 the average day demand will be satisfied, but still not the maximum day demand. The full satisfaction can be achieved only in 2015 with the completion of Phase 3.

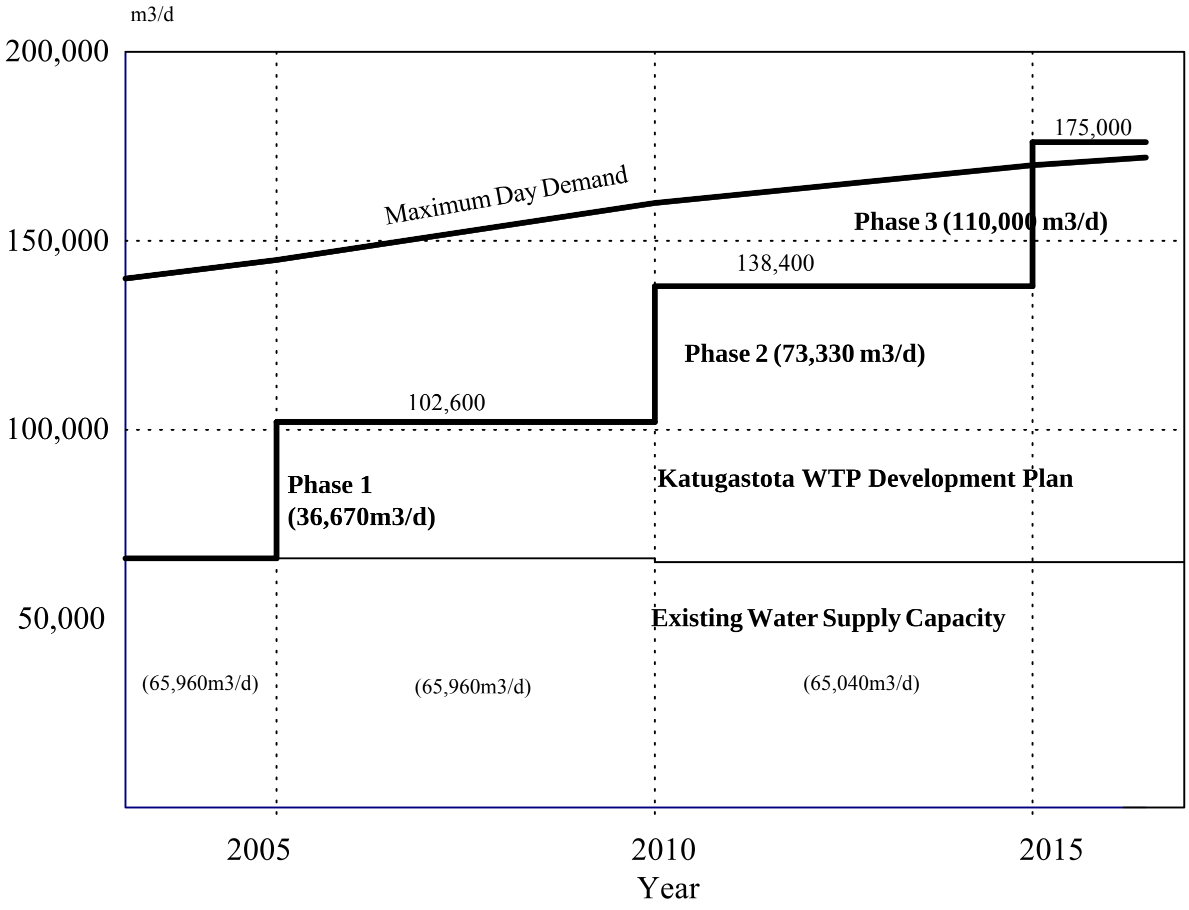


Figure 3.1 Water Demand and Supply

CHAPTER 4
WATER RESOURCES

CHAPTER 4 WATER RESOURCES

4.1 General

The major water supply source is Mahaweli River with a total capacity of 52,945 m^3/d, which feeds KMC system (33,400 m^3/d), Peradeniya University System (9,000 m^3/d), Penideniya TTC System (545 m^3/d), Dept. of Agriculture System at Kundasale (1,900 m^3/d), Udu/Yatinuwara (4,600 m^3/d), Pallekele (2,000 m^3/d) and Polgolla (1,500 m^3/d).

Kotmale Oya is another perennial stream with a catchment of 554 km^2, and Kothmale Reservoir was constructed across this stream for hydroelectric power generation. It has not yet been utilised for any water supply system, though there is a possibility to use as a source with proper water management. Atabage Oya is another perennial stream with a catchment area of 74 km^2, with water quality similar to Mahaweli River, but not yet utilized as a source of water supply. Nillambe Oya has a catchment area of 66 km^2, and a reservoir has been constructed across this stream for hydropower generation. This stream has been tapped as the source of Udu/Yatinuwara water supply system (11,500 m^3/d). Hulu Ganga, which is another perennial stream, has a catchment area of 160 km^2, and it has been utilized as the source for Kundasale water supply system (13,000 m^3 /d).

In Greater Kandy the cover of overburden is relatively thin and therefore there is a good prospect of finding groundwater resources in rock masses, which are joined, fractured and possibly weathered. Such rock masses comprising of quartzite, limestone and calc-gneiss bands provide a very good yield. However, to date the current data on the groundwater availability at various locations in the Kandy district is very sketchy, and therefore it is not possible to quantify the capacity, and the corresponding sustainable yield of aquifers.

Fifteen water supply systems in Greater Kandy are fed by ground water from boreholes only and two more are fed by a combination of boreholes and surface water sources. These were originally built as rural systems to serve small communities in certain specific localities, where after early investigations ground water could be found with adequate quantities. Most of these systems are currently malfunctioning due to the wells having small discharges at less than 1000 m^3/d, and some still worse with several hundred m^3/d, whilst some are yielding hard water exceeding the maximum desirable level of 500 mg/l (though below the maximum permissible level of 600 mg/l). Some of these wells contain a high iron content rendering the water unsuitable for drinking and washing. Furthermore, yield of many of these wells is unreliable as it depletes during the dry seasons, with perhaps deterioration of quality and failing to produce the anticipated demand. The mismatching of the well design and pump specifications at low yields further aggravates this situation. Due to the wells extracting ground water from aquifers above the bedrock layer they become vulnerable during the dry seasons. Such factors will produce a low service level. At places like Ampitiya and Gohagoda, the boreholes cause the lowering of the ground water table in the nearby area, affecting the paddy fields and shallow wells.

The boreholes are not suitable to incorporate into a large water supply system, because there will be a necessity to have a multitude of boreholes at different locations to feed a large area. Furthermore, the unit production cost of borehole systems is also much more than normal system.

The topography of Greater Kandy is mostly continuous steep small mountains with shallow bedrock, and flat lands are seen in limited areas. Therefore, potential areas for groundwater development are limited and unevenly distributed. Notwithstanding, it is prudent to pursue in this endeavour, as this is the most feasible alternative for remote areas to provide limited supplies. This is because such systems are more economical than to utilize centralized surface water sources with complicated and expensive treatment systems. Preliminary studies also indicate that there are good prospects of finding potential ground water sources quantitatively and qualitatively in remote areas.

There are several other tributaries of Mahaweli River and small streams, but these are not considered as potential sources due to inadequate flow, reduction of flow during dry seasons, pollution, and the need for treatment and pumping, cost of which are prohibitive and uneconomical.

4.2 Mahaweli River

This is the largest River in Greater Kandy with a total catchment area of 3,118 km^2 (1,292 km^2 at Polgolla and 1,109 km^2 at Nanu Oya mouth), and a daily average flow rate of 5.5 million m^3/d, and annual average rate of flow of 2 billion m^3/d, which has a host of major tributaries namely Kotmale Oya, Atabage Oya, Nillambe Oya, Pinga Oya, Hulu Ganga, Maha Oya, Hasalaka Oya and Heen Ganga and a few other minor ones within the district. The Mahaweli River is the major source of water supply to Greater Kandy as discussed in the previous section. It crosses the area from a southwest to a northeast direction up to the centre of Kandy, and then flows northwards. The lowest land elevations in the Greater Kandy are along the Mahaweli valley.

The flow of Mahaweli in the reach under consideration is regulated by the operation of Kothmale Dam at upstream end, and Polgolla Dam at downstream end. River flow is monitored daily at Peradeniya Gauging Station by the Irrigation Department, and inflows to Polgolla dam is estimated based on downstream release and flow for power generation.

According to information obtained from the Irrigation Department for the Mahaweli River flow from October 1989 to September 1999 measured at Peradeniya Gauging Station (tributary area 1,168 km^2), the median value of flow at Peradeniya was determined to be 23.68 m^3/d or 2,046,000 m^3/d, and for 7-day average median flow was 24.57 m^3/s or 2,122,900 m^3/d as confirmed in the Interim Report (1).

Storage volume of Polgolla Reservoir is 4.1 MCM at normal operating level (at 440.74 m AMSL, surface area 1.2 km^2) and the minimum storage volume is 2.0 MCM at 438.90m AMSL (surface area 0.7 km^2). Average retention time in Polgolla Reservoir is around two days based on the median flow at Peradeniya. However, due to accumulation of silt periodically the actual retention time may become much lower than two days, from time to time.

The Normal Operating Level at Polgolla reservoir has been set at 440.74 m AMSL. However, under normal circumstances when there is no rains or a threat of floods, it has now been the established policy not to open the gates to discharge any excess flow up to 10:00 pm of the day, due to safety concerns of the people using the river downstream. Consequent to this, according to the Polgolla Headwork's management, at times the water level would rise up to about 441m AMSL during daytime. With this rise the discharge downstream will increase considerably, which will amply alert the downstream users to be cautious, and if the level continues to rise further, the gates will be opened irrespective of the time of the day.

The Low Water Level is set at 438.30m AMSL, and any further drop in this level will cause the power generation at Ukuwela Power Station to be shut down. The lowest water level recorded during silt removal was 434.34m AMSL.

Under flood conditions the gates will be kept open to control the reservoir level, as designed. According to the historical data on the maximum discharge in the river, it is quite evident that there is no possibility for the flood water level to rise above 441m AMSL even under the worst possible flood conditions. Table 4.1 summarises an historical record of the 39 worst floods of the river in the past 58 years from 1943, and the high flood levels reached on each occasion. The table has been prepared on the decreasing order of the intensity of the floods.

Polgolla Dam was commissioned in 1976 and the highest flood recorded after this date was in 1978, with the level reaching 440.2m AMSL at Polgolla. In August 1985, Kothmale Reservoir was also commissioned, which was located upstream of Polgolla Dam. This has facilitated the control of floodwaters in a more effective manner. Thus, the risk of rising the flood water level above 440.70 m AMSL is extremely remote, with the proper regulation of the sluice gates of Kothmale Reservoir, Polgolla Dam and the downstream Victoria Reservoir, which was commissioned in April, 1985.

Mahaweli Authority has also evaluated data in respect of worst flood discharges up to a return period of 500 years as shown in the following Table 4.2.

period of 500 years as shown in the following Table 4.2.

Table 4.1The High Flood Levels of Worst Floods of Mahaweli River at Polgolla in the Past 58 Years

Rank	Year	Maximum Discharge (m^3/s)	High Flood Level (m AMSL)
01	1978	3054	440.2
02	1947	2550	439.6
03	1957	1875	438.3
04	1956	1758	438.1
05	1968	1758	438.1
06	1959	1624	437.8
07	1943	1522	437.8
08	1971	1458	437.7
09	1972	1412	437.4
10	1967	1323	437.0
11	1975	1241	437.0
12	1966	1210	436.9
13	1955	1134	437.0
14	1952	1092	436.8
15	1950	1007	436.9
16	1964	975	436.7
17	1948	960	436.6
18	1974	933	436.6
19	1965	902	436.6
20	1961	897	436.6
21	1963	894	436.5
22	1951	871	436.3
23	1979	853	436.5
24	1970	828	436.3
25	1946	745	436.1
26	1953	690	436.0
27	1976	689	435.8
28	1969	682	435.8
29	1954	667	435.7
30	1977	658	435.6
31	1962	620	435.6
32	1981	600	435.5
33	1949	593	435.7
34	1958	564	435.7
35	1945	557	435.4
36	1944	457	435.1
37	1973	445	435.2

Rank	Year	Maximum Discharge (m^3/s)	High Flood Level (m AMSL)
38	1980	382	435.1
39	1960	364	435.1

Generally, water supply structures are designed to remain serviceable for a duration of 100 - 200 years and according to above forecast the maximum flood level, which can be reached by the river at Polgolla in 200 years return period, is 440.74m AMSL. Hence, the assumption of a flood level of 441m AMSL for design of Intake structure is quite safe and justifiable.

Table 4.2 Forecast of Worst Flood Conditions

Return Period (Years)	Anticipated Maximum. Flood Discharges (m^3/s)	High Flood Level (m AMSL)
500	4000	441.80
300	3725	441.19
200	3425	440.70
100	3200	440.43
50	2850	439.83

The Mahaweli River Authority has set the minimum flow of the river at 180,000 m^3/d except for extremely dry weather conditions. However, it is in record that in 1992 a serious drought took place causing the rainfall in January to fall to about 40 % of its normal average monthly rainfall level with February and March having no rainfall. The river flows also reflected this reduction of rainfall by dropping down the flow to 166,600 m^3/d. The number of days recording the flows below 180,000 m^3/d was eight in 1992, two in 1993 and three in 1997. The maximum daily demand of Greater Kandy in year 2015 is assessed to be 169,980 m^3/d of which the existing systems (KMC, Nilambe Oya, Hulu Ganga, Udu/Yatinuwara etc.) will continue to supply 65,040 m^3/d from year 2005 to 2015. Hence, the required abstraction from Mahaweli River is 104,940 m^3/d (say 110,000 m^3/d), and according to the past flow records of the river this appears to be realistic. Nevertheless, the possibility of arising abnormally high dry periods in future cannot be ruled out, and in such situations restricting the supply will become inevitable. This underscores the need to preserve the existing groundwater sources for possible standby utilization in such a situation.

As already mentioned the source of supply for KMC system and a few other systems is Mahaweli River. The proposed augmentation of Greater Kandy water supply system is also based on the same source, as there is no other alternative surface water or ground water source, which can provide a bulk volume of 110,000 m^3/d with a suitable raw water quality. NWSDB has already secured the water rights from the Mahaweli Authority for the utilization of 180,000 m^3/d from the river, which includes the existing systems utilizing Mahaweli River as the source such as KMC system (33,400 m^3/d). Hence, there is still a certain surplus remaining for further extraction from the river elsewhere, if the need arises.

CHAPTER 5
FUNDAMENTALS FOR DETAILED DESIGN

CHAPTER 5 FUNDAMENTALS FOR DETAILED DESIGN

5.1 Scope of Work

The Scope of Work states that the Project shall provide a new intake facility, a treatment plant, a transmission system to supply additional water required for the existing Greater Kandy service area, service reservoirs with necessary booster pump stations, distribution pipelines from the proposed service reservoirs to the existing distribution system, and expansion of distribution network to un-served areas.

After completion of Phase 1 of the Project, water production capacity will be 36,670 m^3/d. However, water intake structure, main part of raw water transmission pipeline, and administrative common facilities will be sized for Phase 3 capacity, which would be 115,500 m^3/d, including for a five percent loss through the works. Transmission of water to Greater Kandy service areas under Phase 1 will be for Kahawatta, Madawala, Uduwawala, Gohagoda, and KMC service areas via Upland, Asgiriya, and Bahirawakanda reservoirs. Likewise, necessary distribution system expansions in the study areas will be covered under Phase 1.

a) intake : capacity of intake will be 115,500 m^3/d and raw water pumps to deliver 38,500 m^3/d (or 446 l/s);
b) raw water transmission pipe : pipes used for raw water transmission main from intake to treatment plant should be of 800 mm dia. DI pipes of 2,200 m length to satisfy a capacity of 115,500 m^3/d (pressure main will be expanded in Phase 2);
c) balancing tank : to be constructed in between raw water intake facility and water treatment plant;
d) treatment plant : production capacity of 36,670 m^3/d;
e) clear water pumps : deliver 36,670 m^3/d;
f) clear water pumping station, chemical building, administration building, etc.;
g) transmission main from treatment plant to service reservoirs : approximately 47,000 m. of transmission system. DI pipes with diameters from 300 mm to 700 mm and uPVC pipes with diameters from 110 mm to 225 mm will be used;
h) 19 service reservoirs : (Primrose service reservoir was excluded due to duplication with ADB Project);
i) distribution pipelines of approximately 24,000 m length. : In the distribution system uPVC pipes and DI pipes will be used, dependent on pipe sizes;
j) communication and power supply to intake, pumping stations and treatment plant;
k) plant and equipment necessary for operation and maintenance.

The tentative quantities and details set out for the project in the Scope of Work are listed above and it is stated that the quantities specified may be changed according to the requirements at the time of review and detailed design based on the on-going field survey including topographic survey and soil investigation works.

5.2 Proposed Design Capacities

From the data reviewed in previous section, and further considered in the following section for transmission and distribution systems it is concluded that the capacities for Phase 1 remain essentially unchanged, and under this phase of the Project, water production capacity is 36,670 m^3/d.

A part of raw water transmission main in between balancing tank and water treatment plant is sized for Phase 3 capacity, which is 115,500 m^3/d.

The distribution systems comprise the most northern portion of Greater Kandy, namely the service areas in Kahawatta, Akurana, Telembugawatte, Kurugoda, etc.

The remaining facilities are generally as specified in the Scope of Work.

5.3 General Procedures

5.3.1 Units

The International System of Units (SI units) will be used for the Project in accordance with ISO 31. The main units are shown in Table 5.1.

5.3.2 Drawings

Drawings are prepared in A1 size and the bottom of the drawing will be reserved for title block and notes. Lettering is generally be horizontal in letters large enough to be read easily at a reduced A3 size. North will point towards the top of the sheet or to the right.

5.3.3 Drawings and Scales

(1) Intake and Treatment Plant

Site, yard piping, electrical distribution and paving drawings are generally be shown at 1:100 or 1:200, as appropriate. Details will be shown at 1:10, 1:20, 1:30 or 1:50 scale

(2) Transmission Mains

For the transmission mains a plan and profile drawing sheet are used. Match lines will be provided for turning corners or up steep grades so that the plan view or profile will still fit within the area allowed for the plan or profile.

Table 5.1 Applied Units

Quantity	Symbol	Unit	Symbol
Length	L	metre	m
Mass	m	kilogram	kg
Time	t	second	s
Area	A	square metre	m
Volume	V	litre or cubic metre	l or m^3
Force, Weight	F, W	Newton	N
Moment of Force	M	Newton metre	N.m
Velocity	u, v	metre per second kilometre per hour	m/s km/h
Acceleration [1]	a	metre per second squared	m/s^2
Moment of Inertia	I		m^4
Modulus of Elasticity	E	Pascal	Pa
Shear Modulus	G	Pascal	Pa
Poisson Ratio		dimensionless	
Density (Mass Density)		kilogram per cubic metre	kg/m^3
Specific Weight		Newton per cubic metre	N/m^3
Pressure and Stress		Pascal	Pa
Temperature	T	Degree centigrade	°C
Frequency	f	Hertz	Hz

[1] Acceleration due to gravity = $9.81 m/s^2$

Scales are 1:500 horizontally in order that 300 m in one plan, or 600 m can be shown on a single sheet. Vertical scales are 1:200. “Top of pipe” will be shown in the profile.

Pipeline details and standard drawings are generally in the scale 1:10, 1:20, 1:25, 1:50, or 1:100 scales as required. Stations, horizontal angles and pipe size are shown in the plan and profile and not under the profile. Slope is not shown beneath the profile and but appears only where considered necessary for construction purposes. Stationing is from i) the Gohagoda intake to the Katugastota WTP and ii) the Katugastota WTP to the reservoirs.

For the overall plan 1:2000, 1:2500, or 1:5000 scales is used. For all pipelines, plan(s) and profile drawing sheets, showing both the plan and profile will be used.

In general the first two letters refer to the structure or process number assigned as follows:

00	:General
01	:Raw water intake and balancing tank
02	:Miscellaneous for raw water intake
03	:Raw water transmission main
04	:Overall system of WTP
05	:Distribution chamber
06	:Flocculation basins and sedimentation basins
07	:Filtration units
08	:Clear water reservoir
09	:Clear water pump station
10	:Chemical building
11	:Backwash water recovery facility
12	:Sludge lagoons
13	:Electrical substation and generator building
14	:Administration building
15	:Maintenance building
16	:Yard piping for WTP
17	:Miscellaneous for WTP
20	:Transmission pipelines
30	:Service reservoirs
31	:Yard piping for service reservoirs
32	:Miscellaneous for service reservoirs
40	:Distribution pipelines
50	:Miscellaneous

The third symbol in the sequence of numbers is a letter indicating the discipline as follows:

G	:Overall system
C	:Civil
S	:Structural
A	:Architectural
M	:Mechanical
E	:Electrical
I	:Instrumentation
STD	:Standard drawings

Lastly, the final set of numbers indicates the drawing sequence within the structure or process.

CHAPTER 6
INTAKE AND WATER TREATMENT PLANT

CHAPTER 6 INTAKE AND WATER TREATMENT PLANT

6.1 General

The water supply systems aim basically to guarantee the users a constant supply of hygienic, safe and clean water at their service taps, free from hazards relating to the quality of water or other inconveniences. To accomplish it, after long years of operation of equipment, facilities and integrated systems, it may sometimes be necessary for large-scale rehabilitation/improvement works in order to restore them to their original condition, or to upgrade their efficiency, even if these facilities have been carefully operated and well maintained.

In 1992, a basic design study was conducted prior to detailed design for rehabilitation of the existing Ambatale Water Treatment Plant under a grant in an aid programme of the Government of Japan. Through a investigation of the Ambatale Water Treatment systems, several defects were identified. Those were i) difficulty in operation of the deteriorated equipment and facilities, ii) uneven distribution of raw water inflow to each settling tank due to inconsistent system development, iii) lack of proper operational skills for the complicated water treatment systems, and iv) improper construction works of the facilities during the extension of the systems.

According to the lessons learnt from the Project for Rehabilitation of Ambatale Water Treatment Plant, and the field-proven performance of other existing water treatment plants in the Kandy area, it was found that the technologies commonly utilised in the industrialized countries might some times be inappropriate. For example, excessive automated operation of the plant is not necessarily appropriate for the Greater Kandy Water Supply Augmentation Project, because it is not only affordable economically, but also there is an abundance of unskilled labour, which makes labour-intensive technologies more attractive.

Thus, the following technical principles are recommended in the detailed design of water treatment equipment and facilities for the Greater Kandy Water Supply Augmentation Project.

- To the maximum extent possible, the use of mechanical equipment should be limited which easy operation and low maintenance can be achieved,
- Hydraulically based devices that use gravity for works such as rapid mixing, flocculation, and filter rate control are preferred to mechanised and/or automated equipment in consideration of the available favourable topography of the plant site,
- Mechanisation and automation are appropriate only where operations are not readily accomplished manually, or where they greatly improve the reliability assuring safe and stable water supply, and

- Indigenous materials and products that are easy and safe for use in construction should be used to reduce costs, and to bolster the local economy and expand industrial development.

For the detailed design, the same design horizon recommended by the 1999 JICA F/S is adopted. The project will be implemented in three phases. Phase 1 project is designed to produce 36,670 m^3/day, based on the daily maximum supply quantity, which is 1/3 of the total overall capacity of 110,000 m^3/day.

Common facilities including intake, balancing tank, part of raw water conveyance pipes, structure for receiving well/distribution chamber, chemical building, administration building, and maintenance building will be constructed in Phase 1, for the overall capacity.

Five percent of the production loss including in-plant water consumption and three percent of recirculation is considered for the design of equipment and facilities for the intake structure, balancing tank, receiving well/distribution chamber, flocculation basins, sedimentation basins, filter units, and chemical, and chlorination facilities. These are summarised in the following Table 6.1.

The proposed general layout plan of the water treatment plant, which is designed based on the design criteria discussed in detail hereunder, is attached in Volume V, Tender Documents. Capacity calculation is attached in Volume IV, Data & Attachments.

Table 6.1Design Horizon

Facilities	Design Capacity for Phase 1
1) Intake structure	115,500 m^3/day (3/3+5%)
2) Intake facilities	38,500 m^3/day (1/3+5%)
3) Balancing tank	115,500 m^3/day (3/3+5%)
4) Raw water conveyance pipe	*115,500 m^3/day (3/3+5%)
5) Receiving well/distribution chamber	115,500 m^3/day (3/3+5%)
6) Flocculation basins	39,700 m^3/day (1/3+5%+3%)
7) Sedimentation basins	39,700 m^3/day (ditto)
8) Filter units	39,700 m^3/day (ditto)
9) Clear water reservoirs	36,670 m^3/day (1/3)
10) Transmission facilities	36,670 m^3/day (1/3)
11) Chemical and Chlorination Facilities	39,700 m^3/day (1/3+5%+3%)

Notes: * Pressured pipe to the balancing tank will be 1/3+5% only.

6.2 Process Design

Consequent to the analysis of water quality of the raw water sources conducted during the review stage, the recommended treatment process is the rapid sand filtration system, as proposed by 1999 JICA F/S. The process comprises of pre-treatment (pH adjustment, pre-chlorination, and coagulation), flocculation, sedimentation, filtration, and disinfection. This treatment is widely used in Sri Lanka with river sources.

Available monitoring parameters for process water quality control at the existing KMC Water Treatment Plant, which draws the raw water at Getanbe from the Mahaweli River are turbidity and pH of the raw water after grit removal; pH of settled water; and turbidity, pH, and residual chlorine of the treated water.

Variation of turbidity and pH from the month of January through December 2000 is summarised in Figure 6.1 and Figure 6.2. Detailed data is attached in *Appendix 1, KMC WTP Operation in the Year 2000.*

The maximum turbidity in the raw water recorded was 327 NTU in the month of April. Average and minimum turbidities were 37 NTU and 6.0 NTU, respectively. Over a 70 percent of time turbidity was less than 30 NTU, and approximately 50 percent of the time was lower than 19 NTU. The pH varying from 6.7 to 7.2 showed slightly acidic or neutral properties which results in easy operation of the plant in terms of water treatment, without a cumbersome process of pH control. The water quality in turbidity is therefore identified as comparatively favourable for the water source in applying the rapid sand filtration process; even daily fluctuation of turbidity is considerably insignificant.

6.3 Hydraulic Design

Most conventional water treatment plants require approximately 4 to 6 m of head loss across the plant. This means that a difference of 6 m must exist between the water level at the head end of the plant, and the high water level in the clear water reservoir, which is at the tail end of the treatment plant process train.

The prospective plant site in Katugastota is relatively inclined towards the south east side. The high water level of the clear water reservoir may be set at the planned ground level taking into consideration of the groundwater table. The water level at the head end of the process or the distribution chamber must therefore be approximately 6 m above the ground level. The majority of the unit processes in the first half of the process train is above the grade line unless a pumping system is provided.

The lowest water level is set at 442 m AMSL, or one metre above the designed highest water level of the Mahaweli River, so that the drainage work for the sludge lagoons would be uninterrupted even during high water level at the Mahaweli River. Therefore, the bottom level of the sedimentation basins will be determined according to the required head loss of sludge discharge pipeline from the sedimentation basins to the sludge lagoons. The designed hydraulic profile is shown in Volume IV, Tender Documents.

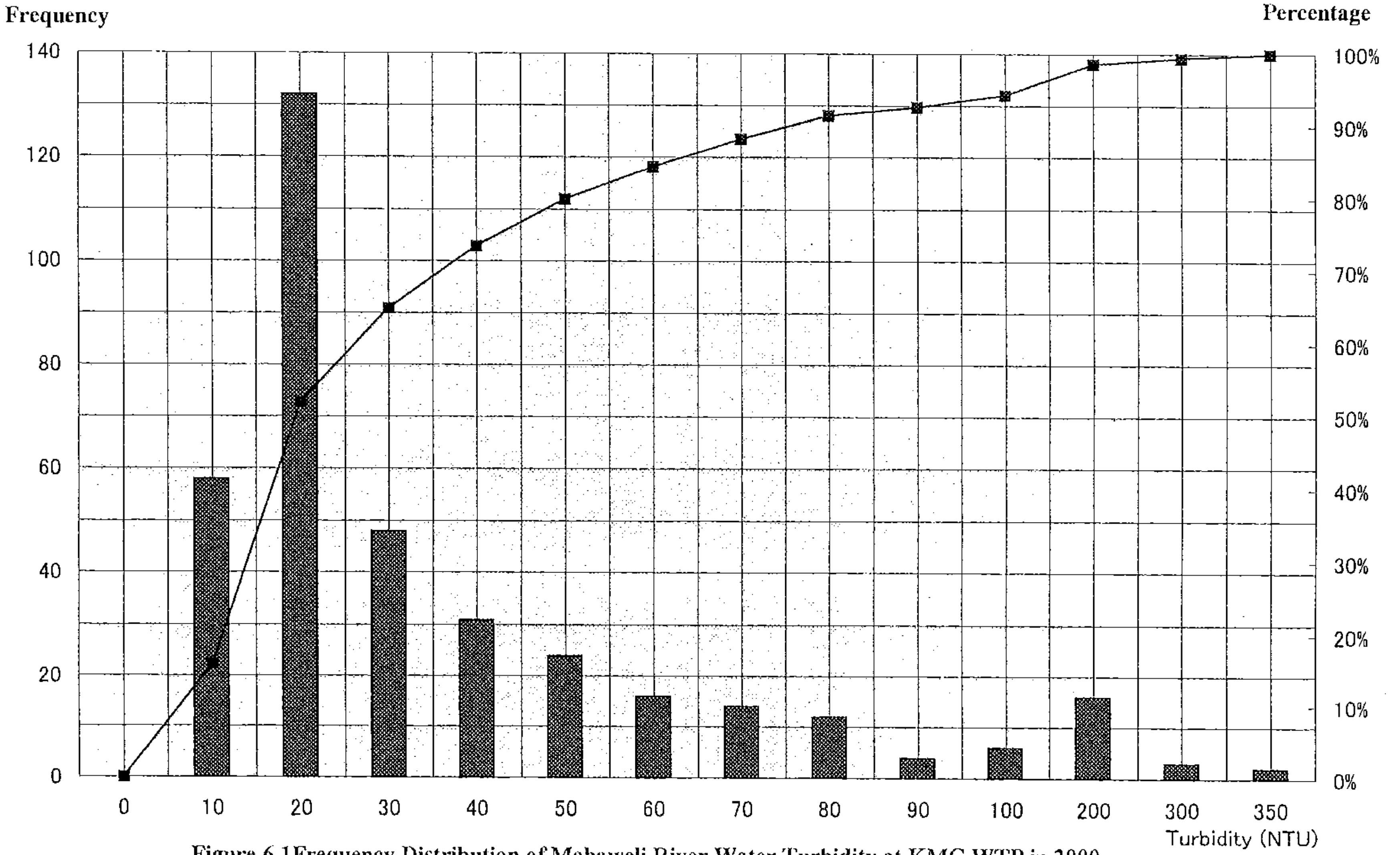


Figure 6.1Frequency Distribution of Mahaweli River Water Turbidity at KMC WTP in 2000

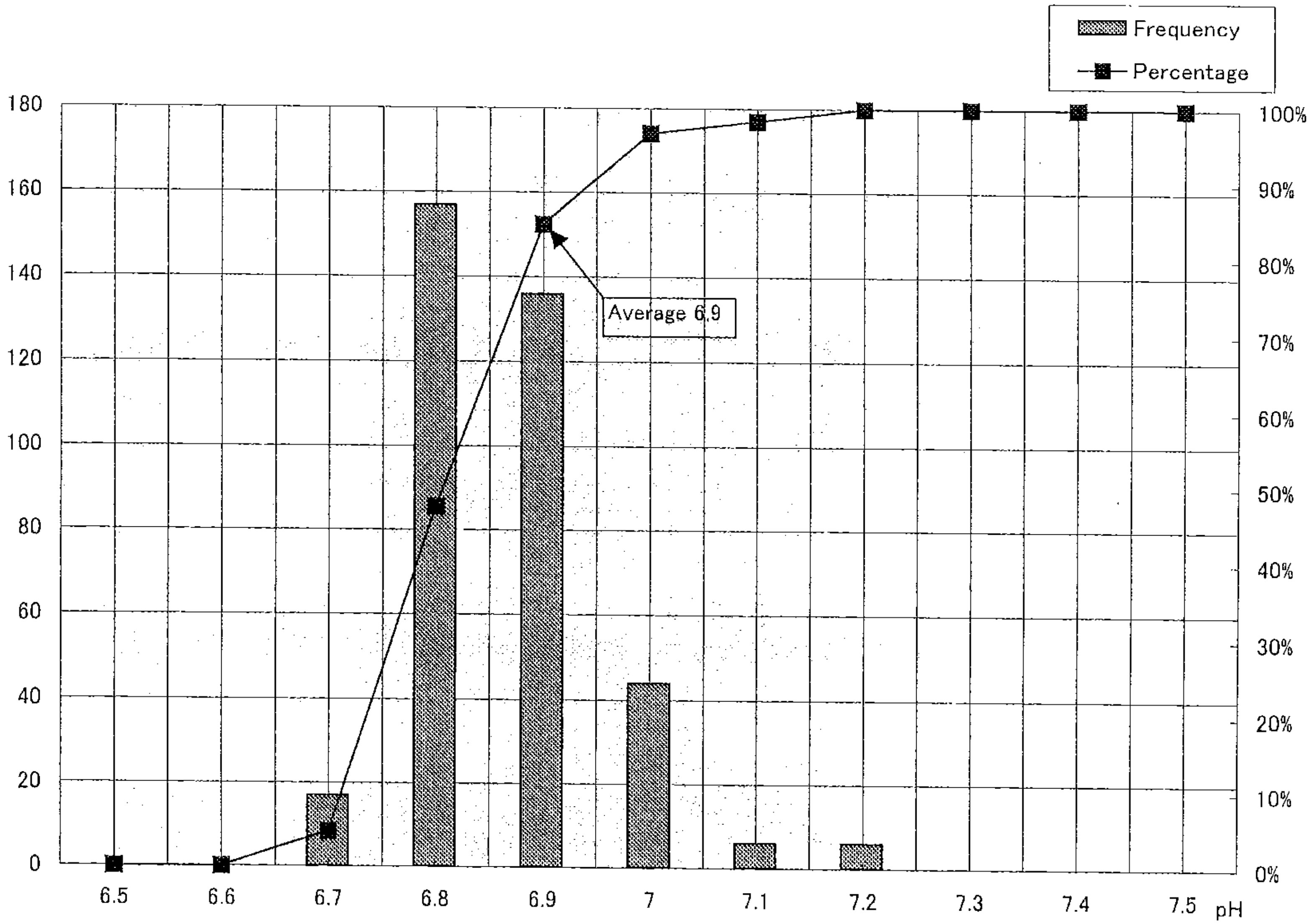


Figure 6.2 pH Frequency of Mahaweli River at KMC WTP in 2000

6.4 Raw Water Intake and Balancing Tank

6.4.1 Raw Water Intake Facilities

The intake is located at Gohagoda on the left bank on a short straight section of the Mahaweli River, 4.1 km up-stream of the Polgolla Dam as proposed in the 1999 JICA F/S. The proposed site is currently grassland at elevations ranging from 440.5 m to 442.5 m, and gradually becoming a gentle climbing slope from the riverside. River flow is smooth with no significant eddies when the Polgolla Dam discharges the flow. However, when the Dam is closed the flow is stagnated and siltation is possibly taking place.

The raw water is taken from the Mahaweli River to grit chamber through the intake mouth with the bottom elevation at 436 m AMSL, which is the present riverbed level and 2.3 m below the low operating water level of the Polgolla Dam. The lowest low water level is set at 437.6 m AMSL, 1.6 m above the riverbed, which was surveyed by the JICA Study Team during the sludge discharge operation for maintenance of the Polgolla Dam on 26th April 2001. The low water level is set at 438.30 m AMSL, same as low operating water level of the Polgolla Dam. The flood water level is estimated at 441 m AMSL based on available data given by the Mahaweli Authority of Sri Lanka as described in the previous chapter. Therefore, the ground level and motor floor level of the intake facilities is planned at 442.5 m AMSL (1.5 m above the high flood level) and 443 m MSL (2 m above the high flood level), respectively.

To prevent large debris from entering the raw water pumps, the river water should be screened to limit the size of solids, which would otherwise damage the pumps. It is proposed to install two sets each of coarse and fine screens at two trains of inflow conduits. The coarse screen is cleaned manually as accumulated debris to be removed should be minimal except during floods. The fine screens are mechanically operated on a timing device. Thereafter, the raw water is introduced to two trains of grit chambers with a detention time of approximately 15 minutes for Phase 3 capacity where grit with a diameter larger than 0.1 mm will be removed. Incidentally, the designed particle size to be removed at grit chambers of the existing KMC water treatment plant is 0.15 mm, and hence the grit removal will be more effective than the KMC system. The effective depth for grit accumulation of grit chambers is set at 1.0 m. In the event of maintenance, two grit chamber can be isolated each others and emptied by operating inflow and effluent sluice gate valves or stop logs, without interrupting the performance. Then, mobile pumps will be installed in one of the grit chamber to discharge the settled grit on the bottom regularly. The designed surface load is held at the low level of 200 mm/min to cope with unexpected overloading during rainy season.

To meet the designed water demands in 2005, two units of raw water intake pumps are installed in Phase 1 to supply the treatment plant with a constant flow, with one unit as standby. With each unit pumping at 38,500 m^3/d (0.446 m^3/sec), three units will meet the 2015 flow with a fourth, as standby, and space will be provided for two more pumps to meet the 2015 demand. Detailed type and specification of pumps are referred to Chapter 9, Mechanical Facilities.

The pumping head required is the total of static head and friction head loss resulting from pumping a total of 115,500 m^3/d by three units of raw water intake pumps, through the raw water transmission main with capacity for the design year 2015. The designed static head is from low water level at the suction sump to the top level of balancing tank to be installed along the route of the raw water pumping main.

The motor room is provided with a gantry crane with a lifting capacity of 3.5 tons over the motors and discharge piping to remove items for repair. The roof is designed to have enough height to lift the vertical double suction volute pumps and install additional units in the future to meet 2010 and 2015 flows. The motor room would also include the motor control panel, alarms, flow indication equipment, and telemetry panels.

1) Number	:	2 inflow conduits, 2 grit chambers, 1 pump room, 1 motor room, 1 electrical room
2) Dimensions	:	6.0 m width x 33.5 m length x 3.1 m depth x 2 basins
3) Effective depth	:	1 m to allow for grit acm3ulation)
4) Detention time	:	15.3 min. for Phase 3 capacity (10 to 20 min.
5) Surface load	:	200 mm/min (200 to 500 mm/min)
6) Average velocity	:	3.65 cm/sec (2 to 7 cm/sec)

6.4.2 Balancing Tank

A balancing tank has a function that avoids negative pressure along the raw water conveyance pipe caused by the up and down gradient of the ground level. The set high water level at the balancing tank is required to be 476.0 m AMSL. An overflow chamber is provided to discharge all of the raw water assuming that all outlets are blocked.

The raw water conveyance pipeline is of 800 and 1,000 mm DI pipe with a total length of 1.5 km, consisting of 0.4 km of 800 mm pressure pipe up to the proposed balancing tank, which will only cater for 2005 demand, and 1.1 km of 1,000 and 800 mm gravity flow from the balancing tank to the receiving well in the treatment plant, which will cater for 2015 demand. Along the gravity flow pipe, two sets of pressure regulating system by means of orifices with control valves are to be installed to control excess pressure.

1) Number	:	1 inflow conduits, 1 effluent chamber, 1 overflow chamber
2) Dimensions	:	9.0 m width x 7.0 m length x 4.1 m depth x 1 basin
3) Detention time	:	Approx. 3 min. for Phase 3 capacity

6.5 Pretreatment

Coagulation as a pre-treatment process of the rapid filtration system will be applied at the distribution chamber, the head end of the plant so that the destabilization of charges on colloids and suspended solids, including bacteria and viruses may be achieved, followed by the treatment processes of flocculation, sedimentation, filtration, and disinfection.

The coagulation process is achieved by a rapid mixing system which disperses 10 percent alum solution, $Al_2 (SO_4)_3$?$18H_2O$ as a coagulant uniformly throughout the entire mass of water, with maximum possible rapidity. Distinctive products or many types of rapid mixing equipment are available with every manufacturer as shown in Table 6.2. In line with the design concepts proposed in the previous section, the intensity of turbulence is preferably generated hydraulically through the hydraulic jump caused by weirs or flumes to be installed at the distribution chamber.

The advantage of hydraulic mixing is to simply apply raw water potential head generated by the raw water intake pumps. The exclusion of mechanical moving parts renders the general design concept a reality. The mixing energy of the hydraulic jump corresponds to a velocity gradient not less than 300 s^{-1} at the water temperature being taken as 25℃, for the calculation.

In case the alkalinity of the raw water is less than 20 mg/l, pre-lime is to be employed at the distribution chamber using 10 percent lime solution as an agent for pH adjustment, prior to the coagulation to ensure the effective coagulation process. In addition, pre-chlorination should be applied using gas chlorinators from time to time, for removal of iron and/or manganese and the algal control, if those parameters exceed the Drinking Water Standards.

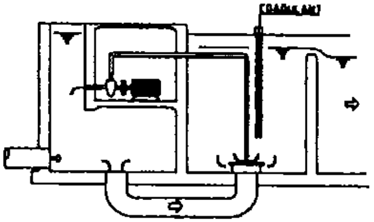
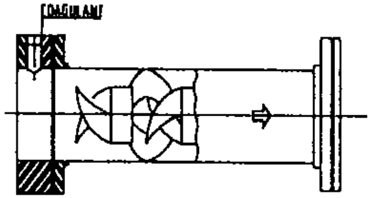
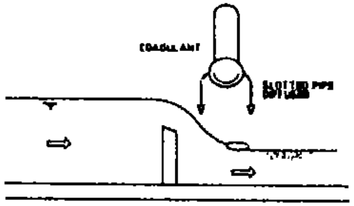
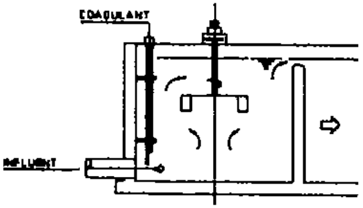
The detention time and effective depth of mixing chamber are designed to be 2.5 minutes and 3.9 m, respectively. Adequate baffles, surface area as well as weirs is provided with the distribution chamber to secure proper coagulation and flow measurement.

Mechanical mixers are generally propriety devices, whose major technical advantages are that mixing is not a function of flow and they are flexible in adjusting the degree of turbulence to suit the particular treatment needs. In some cases, where the required head loss for hydraulic rapid mixing is not given at the site due to unfavourable topographic or soil conditions, mechanical mixers may be considered as an alternative.

The applied design parameters of the pre-treatment process are summarised in the following;

1) Type : Distribution chamber with hydraulic rapid mixing by weir
2) Number : 1 unit with a capacity of 115,500 m^3/day to cater for till Phase 3 extension
3) G value for rapid mixing : 330 300s^{-1} (> 300s^{-1})
4) Applied chemicals : Chlorination-------Liquid chlorine (99.9 percent)
pH control--------- Lime (10 percent solution)
Coagulant--------- Alum (10 percent solution)

Table 6.2 Comparison of Rapid Mixing Process

Type of Rapid Mixing	In-line Jet Mixer	Static In-line Mixer	Hydraulic Mixing	Mechanical Mixing
Typical Drawings				
Design Criteria (for reference only)	G value = 500 to 1,000 $^{s-1}$ Pressure = 0.7 kg/m2 Time = 0.5 sec.	G value = 500 to 1,000 $^{s-1}$ Headloss = max. 600 mm Time = 1-3 sec.	Headloss = 300-600 mm (300 mm provides G-value of 1,000^{s-1} at 20 degree)	G value = 500 to 1,000 $^{s-1}$ Time = 1 min. Required Power = 2.5 kW per 1 m3/s of raw wagter.
Advantages	1. No additional headloss 2. Controllable degree of mixing 3. Less power consumption 4. Effective mixing	1. No moving part 2. Low maintenance cost	1. No moving part 2. No clogging problems 3. No external energy 4. Low maintenance cost 5. Combination with flow mesurement 6. Easy monitoring for chemical feed	1. No additional headloss 2. Adjustable mixing effects
Disadvantages	1. Clogging of nozzle 2. Difficulty in applying to extra large pipes. 3. Complexive contruction schedule.	1. Inflexible mixing effects for fluctuation of treatment capacity. 2. Performance relys on the manufacture. 3. Clogging problems for chemocals or algae. 4. High loss of head	1. Inflexible mixing effects for fluctuation of treatment capacity. 2. High loss of head.	1. Lack of instantaneous mixing characteristics 2. Short-circuiting 3. O&M for mechanical parts

6.6 Flocculation

Flocculation is the process of gentle and continuous agitation, during which action suspended particles in the water coalesce into larger masses, so that they may be removed from the water in subsequent treatment processes, particularly by sedimentation. Flocculation follows directly after the rapid mixing process and, like rapid mixing, the agitation may be induced either by mechanical or hydraulic means.

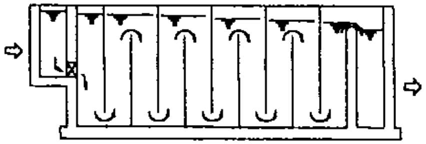
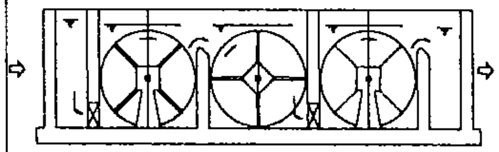
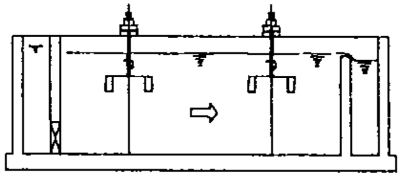
The most common methods for flocculation are categorised into hydraulic flocculation and mechanical flocculation processes, which are further classified into horizontal and vertical flocculation units as summarised in Table 6.3. Mechanical flocculators are characterised by their flexibility for the fluctuating water treatment capacity and controllable mixing intensity, because of their greater versatility; that is, the speed of the mechanically operated paddles can be adjusted to suit variations in flow, temperature, or raw water quality. However, the principle elements of mechanical flocculator systems comprise agitator impellers, drive motors, speed controllers and reducers, transmission system, shafts and bearings which will intricate operation and maintenance procedures.

As discussed, the provision of the Katugastota WTP is essential in order to enhance supplies to meet the anticipated increasing demands in the Greater Kandy area. Before commencement of the Phase 2 Project, with a production capacity limited to 36,670 m^3/day in Phase 1, there is a potential risk of a supply deficit being experienced. Hence, the proposed Water Treatment Plant would be operated at full designed capacity immediately from the time of commissioning. This means, that fluctuations of flow for treatment capacity are expected to be minimal, and would be manageable by the provision of a number of treatment trains, and the designed flow rates can easily maintain sufficient head losses in the channel for mixing.

Therefore, as gravity flow is available, the proposed approach for this plant is to use hydraulic flocculators that would neither require mechanical equipment nor a continuous power supply. They can be built primarily from local materials including concrete, brick, wood, or masonry at relatively low cost.

Vertical-flow baffled channel flocculators with a detention time of approximately 30 min are designed, as recommended in the 1999 JICA F/S. Two trains is provided so that in the event of lower flows than the designed capacity, or maintenance works, one train may be shut down accordingly to attain a suitable flocculation intensity, G-value range from 70 to $10s^{-1}$. The width of the flocculation channels is sized in thirds to adjust the hydraulically required flocculation intensity from 70 to 10 s^{-1}, i.e. higher intensity to gentle mixing towards sedimentation process.

Table 6.3 Comparison of Flocculation Process

Type	Hydraulic System	Mechanical Flocculagtors	
	Baffled Channel	Horizontal Shaft with Paddles	Vertical Shaft with Blades
Typical Drawings			
Performance - Flocculation - Reliability - Operation Flexibililty - Capital Cost - Construction - Maintenance - Flow Condition	Good to excellent Good to excellent Moderate to poor Low Easy Low cost and easy Near plug flow	Good to excellent Good to excellent High Moderate to High Moderate High Short circuiting	Fair to good Good Good High Easy to moderate Moderate Short circuiling
Advantages	1. Simple and effective floc formation 2. Low O&M cost 3. No moving parts	1. Good floc formation 2. Effective/adjustable flocculation effects 3. No loss of head	1. Good floc formation 2. Adjustable flocculation effects 3. No loss of head 4. Easy to input high energy 5. Easy maintenance for mechanical part
Disadvantages	1. Inflexible mixing effects for fluctuation of treatment capacity. 2. High (0.6 to 0.9 m) loss of head 3. Limited eanergy input	1. Precise installation of treatment capacity. 2. High O&M cost 3. Regular O&M 4. Short circuiting	1. Many units reuired 2. Short circuiting

The applied design parameters for the flocculation process are:

1) Type	:	Vertical-flow baffled channels
2) Number	:	2 trains with 3 staged tapered flocculation
3) Detention time	:	Approx. 30 min (from 20 to 40 min)
4) G value	:	Approx. 10 to 70 s^{-1}
5) Dimensions	:	1.1 m width x 11 m length x 3.50 m depth x 2 channels 1.5 m width x 11 m length x 3.50 m depth x 2 channels 2.3 m width x 11 m length x 3.50 m depth x 2 channels

6.7 Sedimentation

The sedimentation or clarification process in water treatment provides for the settlement and removal of a majority of the settleable solids of heavier and larger suspended particles from water, prior to the subsequent filtration process. To maximize filtration process, the settled water turbidity preferably should be between 2 to 5 NTU as observed during normal operations. However, the sedimentation is greatly dependent upon the adequate pretreatment processes, including coagulation and flocculation. The efficiency of the sedimentation basin is determined by the surface loading ratio *(Q/A)*, where *Q* is the rate treatment capacity, and *A* is the surface area of the sedimentation basin. The subsequent loading on the filters accordingly has a marked influence on their capacity; the length of filter runs in relation to the washing schedules, and the quality of the filtered water.

As tabulated in Table 6.4, the sedimentation system is classified into four major types: horizontal flow sedimentation units; up-flow sedimentation units; solids contact/slurry recirculation units; and sludge blanket clarifier units.

Horizontal flow sedimentation is commonly used in municipal water supply systems. It is based on gravity flow separation process, in which a settling basin provides a quiescent environment that enables particles of specific gravity heavier than water to settle to the bottom of the tank. The outstanding feature of horizontal flow tanks is the flexibility to tolerate shock loads in terms of both quantity and quality of raw water. In fact, rectangular sedimentation unit can handle 50 to 100 percent higher flow rates than the original design capacity for short periods without significant deterioration of settled water quality. Consequently, the flexibility and predictable performance under most conditions brings about easy and stable operation and low cost maintenance, even though the capital cost may be higher than the other systems.

Up-flow sedimentation, which is usually applied to small-scale community plants due to easy operation and maintenance, is recommended when the raw water characteristics and hydraulic conditions are stable. The up-flow unit provides low construction costs, and easy operation and maintenance due to its compact and simple structure. The Mahaweli River water is in general not stable in quality during rainy season, so that the up-flow sedimentation unit is not recommendable.

Sludge contact, or slurry recirculation, is a kind of modified up-flow unit process combining pretreatment processes of coagulation, flocculation, and settling in one tank. The unit circulates high density, and stable micro-flocs by means of density flow developed by low lift pump blades installed in the coagulation/flocculation zone. The inflowing micro-flocs, developed in the coagulation zone, are absorbed by the circulating flocs, and subsequently precipitate in the settling zone (so called seeding effects). The seeding effects used with relatively high turbid raw water enable high efficiencies for those pretreatment processes included in the separate compartment formed by steel members provided in the tank. hereafter, a higher rate of surface loading can be applied than in conventional horizontal or up-flow units. Nevertheless, the operation and maintenance is not necessarily easy to control. The optimum operational conditions are dependent on several parameters, such as raw water turbidity, pH, temperature, alkalinity, and slurry concentration, that should be monitored by properly trained, or experienced, skilled operators and/or engineers. The submerged steel members installed inside the tank must be periodically cleaned and painted to prevent corrosion problems.

In the context of constantly high turbid raw water, sludge blanket clarifiers may be applicable. However, the actual turbidity of the Mahaweli River is not so stable. Incoming suspended solids fed into the slurry zone (so called, sludge blanket) are coagulated and adhered to within the sludge blanket. The increased sludge volume is then discharged periodically by operating sludge discharge valves, while the separated supernatant water flows to the filtration process. The key factor for successful operation is to maintain the sludge blanket in optimum condition despite the inevitable fluctuation of turbidity, pH and alkalinity of the raw water, which is difficult to regulate without experience. In addition, raw water with algae may be difficult to treat because they may float, carrying the sludge blanket and flocculated solids to the surface and overflow to the filters. In both sludge contact and/or sludge blanket clarifiers, skilled supervision is essential to accomplish stable operation, because the treatment principle is only secured by the balanced velocity between flocculated particles settling and up-flow. Although this type of process is being used at Ambatale, the characteristics of the Kelani River, are likely to be different from those of the Mahaweli River. The anticipated difficulties in operation to cope with the fluctuation of the Mahaweli River water quality, and the need to provide a reliable strategic treatment regime in a relatively remote location, draw the conclusion that sludge contact and sludge blanket clarifiers are not appropriate for the Mahaweli River water source.

Inclined plates are used in sedimentation processes including horizontal flow basins, up-flow basins, reactor clarifiers, and sludge blanket clarifiers. The operation efficiency may possibly improve by 50 to 150 percent in relation to the available allowances in original designs.

However, for those water supply bodies in tropical countries, the use of inclined plates should be limited, in most cases, to expand settling basin capacity and/or improving plant effluent quality due to hot and sunny climates promoting algal growth on plates, which can bring about maintenance problems.

The actual operation results of the KMC Water Treatment Plant suggest that the sludge blanket unit will have difficulty in coping with the fluctuations in raw water quality. The raw water quality demonstrates a propensity for turbidity to fluctuate frequently after precipitation, which often results in insufficient treatment in clarifying process, as experienced in the existing KMC Water Treatment Plant. Eventually, the clarified water turbidity may exceed 5 NTU resulting in the deterioration of filtered water quality over 1 NTU.

Thus, the sludge contact and sludge blanket clarifiers are not recommended due to their incompetence to handle shock loads, whilst horizontal flow rectangular basins are most stable against unpredictable conditions and serve as the most appropriate sedimentation process.

The available land space at the proposed Katugastota site for the major facilities is about 100 m x 150 m or approximately 1.5 ha plus fringe areas, which somehow allows for construction of a total of 110,000 m^3/d of conventional horizontal flow sedimentation unit employing full gravity system from pre-treatment to filtration and through disinfection processes.

The applied design parameters for the sedimentation process are:

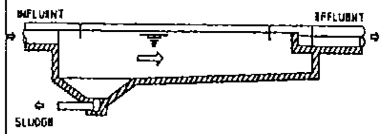
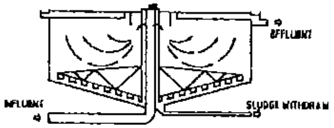
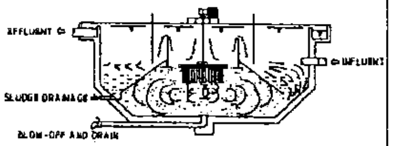
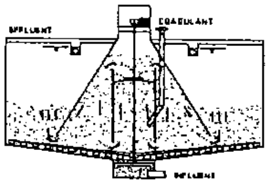
1) Type : Rectangular plug flow
2) Number : 2 trains with hydraulic sludge removal pipes
3) Surface loading : 25 mm/min (< 30 mm/min)
4) Passing velocity : 0.31 m/min (< 0.4 m/min)
5) Collecting trough loading : 370 m^3/m/day (< 500 m^3/m/day)
6) Dimensions : 11 m width x 41 m length x 4 m depth x 2 trains
7) Intermediate chlorination : Effluent chamber to filter units

6.8 Rapid Sand Filtration

Filtration is the last safeguard process in the water treatment system to secure physicochemical safety through the combination of physical, chemical, and in some instances biological process for separating the carried over minute impurities from settled water by passage through porous media.

The design variables for rapid sand filtration process include in order of importance: type of filter media and filtration rate; washing arrangements; type of filter rate control, and auxiliary arrangements.

Table 6.4 Comparison of Sedimentation Process

Type of Clarifier	Horizontal Flow Sedimentation Unit (rectangular basin)	Up Flow Sedimentation Unit (radial-upflow)	Soilds Contact/Slurry Recirculation Unit	Sludge Blanket Clarifier Unit
Typical Drawings				
Design Criteria (for reference only)	1. Surface loading : 0.83-2.5 m/h 2. Water depth : 3-5 m 3. Detention time : 1.5-3 h 4. Width/length : 1/3 ~ 1/5 5. Weir loading : < 400m3/m.d	1. Surface loading : 1.3-1.9 m/h 2. Water depth : 3-5 m 3. Settling time : 1-3 h 4. Weir loading : 250 m3/m.d	1. Flocculation time : approx. 20 min. 2. Settling time : 1-2 h 3. Surface loading : 2-3 m/h 4. Weir loading : 350 m3/m.d	1. Flocculation time : approx. 20 min. 2. Settling time : 1-25 h 3. Surface loading : 2-3 m/h 4. Weir loading : 7.3 to 15 m/m.h 5. Upflow velocity : <10 mm/min. 6. Slurry circulation rate : up to 3-5 times the raw water inflow rate
Advantages	1. More tolerance to shock loads in Tu and Temp. 2. Predictable performance under most conditions 3. Easy operation and low maintenance costs 4. Easy adaptation to high-rate settloing modules for future expansion	1. Economical compact geometry 2. Easy sludge removal 3. High clarification efficiency	1. Incorporates coagulation/flocculation and clarification in one unit 2. Good flocculation and clarification efficiency due to a seeding effects in case of stable raw water quality 3. Tolerates slightly limited changes in raw water quality and flow rate	1. Incorporates coagulation/flocculation and clarification in one unit 2. Compact and economical design 3. Tolerates limited changes in raw water quality and flow rate 4. Preferable to highly turbid raw water
Disadvantages	1. Subject to density flow creation in the basin 2. Requires careful design of the inlet and outlet structures 3. Usually requires separate flocculation facilities	1. Problems of flow short-circuiting 2. Less tolerance to shock loads in Tu and Temp. 3. A need for more careful operation 4. Limitation on the practical size of the unit 5. May require separate flocculation facilities	1. Requires greater operator skill 2. Less reliability than conventional due to a dependency on one mechanical part 3. Subject to upsets due to thermal effects 4. Time consuming for seeding sludge preparations	1. Very sensitive to shock loads 2. Sensitive to temperature change 3. Several days required to build up the necessary sludge blanket 4. Plant operation depends on a single mechanical part 5. Requires greater operator skill 6. Inefficient treatment in lower treatment capacity due to difficulty of maitaining sludge blancket properly 7. Difficuly of algae contained raw water due to float to surface
Proper Application	Most municipal and industrial water works Particularly suited to larger capacity plants	Small to mid-sized municipal and industrial treatment plants Best suited where the rate of flow and raw water quality are constant	A plant that treats a steady quality and quantity of raw water	Flocculation/sedimentation treatment of raw water with a constant quality and rate of flow Plant treating a raw water with a low content of solids

Notes : The reactor clarifiers and the sludge blanket type clarifiers are often considered to be in the same category.

6.8.1 Type of Filter Media and Filtration Rate

Dual-media filter beds consisting of anthracite and sand provided in the original filter bed of filter Nos. 1 to 12 at Ambatale Water Treatment Plant made possible (i) higher filtration rates than of conventional filters, resulting in a reduction in the total filter area and cost for the given design capacity and (ii) longer filter runs at any given loading. However, an unexpected loss of anthracite took place because of an inconsistent washing schedule using the combined air scouring and water backwash, without wash troughs. The filters eventually did not function properly with a deterioration of the filtered water, which resulted in exceeding the water quality beyond the Sri Lankan Drinking Water Standards.

During the Ambatale Rehabilitation Project, the JICA Study Team provided with a single media of sand, 900 mm thick and 0.9 mm effective size, with a filtration rate of 202 m^3/day based on a pilot filtration study in 1996. The subsequent operation results of the Ambatale Water Treatment Plant reflected a satisfactory production record to date. The data indicated that only on six days in the period from April 1999 through April 2000 the filtered water quality exceeded the acceptable level of 1.0 NTU. Undesirable operation of the filters seldom happens, except when the clarifiers fail to remove turbidity to less than 5 NTU. This is mostly caused by sharp fluctuations of inflow turbidity.

For Kandy Project, water demand is expected to rise sharply, and therefore a filtration rate of 150 m ^{3}/day plus a 30 percent allowance to make 200 m^3/day is recommendable during the transition period, between Phase 1 through Phase 3. This rate is justified in view of the designed filtration rate of 154 to 173 m^3/d at KMC treatment plant within almost the same range, and operating successfully.

The required filter area and number of units are interrelated. The maximum size of filter bed should be limited to less than 150 m^2, so that uneven flow of air scoring and washwater can be avoided.

The applied design parameters for the filter media and filtration rate are:

1) Filtration rate : 150 m^3/day (< 200 m^3/day during backwashing)
2) Filter media : Silica sand, 1,200 mm thickness,
E.S. = 1.0 to 1.2 mm, U.C. <1.5
3) Nos. of filters : 4 units
4) Dimensions per unit : 7.2 m x 9.6 m (=69.1 m^2/unit < 150 m^2)

6.8.2 Filter Wash Arrangements

Backwashing is designed to remove the suspended materials that have been deposited in the filter bed during the filtration cycle. Thus, the washing arrangements should be compatible with the applied filter bed in consideration of (i) kind of the applied filter media, (ii) sizes of the filter media, and (iii) thickness of the filter bed. Likewise, it should be remembered that proper backwashing is achieved only through well-organised auxiliary wash system of surface washing or air scoring.

The applied deep bed filter is not compatible with surface wash system, even with fixed grid or rotating arm types, because the mixing energy provided by the surface wash may not reach towards the deeper portion of the bed where the retained material is clogged. A rotating arm type with dual-arm agitators is available for deep or dual media filters. However, this is not recommended due to the more complex structure and the inevitable maintenance of the rotating parts. Therefore, the air scoring system is applicable in this case, which is widely employed in existing water treatment plants in Sri Lanka.

The rates of backwash need to be high enough to wash out the clogged substances in the filter media, but no higher. The percentage of expansion that accompanies any backwash rate is a function of the sand size, specific gravity and temperature of the water. Considering the relatively high temperatures and the existing conditions, a combination of 0.25 to 0.30 m^3/m^2/min of backwash and 1.0 m^3/m^2/min of air scoring is recommended. Backwash water will be tapped from the filtered water effluent chamber at the filter units into which the filtered water flows more than the required amount of the backwash, and pumped to each filter as necessary.

The applied design parameters for the filter wash arrangement are:

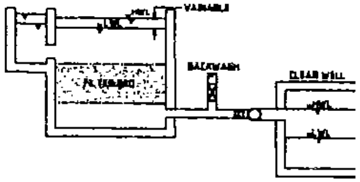
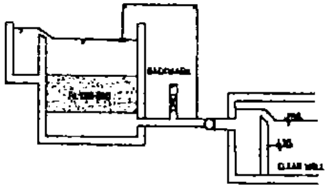
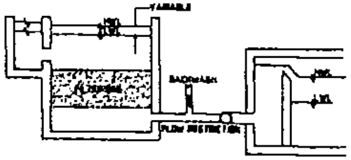
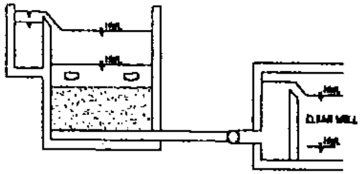
1) Backwash rate : 0.25 to 0.30 m^3/m^2/min
2) Auxiliary wash : Air-scoring, 1.0 m^3/m^2/min
3) Backwash water : Tap the filtered water chamber at the filter units

6.8.3 Type of Filter Rate Control

As shown in Table 6.5, typical filter rate controllers are more or less dependent on mechanical or instrumentation systems, except for the self-backwash filter system. However all systems have their own inherent advantages and disadvantages.

The self-backwash system is applicable in certain circumstances, but not in all respects because backwash water has to be provided for at least eight other filter units. This increases the total construction cost and it is dependent upon the applied filtration rate. The washing strength is not adjustable unless backwash pumps are provided, which writes off the advantages and leads to a more costly work. The structure needs to be deeper and the effluent weirs will not function correctly, if not precisely constructed.

Table 6.5 Comparison of Filteration Process

Type of Filters	Constant Rate Filtration	Constant Level Filtration	Declining Rate Filtration	Constant Rate Filter with Influent Splitter and Varing Water Level
Typical Drawings	 (Flow meter & flow modulation valve)	 (Influent control, level sensor & modulation valve)	 (No influent control, no modulation valve an orifice plate)	
Main Equipment	1. Inlet gate 2. Outlet valve (flow modulation valve) 3. Flow meter 4. Backwash valve 5. Air scouring valve 6. Washout gate 7. Washwater pump (elevated tank) 8. Air blower	1. Inlet gate 2. Concentric siphon 3. Partialisation box 4. Outlet valve 5. Backwash valve 6. Air scouring valve 7. Washout valve 8. Washwater pump 9. Air blower	1. Inlet gate 2. Flow restriction (orifice plate) 3. Outlet valve 4. Backwash valve 5. Air scouring (surface wash) valve 6. Washout gate 7. Washwater pump (elevated tank) 8. Air blower (surface wash pump)	1. Inlet gate 2. Outlet valve 3. Backwashing and airscoring sytem 4. Washout channel 5. Air scoring blower
Filter Washing System	Backwash by elevated wash tank/pump Air scour wash	Backwash by elevated wash tank/pump Air scour wash	Backwash by elevated wash tank/pump Air scour wash/surface wash	Backwash by elevated wash tank/pump Air scour wash/surface wash
Advantages	1. A widely accepted filtration Process	1. A widely accepted filtration Process	1. Simple control 2. Low maintenance Cost	1. Simple control 2. Low maintenance cost 3. Limited use of mechanical equipment
Disadvantages	1 High capital cost 2. Highest maintenance cost 3. Easily damages on flow meter/flow modulation valve	1. High capital cost 2. High maintenance cost	1. Requires more than six units of filters in one module 2. Potential of initial turbidity break through	1. Deeper filter cells
Proper Application	Most plants with qualified operators and Support personnel	Most plants with qualified operators and support personnel	Middle capacity plants in developing countires	Middle/large capacity plants in any countries

An integral requirement for the sustainable operation of filters is to distribute the settled water evenly into each filter, and to backwash them regularly, if the loss of head reaches the designed level or after 24 to 48 hours of filter run, dependent on the settled water quality. Unscheduled backwashing will be inevitable in situations where the turbidity of the settled water is beyond the desirable level of 5 NTU. Inflow weirs, without filter controllers are recommended to hydraulically distribute the settled water evenly to each filter unit. Effluent weirs to be installed at the tale end of each filter unit is recommended to achieve a constant rate filtration system, which secures stable operation of filtration. The water level in each filter unit rises as necessary to accept an equal portion of influent and indicates head loss.

The applied filter control system is:

1)	Filtration system	:	Constant-rate filter with influent splitting and varying water level
2)	Inflow/effluent control	:	Weirs

6.8.4 Auxiliary Arrangements

The major requirements for the filter underdrain system are the support of the filter media, and the uniform distribution of the scouring air and backwash water across the entire filter bed. In many instances, bases can be with reinforced concrete slabs with plastic strainers, precast concrete percolated block, or glass-tube orifices, or simple perforated-pipe lateral systems as shown in Table 6.6.

The filter underdrain system is selected based on the combination of filter media and washing system, from strainers, dual lateral blocks, and precast concrete perforated underdrains, as commonly adopted. The selection criteria are reliability, simplicity of design/construction, durability, and low head loss during washing.

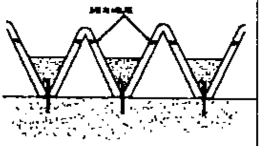
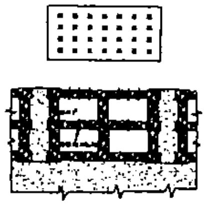
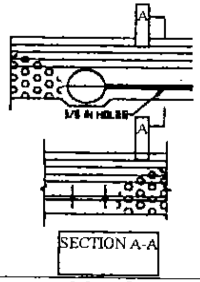
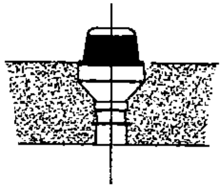
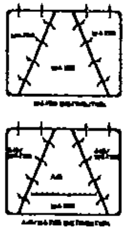
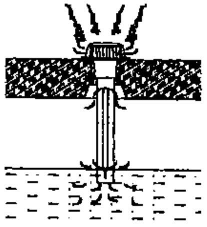
For this project, a nozzle type is preferably the most appropriate strainer, to provide easy installation and most stable underdrain system in combination with the proposed air scouring and washing systems. Supporting gravel is not necessarily required for the strainer underdrain system.

The valves that control necessary filtration process are of electrically operated type, which is in recent years made relatively easy for operation and maintenance than that of pneumatic systems.

The applied underdrain system is:

1)	Underdrain system	:	Strainer type
2)	Supporting gravels	:	Minimal or not applicable
3)	Valves	:	Electrically operated

Table 6.6 Comparison of Underdrains

Type	Ordinal Backwash Filters				Airscour and Backwash Filters	
	Precast concrete laterals	Dual-parallel lateral blocks (tile blocks)	Pipe laterals	Strainer	Dual-lateral blocks (polyethylene blocks)	Strainer
Typical Drawings						
Headloss at Ordinary Backwash Rates	1 - 1.5 m	0.6 - 1.8 m	0.9 - 1.5 m	1 - 2 m	0.6 - 1 m *1	0.4 - 0.6 m *2
Orifice Size (Diameter) (For reference only)	8 - 10 mm	4 - 6 mm	6 - 10 mm	0.25 - 0.75 mm	6 mm	0.25 - 0.75 mm
Particulars	1. 0.3 m lateral spacing 2. 75 mm orifice spacing on either side of the lateral 3. Maximum lateral length of 4.8 mm	1. 0.3 m lateral spacing 2. 516 or 193 orifices per m2 area 3. Maximum lateral length of 15 m	1. 0.3 m lateral spacing 2. Orifices are spaced 75-100 mm. apart and 45degree down-angle from the horizontal on both sides of the lateral 3. Maximum lateral length of 6 m	1. Plenum or lateral bottom 2. Strainers spaced 150 - 200mm apart 3. A space less than 250mm for the lateral	1. 0.3 m lateral spacing 2. 247 dispersion orifices per m2 of bed area 3. Maximum jointed lateral length is 15 m 4. Gravel layers required on top of the blocks	1. The preferred height of the plenum bottom is 0.6 m 2. Durable and proven types of strainer should be selected 3. A gravel bed is usually not required above the strainers

*1-under simultaneous air and water backwash at 0.9m/min. constant air rate and, 0.6 and 0.8 m/min. backwash rate
*2-under 0.8 m/min. wash rate

NJS Consultants Co., Ltd

6.9 Chemical Applications and Chlorination

Alum as a coagulant, lime for pH control, and liquid chlorine as a disinfectant are employed on the proposed Katugastota WTP, similar to the existing Ambatale and KMC Water Treatment Plants. The dosages (in mg/l) and applied points of each chemical is shown in Table 6.7 in reference to operation conditions of the existing KMC WTP facilities as shown in *Appendix 1, KMC WTP Operation in the Year 2000.*

All of the equipment and faculties for chemical applications and chlorination are provided in the Chemical Building, which will be constructed near by the Administration Building for easy administration.

Table 6.7 Chemical Dosage

	Max.	Ave.	Min.	Dosing Points
1) Alum	60	30	10	Distribution chamber
2) Pre lime	30	10	5	Ditto
3) Post lime	20	5	5	Effluent chamber of filter units
4) Pre chlorine	5	2	1	Distribution chamber
5) Intermediate chlorine				Alternative for pre-chlorine at the effluent channel of sedimentation basins
6) Post chlorine	2	1	1	Effluent chamber of filter units

6.9.1 Alum

Alum will be delivered in bags containing 50 kg of aluminum sulphate $Al_2\ (SO_4)_3\ \cdot 18H_2O$. According to the water quality records at the KMC WTP, the maximum dosage is not likely to exceed 30 mg/l, but provisions will be made to enable the operators to satisfy dosage demands up to 60 mg/l with a 10 percent solution. The flow of alum solution is manually controlled according to the alum demand and to the actual raw water flow. It is noted that KMC system is using Alum at an average rate of 30 mg/l, and hence the design is safe and satisfactory.

The alum feeding facilities is consist of two dissolving tanks, having a total net capacity equivalent to at least one or two days retention time at the maximum dosing rate. Two tanks, one for duty and another for standby with dimensions of 2.0 m x 2.0 m x 2.5 m (deep) is built in reinforced concrete or mild steel with suitable acid resistant lining. Each dissolving tank is provided with a screen, dissolving tray, electrically driven mixer, overflow pipe, drain pipe, solution suction pipe, each complete with manual diaphragm or ball valve, and level gauge (float and counterpoise along a graduated scale).

6.9.2 Lime

Lime will be delivered in bags, containing 25 or 50 kg of imported hydrated lime. The maximum lime dosage is not likely to exceed 20 mg/l in accordance with the operating record of KMC Water Treatment Plant, but provisions will be made to enable the operator to satisfy dosage demands up to 30 mg/l with a 10 percent solution. The flow of lime slurry will be manually controlled according to the lime demand and the actual water flow.

Two slurry tanks are provided, having a total net capacity equivalent to at least one or two days retention time at the maximum dosing rate. Two tanks, one for duty and another for stand by with dimensions of 2.0 m x 2.0 m x 2.5 m (deep) are built in reinforced concrete or mild steel. Each slurry tank will be provided with a loading hatch with dust removal unit, a screen, an electrically driven mixer, overflow pipe, drain pipe and slurry outlet valve, each with manual diaphragm or ball valve, level gauge (float and counterpoise along a graduated scale).

6.9.3 Storage of Alum and Lime

Alum and lime storage at the treatment plant will be sufficient for at least 30 days of operation, at an average dosage of 30 mg/l of alum and 10 mg/l of lime, respectively. Bag stacking does not exceed 3 m high. The chemical storage for each facility is provided with suitable loading equipment to accommodate the specified maximum daily consumption of alum and lime.

6.9.4 Chlorine

Chlorine will be supplied in tonne containers of liquid chlorine. The facilities will include all equipment for storage, handling, dosing and injection of chlorine, together with safety equipment. The operation of the chlorinators will be controlled on a “START-STOP” basis according to the level in the distribution chamber, and/or clear water reservoir, similar to that detailed for the existing facilities of both the Ambatale and KMC Water Treatment Plants.

One chlorine drum of each row is supported on a weighing machine, which is provided with an adjustable tare lever and with supports for the drums. A row of chlorinators is equipped with one immersion pit, to reduce the damage in case of chlorine leakage. Evaporators is not necessary as a tonne container can feed evaporated chlorine about 10 kg/hr with no additional heat input or evaporator in premises at 20 to 25℃. The necessary number of chlorine cylinders is provided without evaporators based on the said conditions.

The dosing points for pre and intermediate chlorine shall be selected accordingly to the raw water quality and operation and maintenance purpose such as shock dosing for algae control in the flocculation, sedimentation, and filtration tanks. Subsequently, post chlorine shall be adjusted to retain necessary chlorine residual in the distribution network.

6.10 Clearwater Reservoir

The clearwater reservoir is to be constructed complete with two compartments on the plant site. The facility has a total volume corresponding to at least one hour of operation plus in-plant water. The amount needed for washing filter units will be stored in the effluent chamber at filter units.

Downstream and upstream isolation of each compartment is provided. Each compartment is designed to accept the nominal design flow without change of the normal operating levels. A sufficient number of baffles are installed in order to prevent dead zones in the clear water reservoir. An emergency overflow also are provided.

A pre chlorine contact chamber is designed at the effluent chamber of filter units to accomplish proper mixing of chlorine and filtered water.

6.10.1 Filter Washwater Tank

As mentioned in the previous section, the filter washwater tank is provided directly connected with the filer units as a filtered water effluent chamber.

A filter washwater tank may be advantageous in case of small-scale water treatment plants with several filter units, which possibly reduces the required capacity of backwash water transmission pumps. However, the number of filter units at the proposed Katugastota WTP in Phase 3 will be 12 units provided that number of filter units in Phase 1 is four. In this situation, the backwashing will be necessarily conducted at least once in every two hours or less, in the event of an emergency. The filter washwater tank should be then filled up in 30 minutes or so, which means that the backwash water transmission pumps will be operated continuously in the proposed washing method.

The proposed direct washing method by pumping is therefore desirable as backwashing will be able to be conducted anytime, if necessary.

6.11 Sludge Treatment

The sludge withdrawn hydraulically from the sedimentation basins is conveyed to sludge lagoons, which is considered the most appropriate sludge treatment process in tropical countries, as recommended in the JICA F/S. The dried sludge will be disposed of outside the treatment plant periodically by trucks. The expected amount of sludge generated in the sedimentation basins is estimated at 98 percent water content, and the estimated total volume is 35,380 m^3/year. The designed water content of dried sludge in the lagoon is 70 percent. The dried sludge volume is then computed to be 2,360 m^3/year. Two lagoons with a volume of 2,450 m^3 (>2,360 m^3/year) each are provided, including one lagoon for standby, taking unexpected weather conditions into account.

The applied design parameters for the sludge lagoons are:

1) Nos. of lagoons : 2 (one for standby)
2) Dimensions : 45 m x 30 m x 2 m (effective depth)

6.12 Sampling of Process Water and Laboratory Equipment

For a permanent sampling of raw, settled, and treated water are drawn to the laboratory, to enable the control of the main parameters of the process water quality. The raw water is taken from the raw water main without sampling pump. The settled water is taken from the settled water effluent channel to filter units by sampling pumps. The finished or treated water is tapped from the service water pipeline.

At each treatment facility, the various treatment units (rapid mixing, flocculator, sedimentation basins, filters, chemical tanks, etc.) are provided with sampling taps in order to enable manual sampling of the various stages of water along the treatment processes.

A laboratory will be provided complete with necessary equipment, glassware and chemicals to enable the determination of the main physical and chemical parameters of the water with particular reference to the tests listed below and the analytical methods given in “Standard Methods for the Examination of Water and Wastewater” latest edition published by APHA, AWWA, WEF or the UK Standing Committee of Analysists, “ Methods for the Examination of Waters and Associated Materials”, HMSO, London. Since this plant will be the first major treatment facility in the Central Region, provision will also be made for investigative studies to be undertaken on optimisation of chemical dosing rates etc., so as to identify the best operating regime for the plant and to develop essential operating data to assist in improvement of the existing water supply systems, and in the future design of water supply systems in the area.

1) Chemical/Physical tests :

- taste and odour
- temperature
- pH value
- colour
- turbidity
- Conductivity
- Dissolved solids
- Suspended solids
- Alkalinity
- Total hardness
- Calcium
- Mangnesium
- Oxygen-dissolved
- Fluoride
- Chloride
- Sulphate
- cyanide
- Silica-reactive
- Phosphorus
- Nitrogen-nitrite
- Nitrogen-nitrate
- Aluminium
- Iron
- Manganese
- Biochemical oxygen demand
- Chemical oxygen demand
- Chlorine residual
- Sludge evaluation and Treatability testing
- Sludge cake solids content

2) Treatment process chemical test:

- Alum
- Lime

3) Bacteriological tests:

- Total coliform
- Colony counts
- E. coli
-

6.13 Pipework

Site pipework for the water treatment plant are consist of piping underground between structures or process units carrying liquids to various destinations of the plant. These include:

? raw water (from intake facility to distribution chamber through the balancing tank);
? treated water (from transmission pump to service reservoirs);
? plant water (used in treatment plant for i.e. alum dissolving);
? potable water (drinking water for staff);
? chlorine solution (pre- and post-disinfection);
? alum solution (to distribution chamber);
? lime solution (to distribution chamber);
? sewage (from toilets and wash down);
? wash water return (from washwater receiving tank to distribution chamber);
? wash water (from backwash tank/clearwater reservoir to filtration units);
? sludge wastewater (from sedimentation basin to sludge lagoons);
? supernatant (from sludge lagoon to river);
? overflow and drainage (rain runoff to river);
? fire protection water (from treated water main for fire protection), if any.

In addition, electrical distribution, grounding systems and instrumentation wiring will be installed underground. They will be constructed in designated reserves, generally along the plant access roads, between, and around, structures. Manholes, pull boxes or connection chambers for bends, valves, meters, etc will be provided.

6.14 Administration Facilities and Proposed Organization Chart

A two-storey building is to be constructed in the plant site. The ground floor will include an entrance with receptionist alcove, general office area, OIC room, stairs to the second floor, the laboratory and laboratory chemical storage room, chemist's room, a store, and toilets. Upstairs includes offices for the manager, engineers, conference room, a small library for drawings and engineering manuals in monitoring room, toilets and stairs to the lower floor would also be provided.

Ground floor	Dimensions	First floor	Dimensions
- General office	10 m x 7 m	- Manager room	7 m x 5 m
- OIC office	5 m x 7 m	- Civil engineering room	3.5 m x 5 m
- Staff office	5 m x 7 m	- Electrical eng. Room	3.5 m x 5 m
- Laboratory	10 m x 9 m	- Conference room	10 m x 7 m

Chemist room	3.25 m x 5 m	Monitoring room	10 m x 7 m
Biological room	3.25 m x 5 m	(with small library)	
Chemical room	3.5 m x 5 m		

Notes: Toilet, kitchen, and storage are provided on each floor.

Figure 14.1 shows proposed organisation chart for Katugastota WTP as a basis for the space of administration building. Approximately 80 members will be necessary for operation and maintenance including shift workers.

6.15 Maintenance Building

The maintenance building will include two offices, a garage, workshop, pipe yard, lockers for operators, showers, toilets, mechanical storage, and electrical storage. The building is single storey with roll-up doors for vehicle access to the garage, and large equipment to be repaired in the workshop. Pipes for transmission or distribution will be stacked in the pipe yard. Tools necessary for vehicle and minor repair work also will be provided. A crane is provided for use in the garage and workshop.

Ground floor	Dimensions	First floor	Dimensions
Workshop	15 m x 16 m	Office 1	6.5 m x 5.2 m
Garage	8 m x 16 m	Office 2	6.5 m x 4 m
Mechanical storage	8 m x 4 m		
Electrical storage	8 m x 4 m		

Note: Toilet is provided on each floor.

6.16 Facility Layout of Katugastota WTP Site

From the topographic survey data, the proposed treatment plant site is located between 441 m and 447 m AMSL. The available land is divided into three areas from south to northeast. The south triangle corner is suitable for the administration building, chemical building, and maintenance building, where ground level varies from 442 m to 446 m AMSL. The central area of approximately 150 m in length and 100 m in width is a suitable location for construction of the main water treatment processes, including the distribution chamber, rapid mixing, flocculation, sedimentation, filtration, clearwater reservoir, and transmission pump room incorporated with generator room. The elevation of central area varies from 441 to 447 m AMSL, sloping from northwest to southeast towards the existing stream. Remaining area elevation is relatively flat and lower than the other areas of 441 to 442 m AMSL, is located at the northeast of the proposed site and is a suitable location for the sludge lagoons.

The prudent location of various facilities within the proposed Katugastota WTP is important to reduce construction and operational costs. The distribution chamber is located near the inlet of the raw water main, which is introduced to the south western corner of the proposed water treatment site from the Gohagoda intake station. Bulk storage facilities of the chemicals are designed within or near the chemical building. Chemical dissolving basins and chlorinators are near the storage areas and the chemical metering, dosage and mixing equipment.

The administrative building is close to other buildings/facilities so that movement of staff will be minimised. Main process train such as flocculation, sedimentation, filtration, clearwater reservoir, and transmission pump house are arranged along the longest and widest direction of the site, taking into consideration hydraulic requirements and subsoil structure.

Alternative study for selection of the optimum layout of the water treatment plant was conducted as described hereunder in consideration of several constraints for expansion of the proposed site as shown below: The typical layout is summarised in Figure 6.3.

- It is difficult to expand the proposed site towards both eastern and western sides due to the existing private houses.
- Any facilities are not allowed to place in the central part beyond the existing temple due to religious reasons.
- The southern triangle part is too narrow to place process facilities.

1. Facility plan

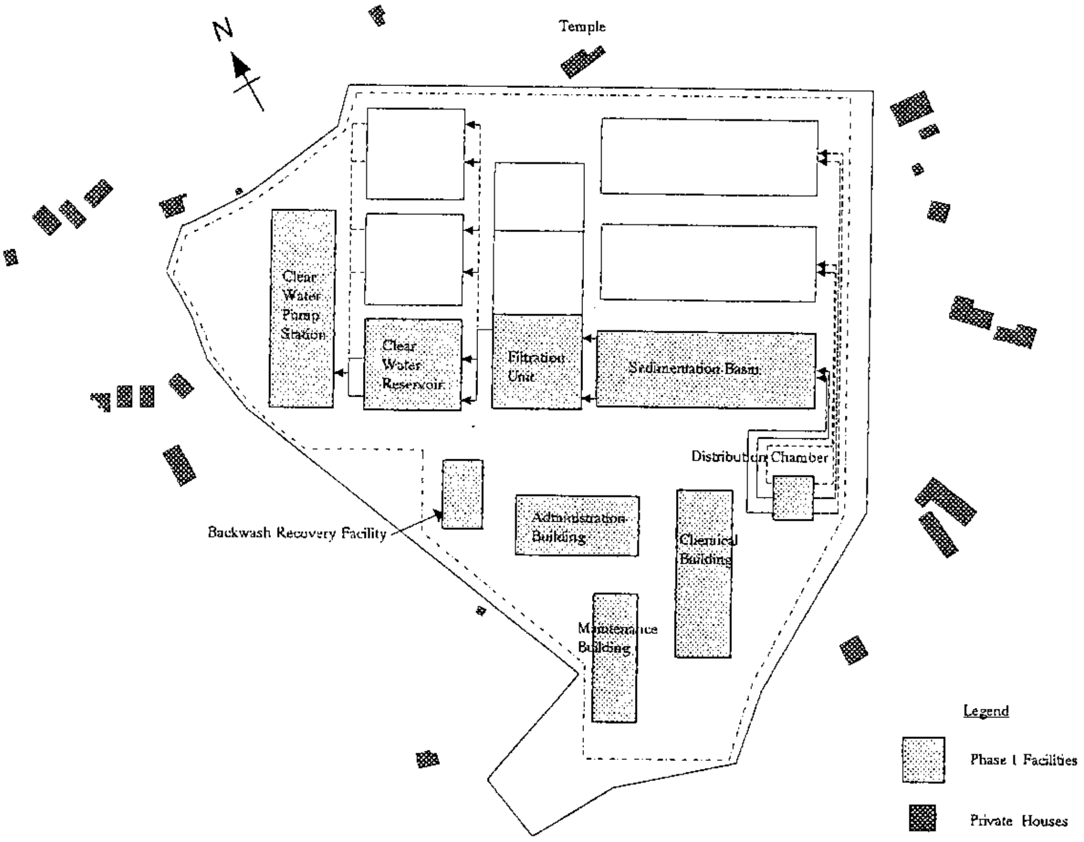
In the adopted plan, the administration building and water treatment facilities including flocculation/sedimentation basins and filter units are centralised to minimise the movement of staff. Alternative plan indicates the filter units, which needs diligent daily operation works, are far away from the administration building. To the end insufficient operation works may be caused. The basement level of backwash recovery tank in the alternative plan will be deeper than the adopted plan and construction, operation and maintenance cost will be increased. The space available around the chemical building is too narrow to arrange the maintenance road properly.

2. Yard pipes

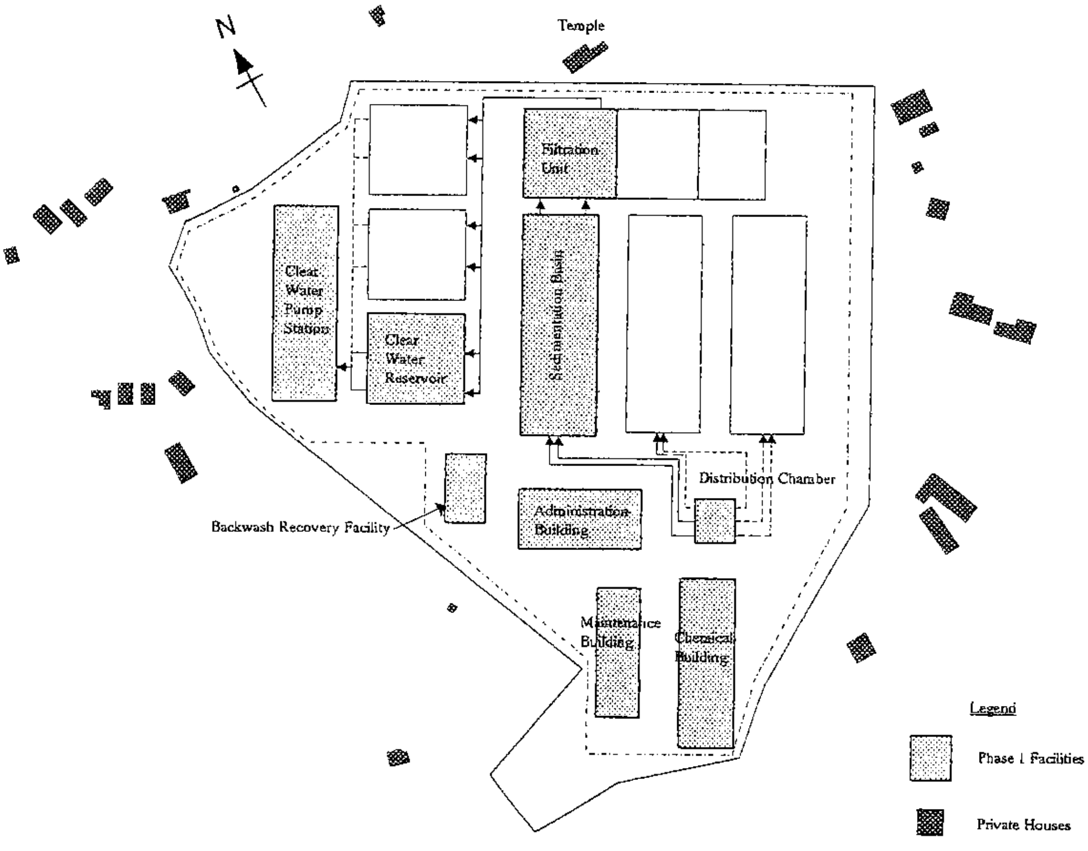
The adopted plan needs longer yard pipe between distribution chamber and flocculation basins and shorter yard pipe between filter units and clearwater tanks and chemical feed pipes than those of the alternative plan.

3. Future expandability

Expandability for Phase 2 and 3 of the adopted plan is superior to the alternative plan. By means of centralisation of facilities, expansion works will be easily worked out without hindrance of the facilities and yard pipes to be constructed in Phase 1. While in the alternative plan space for the future extension is separated into two sections, which may cause difficulties in future extension. For example, the yard pipes for coagulated water and filtered water are exposed to future construction area.



Adopted Plan



Alternative Plan

Figure 6.3 Comparison of Facility Layout of Katugastota WTP

6.17 Site Infrastructure

6.17.1 Service Water Distribution

The service water distribution system in the plant to be provided in the clear water transmission pump room will supply the staff facilities, chemical solution water, and other high-pressure requirements, tapping clearwater from the clearwater reservoir.

6.17.2 Security and Fencing

For security reasons and also to reduce costs, it is advisable that both Gohagoda Intake Station and Katugastota WTP sites are provided with a single access road, whereby they can be protected as a single unit. Guard buildings are placed at the both of access road entrance to the plant.

Fencing encloses the plant, to the river's edge and consists of a 2.5 m high wall topped with barbed wire. Lighting and communications are placed at the guard buildings in addition to the plant lighting system. The standby generators would also supply electricity to these security systems as well as the treatment plant during power outages. At the entrance, gates are installed to prevent illegal access and to record license plate numbers of vehicles entering the premises. Only one entrance would be provided for visitors, staff and delivery of consumables and materials to the treatment plant. While it may be an inconvenience and possibly a health concern for delivery of hazardous chemicals not to have a separate entrance, from the security standpoint the inconvenience is inevitable to protect public drinking water facilities

6.17.3 Access Pavement Marking and Signs

As discussed, access, both ingress and egress, are through a security controlled gate. Parking for visitors and deliveries, except for chemicals, would be provided in a small area near the administration building. Chemical deliveries to storage areas would proceed to the chemical building, which would have a turn-around area and lifting facilities to unload bags of alum and lime and chlorine ton cylinders directly from trucks to areas of storage. Access to residential quarters area is by a side entrance road off the main access road.

Pavements will be marked by centre stripping, pedestrian crossings, parking stripes, arrows and words in English and Singhalese such as "STOP" and 'NO ENTRY". Signs, again in English and Singhalese, will be prominently placed at the junctions of the access road throughout the plant area. Structures will be identified and numbered, parking areas identified, offices numbered, entrances and exits marked, pipelines and valves identified, "DANGER" signs placed in hazardous materials such as chlorine and high voltage electrical areas, pumps identified and numbered, and potable water outlets marked. Electrical panels will be numbered and monitoring devices, alarms and switches identified.

6.17.4 Street Design

All streets will be paved. The main access road from the Katugastota-Gohagoda road into the plant is 3.5 m wide, with one lane in each direction with curbs at the edges. Road base with a 200 mm thick over 225 mm compacted sub base will be provided topped with 50 mm of asphalt. The main access road goes past the plant, with a side branching to the administration and chemical storage area. Roads around and between structures as well as the Gohagoda intake access are 5 m wide and paved.

6.17.5 Landscaping and Architecture

The Katugastota plant and Gohagoda intake is landscaped for visual effect, and to “soften” the harsh concrete effect. Plants grown will be native and manually operated faucets will be provided with hoses for watering after planting. Once established, watering would not be necessary unless a dry period occurs. Lawns would be seeded or sodded in front of the administration building and other structures. Deciduous trees would not be placed near open basins.

Architecture would be “Sri Lankan” basis, especially for the Gohagoda Intake, Katugastota WTP, and Bahirawakande Service Reservoir, which are located in the view preservation area of Kandy City. Only buildings are architecturally designed while the portions of tanks, basins and chambers above ground might have minor architectural effects by modifying the concrete formwork.

6.17.6 Standby Power Generation

As reviewed in the JICA F/S, the proposed water intake at Gohagoda and the new water treatment plant in Katugastota, which will require electricity, supply of 750 kVA and 2000 kVA respectively, will be constructed as part of the first stage work under the Greater Kandy Water Supply Augmentation Project.

Under the electricity development project, a new gantry connected to two national grid stations is planned to be constructed at Katugastota and an exclusive dedicated line may be provided for the new intake and plant as shown in Figure 6.4.

However, the present electricity supply is not reliable, and the CEB’s records indicate frequent power failures. Provision of standby power generators for the intake and treatment plant to ensure continuity of water supply and for security concerns is considered to be must. One building each for the Gohagoda Intake and Katugastota WTP is provided for the standby generators and this is located as near as possible to the main electrical load centre, at the entrance of the Gohagoda Intake and the clearwater transmission pump station in the Katugastota WTP, respectively.

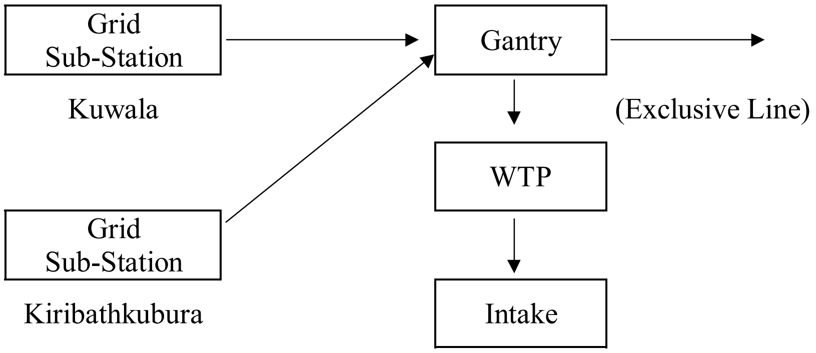


Figure 6.4 National Grid System at Katugastota

CHAPTER 7
TRANSMISSION, STORAGE, AND DISTRIBUTION SYSTEMS

CHAPTER 7 TRANSMISSION, STORAGE, AND DISTRIBUTION SYSTEMS

7.1 General

The proposed Phase 1 transmission system consists of 29 Nos. existing, augmented and new service reservoirs within and outside of KMC are linked with the WTP constructed at Katugastota, and 7 Nos. booster stations where necessary. This system has been designated to utilise the transmission pipelines and the pumping systems most effectively and economically to convey the proposed amount of treated water to each service area, taking into account of the future Phase 2 and 3 requirements as well. To fulfil these requirements the strategy of dividing the entire service area into 11 different zones has been found to be prudent.

This strategy will facilitate the utilization of the existing KMC WTP to serve the major part of KMC areas and its suburban area to the south, east and western boundaries, while the deficit in production at KMC WTP, which is already a subject under consideration and also arising out of diversion of water to the other areas will be supplemented by the proposed Katugastota WTP at its northern boundary. The identified zones are as follows from north to south.

(i) Katugastota – Kahawatte zone to the northern part, which will link Katugastota WTP with Akurana and Kurugoda SRs in Phase 1. No improvement is planned in Phase 2, but in Phase 3 the supply will be extended to serve Bokkawala SR, Pujapitiya SR, Godahena Booster Sump and Galhinna SR.

(ii) Katugastota – Madawala zone to the north eastern part, which will link Katugastota WTP with Kahalla, Balanagala, Bangalawatte and Pihilladeniya SRs in Phase 1. In Phase 2, the supply will be extended to Wattegama and Pitiyegedara SRs. The supply will be further extended to Napana SR in Phase 3.

(iii) Katugastota – Uduwawala zone to the western part, which will link Katugastota WTP with Kondadeniya Booster Sump in Phase 1. This will further be extended to serve Uduwawala and Rajapihilla SRs in Phase 2, and Madadeniya and Nugawela SRs in Phase 3.

(iv) Katugastota – Kundasale zone in eastern part, where there will be no activity in Phase 1. However, in Phase 2 a transmission main from Katugastota – Madawala zone will be extended to this zone to feed Sirimalwatte, Dambarawa, Menikhinna, and Kundasale SRs. In Phase 3 supply to Kolongaswatte, Ambakote, Rajawella and Bulewemude (Low Level) SRs will be augmented by laying new transmission mains from predetermined locations.

(v) KMC – Kandy Four Gravets (1) zone to the southeastern part, which will link with Bahirawakande, Asgiriya and Uplands SRs. This supply will be extended to R2 SR in KMC- R2 zone and Talwatte SR in Phase 2.

(vi) Gohagoda – Yatihelagala zone to the south western part of the proposed Katugastota WTP, which in Phase 1 will link with Gohagoda new SR. In Phase 2 this transmission system will be further extended to serve Gannoruwa, Yatihelagala, and Bogahagoda Booster Sump.

(vii) KMC – R2 zone, where in Phase 2 a new transmission main is planned from the new proposed Katugastota WTP to R2 SR.

(viii) KMC – Kandy Four Gravets (2) zone, which lies to the east of KMC and presently drawing water from the KMC system, where new transmission mains will be laid to augment supply to Heerassagala (Low, Middle and Upper Level) SRs, Hantana Place SR, Elhena and Mullepihilla (Low Level) SRs in Phase 1.

(ix) KMC – Eriyagama zone to the south western part of KMC WTP, where in Phase 2 new transmission mains are planned from KMC WTP to Hindagala and Eriyagama SRs, and to connect with the existing transmission main to Daulagala. In Phase 3, a new transmission main is planned to Kalugamuwa SR from an identified location, and mains will be extended to cover Sooriyagoda, Murutalawa, and Kadugannawa SRs. .

(x) KMC – Uda Peradeniya zone to the south of KMC WTP, where a new transmission main will be laid to the expanded Dangolla SR. No work is planned for Phase 2, but in Phase 3, new transmission mains are planned to Uda Peradeniya, Augustawatte, and Spring Hill Estate SRs from predetermined locations.

(xi) Talatu Oya zone in south eastern part, where no development work is planned for Phase1 and 2. However, in Phase 3 a transmission main will be laid from Talwatte SR in KMC-Kandy Four Gravets zone to Talatu Oya and Haragama SRs.

7.2 Existing Transmission and Distribution Systems

There are eleven water supply schemes (hereinafter referred to as "WSS") including KMC system within the study area of Phase 1 Project. Following is a brief description of the features and the status of the present water supply condition of each of these WSSs.

7.2.1 KMC system

The source of water supply is the Mahaweli River with intake is located at Getambe. Raw water pumping mains consist of a 45 m long main from intake tower to the grit chamber and 500 mm diameter, 600 m long main to KMC WTP. KMC WTP was upgraded from the original capacity of 22,300 m^3/day (5 mgd) to 33,400 m^3/day (7.5 mgd) in 1983 and in 1992 the intake and the WTP were improved by the introduction of a grit removal facility at the intake, replacement of raw water pumps, introduction of transfer pumps and replacement of some equipment at the WTP

The majored main pumping pipeline of the system are as follows:

? 500 mm in dia. main from the WTP to R2 SR (3,636 m^3)
? 250 mm in dia. main from the R2 to R3 SRs (1,136 m^3)
? 200 mm in dia. main from the WTP to Primrose SR (181 m^3)
? 200 mm in dia. main from the WTP to Dangolla SR (118 m^3)

Distribution system consists of two separate sub system. Sub system I was installed around 1880 and is still in use, though in poor condition now. Distribution pipeline of system II, installed in 1966 mainly with CI pipes and uPVC pipes that were added randomly in the latter stages is now 37 years old. Diameters of CI pipes vary from 80 mm to 700 mm and have a total length of about 70 km.

(viii) KMC – Kandy Four Gravets (2) zone, which lies to the east of KMC and presently drawing water from the KMC system, where new transmission mains will be laid to augment supply to Heerassagala (Low, Middle and Upper Level) SRs, Hantana Place SR, Elhena and Mullepihilla (Low Level) SRs in Phase 1.

(ix) KMC – Eriyagama zone to the south western part of KMC WTP, where in Phase 2 new transmission mains are planned from KMC WTP to Hindagala and Eriyagama SRs, and to connect with the existing transmission main to Daulagala. In Phase 3, a new transmission main is planned to Kalugamuwa SR from an identified location, and mains will be extended to cover Sooriyagoda, Murutalawa, and Kadugannawa SRs. .

(x) KMC – Uda Peradeniya zone to the south of KMC WTP, where a new transmission main will be laid to the expanded Dangolla SR. No work is planned for Phase 2, but in Phase 3, new transmission mains are planned to Uda Peradeniya, Augustawatte, and Spring Hill Estate SRs from predetermined locations.

(xi) Talatu Oya zone in south eastern part, where no development work is planned for Phase1 and 2. However, in Phase 3 a transmission main will be laid from Talwatte SR in KMC-Kandy Four Gravets zone to Talatu Oya and Haragama SRs.

7.2 Existing Transmission and Distribution Systems

There are eleven water supply schemes (hereinafter referred to as “WSS”) including KMC system within the study area of Phase 1 Project. Following is a brief description of the features and the status of the present water supply condition of each of these WSSs.

7.2.1 KMC system

The source of water supply is the Mahaweli River with intake is located at Getambe. Raw water pumping mains consist of a 45 m long main from intake tower to the grit chamber and 500 mm diameter, 600 m long main to KMC WTP. KMC WTP was upgraded from the original capacity of 22,300 m^3/day (5 mgd) to 33,400 m^3/day (7.5 mgd) in 1983 and in 1992 the intake and the WTP were improved by the introduction of a grit removal facility at the intake, replacement of raw water pumps, introduction of transfer pumps and replacement of some equipment at the WTP

The majored main pumping pipeline of the system are as follows:

? 500 mm in dia. main from the WTP to R2 SR (3,636 m^3)
? 250 mm in dia. main from the R2 to R3 SRs (1,136 m^3)
? 200 mm in dia. main from the WTP to Primrose SR (181 m^3)
? 200 mm in dia. main from the WTP to Dangolla SR (118 m^3)

Distribution system consists of two separate sub system. Sub system I was installed around 1880 and is still in use, though in poor condition now. Distribution pipeline of system II, installed in 1966 mainly with CI pipes and uPVC pipes that were added randomly in the latter stages is now 37 years old. Diameters of CI pipes vary from 80 mm to 700 mm and have a total length of about 70 km.

7.2.2 Outside KMC System

(1) Alawathugoda Water Supply Scheme

Alawathugoda WSS located in the northern part of Greater Kandy provides potable water to Kurugoda, Konakalagala and Alawathugoda areas. Two sets of borehole fields located at Vilana and Owissa are being used as the sources for extraction of ground water. The total production capacity of two sources at present is about 500 m^3/day as against the designed capacity of 640 m^3/d. Water is conveyed to two service reservoirs, each of capacity 300 m^3, and HWL of 610.5 m AMSL, through separate transmission pipelines. A 200 m long 200 mm DI pipeline is being used to convey water from Vilana borehole system while a 4.5 km long 160 mm uPVC line is used to transmit from Owissa borehole system. Water is distributed by gravity from these two service reservoirs within the served area through a distribution pipeline network. Due to the low elevation of the far north and southern parts the supply is made via break pressure tanks to avail excessive pressures, and the associated problems.

Currently, water is being supplied to the service area on a rotational basis and the average water supply duration to consumers is restricted to about 3 hours per week due to poor yield of boreholes.

(2) Akurana Water Supply Scheme

Akurana WSS is located to the south of Alawathugoda WSS and serves only to Akurana and Ambatenna area. This scheme has two sets of borehole systems as water sources. The source at Welekade has four boreholes and the water is conveyed through a 1.5 km long 225 mm uPVC pipeline to Akurana SR consisting of two tanks each of capacity 300 m^3 and HWL 514 m AMSL located at the same site. The other borehole system pumps directly into the distribution network. The production capacity of this scheme is 1,600 m^3/d, and year by year the lowering of the ground water table is taking place.

(3) Balanagala Water Supply Scheme

This scheme is located to the north east of KMC area and serves the population in Polgolla and Balanagala area. The water source is a borehole system located near Pinga Oya, a tributary of the Mahaweli River, which flows by the side of the Katugastota-Matale Road (A9). There are six boreholes; four old boreholes with only three functioning and two new boreholes yet to be commissioned. Present average production is 1,500 m^3/day but the quality of water is reported to be unsatisfactory associated with colour. The water is pumped through a 3 km long 225 mm uPVC pipeline to Balanagala SR having a storage capacity of 450 m3 and HWL of 515 m AMSL.

(4) Polgolla Water Supply Scheme

This scheme is located to the north east of KMC area and to the south east of Balanagala area. Polgolla WSS abstracts surface water from the Mahaweli River through an intake located just upstream of the Polgolla Dam. There are three raw water mains; a 100 mm CI, a 160 mm uPVC and a 285 mm uPVC, from the intake to the Polgolla WTP. Polgolla WTP was augmented after rehabilitating the existing treatment structure and adding flocculation and filtering facilities. The treatment plant is further being augmented at present to increase the production from 1,500 to 2,000 m^3/day for supplementing the shortage water production.

This system provides water supply to two main service areas namely Bangalawatte and Polgolla. The Bangalawatte (Polgolla – Madawala) area is being served by three SRs located at Napana, Pihilladeniya and Bangalawatte. Napana has a 150 m^3 of storage capacity with a HWL of 502 m AMSL, but the stone masonry structure is in a state of repair for reuse in the future due to its bad structural conditions, and as it is not currently in use. The water level of this reservoir is 20 m lower than that of the other two reservoirs.

Two new SRs each of capacity 100 m^3 had been constructed at Pihilladeniya and Bangalawatte with HWL at 524.14 m and 521.28 m AMSL, respectively by NWSDB in 1999. Treated water from the Polgolla WTP is pumped through a 160 mm uPVC transmission pipeline with a total length of 7.2 km. Distribution pipes from the above two new SRs too had been laid simultaneously.

The Polgolla service area too has three SRs; a 150 m^3 concrete ground reservoir at the Open University premises, a 100 m^3 concrete elevated tank at the Teacher Training College and a 110 m^3 concrete ground reservoir at the Co-operative School. These SRs are fed from Polgolla WTP through three 3” CI transmission pipes having lengths 130 m, 380 m and 917 m respectively.

(5) Kulugammana Water Supply Scheme

Kulugammana WSS is located to the west of KMC and Kondadeniya areas, and serves Heenagama, Nugawela and Kulugammana areas. The source of water for this scheme is three boreholes located in Pinga Oya at Ambatenne, which provides an average supply of 500 m^3/day at present as against a designed capacity of 790 m^3/d. However, the quality of water is reported to be unsatisfactory associated with high iron content, turbidity and colour. The transmission pipeline, consisting of a 225 mm 5 km long uPVC pipe up to the booster pump station, and a 150 mm 420 m long DI pipe between the booster and the reservoir, conveys water to SR located at Magurugala. The concrete ground level SR has a 300 m^3 capacity with a HWL of 583.25 m AMSL. Water is delivered by gravity from the SR through a network of distribution pipelines.

(6) Kondadeniya Water Supply Scheme

This scheme is located to the west of KMC area and serves Kondadeniya area only. The water source is a borehole field located in a marshy area within the flood plain of the Mahaweli River at Katugastota near by the proposed Katugastota WTP site. There are four boreholes producing an average yield of 2000 m^3/day but the water quality is reported to be poor with high iron content. The water is transmitted through a dual 2 km long 160 mm uPVC pipelines to Kondadeniya SR having a capacity of 300 m^3 and HWL of 533.25 m AMSL.

(7) Gohagoda Water Supply Scheme

Gohagoda scheme is located to the west of KMC area along the left bank of Mahaweli River. The water source is a borehole system consisting of three boreholes located at Gannoruwa. Present average production of the boreholes is 2000 m^3/day with good quality water. The water is conveyed to three SRs within the service area. Transmission system consists of an initial 2.3 km long 225 mm uPVC pumping main that bifurcates to serve Yatihalagala SR (150 m^3, 512 m HWL) through a 800 m long 100 mm DI pipeline, and to serve Pallemulla SR (150 m^3, 526 m HWL) via a 2.3 km long 160 mm uPVC pipeline. The third SR at Vegiriya (300 m^3, 528m HWL) acts as a balancing tank and receives water during the hours of low consumption.

(8) Ampitiya Water Supply Scheme

This WSS is located to the south east of KMC area and on the right bank of Mahaweli River. The ground water is the main source consisting of three boreholes at Ampitiya. Present average production of the boreholes is 1300 m^3/day but the water quality is reported to be unsatisfactory with high hardness. Therefore, an agreement has been made with the KMC to supply 350 m^3/day from the KMC's R3 reservoir. Notwithstanding, only 100 m^3/day is supplied at present.

The water is conveyed to Ampitiya SR (900 m^3 SR, HWL: 590 m AMSL) from the boreholes through a 1.9 km long 225 mm uPVC transmission main. Meanwhile, the water from KMC - R3 reservoir is gravitated to Ampitiya SR via a 1.6 km long 160 mm uPVC transmission pipeline, from the tapping point of the KMC service main. From Ampitiya SR the water is pumped to Meekanuwa SR (225 m^3) through a pipeline consisting of 485 m long 160 mm uPVC and thereafter 1.6 km long 160 mm uPVC pipes.

(9) Mullepihilla Water Supply Scheme

Mullepihilla WSS scheme is located in a narrow strip to the west of Ampitiya area. The water source is a stream at Mullepihilla. Present average production is as low as 100 m^3/day. Part of the treated water is pumped to a small SR (45 m^3 balancing tank, HWL: 674.36 m AMSL) through a 1.4 km long 90 mm uPVC transmission main. This pipeline is as well being used as the distribution main to serve the consumers on the way. The remainder of the treated water is gravitated to the distribution system through a 2.8 km long 110 mm uPVC main. The system experiences shortage of water during dry season as the stream dries up during this period.

(10) Hantana Water Supply Scheme

Hantana WSS is located to the south of KMC area. The water source is two small river intakes located at Hantana. Present average production is low at 450 m^3/day and serves only the Hantana Housing Scheme, and the consumers at Hantana Place. Water is gravitated to the Hantana WTP through pipelines consisting of two 30 m and 1.2 km long 150 mm CI pipes, up to a common break pressure tank (BPT), and a common 950 m long 110 mm uPVC pipe from the BPT to the WTP. The WTP has a SR (Hantana R1) having a capacity of 1350 m^3 and HWL 675 m AMSL and the water is pumped to two other SR; Hantana R2 (390 m^3, HWL: 774 m AMSL) and Hantana R4 (18 m^3) through a 2.2 km long 3” GI + 4” uPVC transmission main. The distribution system is partly fed by a gravity main from the Hantana R1 reservoir, while the rest of the scheme is fed by gravity from Hantana R2 & R4 SRs.

The present status of existing distribution network of 10 WSSs outside KMC was reviewed based on the data furnished by NWSDB in December 2000. The results revealed the present supply shortfalls of each WSS, such as inadequacy of production, unsatisfactory quality, low pressures and water does not continuously reach the remote area. These 10 distribution networks are integral part of future distribution network, and therefore, will be utilised to the maximum possible use in the future developments.

7.3 Improvement Plan for Each Service Zone

The further studies executed under the detailed design have basically reaffirmed the conclusions of the JICA F/S Report with regard to the current situation of existing systems. Furthermore, it was revealed that there were areas where still further improvements could be achieved, which would either be a more economical or a more effective alternative than the original proposal. The concept was to use the existing facilities as much as possible, in order to accommodate future demand with minimum reinforcement pipelines laid.

These improvements are summarised as follows:

(1) Polgolla – Gohagoda Zone:

Duplication of pipeline from Main Road to Gohagoda SR: As the capacity of the existing 150 mm dia. uPVC main from the main road to Gohagoda SR is inadequate to carry the full future capacity, a duplicate main 225 mm dia. uPVC, 150 m long is planned.

(2) Katugastota – Uduwala Zone

Bypassing the supply to Kondadeniya Booster Sump: It is proposed to transmit water directly from Katugastota WTP to Kondadeniya SR, bypassing Kondadeniya Booster Sump, which will gravitated to the distribution system through a 2.8 km long 110 mm uPVC main. The system experiences shortage of water during dry season as the stream dries up during this period.

(10) Hantana Water Supply Scheme

Hantana WSS is located to the south of KMC area. The water source is two small river intakes located at Hantana. Present average production is low at 450 m^3/day and serves only the Hantana Housing Scheme, and the consumers at Hantana Place. Water is gravitated to the Hantana WTP through pipelines consisting of two 30 m and 1.2 km long 150 mm CI pipes, up to a common break pressure tank (BPT), and a common 950 m long 110 mm uPVC pipe from the BPT to the WTP. The WTP has a SR (Hantana R1) having a capacity of 1350 m^3 and HWL 675 m AMSL and the water is pumped to two other SR; Hantana R2 (390 m^3, HWL: 774 m AMSL) and Hantana R4 (18 m^3) through a 2.2 km long 3” GI + 4” uPVC transmission main. The distribution system is partly fed by a gravity main from the Hantana R1 reservoir, while the rest of the scheme is fed by gravity from Hantana R2 & R4 SRs.

The present status of existing distribution network of 10 WSSs outside KMC was reviewed based on the data furnished by NWSDB in December 2000. The results revealed the present supply shortfalls of each WSS, such as inadequacy of production, unsatisfactory quality, low pressures and water does not continuously reach the remote area. These 10 distribution networks are integral part of future distribution network, and therefore, will be utilised to the maximum possible use in the future developments.

7.3 Improvement Plan for Each Service Zone

The further studies executed under the detailed design have basically reaffirmed the conclusions of the JICA F/S Report with regard to the current situation of existing systems. Furthermore, it was revealed that there were areas where still further improvements could be achieved, which would either be a more economical or a more effective alternative than the original proposal. The concept was to use the existing facilities as much as possible, in order to accommodate future demand with minimum reinforcement pipelines laid.

These improvements are summarised as follows:

(1) Polgolla – Gohagoda Zone:

Duplication of pipeline from Main Road to Gohagoda SR: As the capacity of the existing 150 mm dia. uPVC main from the main road to Gohagoda SR is inadequate to carry the full future capacity, a duplicate main 225 mm dia. uPVC, 150 m long is planned.

(2) Katugastota – Uduwala Zone

Bypassing the supply to Kondadeniya Booster Sump: It is proposed to transmit water directly from Katugastota WTP to Kondadeniya SR, bypassing Kondadeniya Booster Sump, which will conserve energy and make maintenance simpler and easier.

(3) Katugastota – Kahawatte Zone

Increasing the capacity of transmission pipeline from Kahawatte SR to Kurugoda SR: Originally it was planned to lay a 250 mm dia. uPVC line in Phase 1, followed by a 250 mm dia. DI line in Phase 3 in this particular section. Part of this pipeline is expected to be laid along A9 main road, which is already occupied by a water pipe and a telecom cable. Therefore, it is unlikely that two more transmission mains also could be laid on the same road, and hence it has been decided to lay a 350 mm DI pipeline in one operation in Phase 1, to accommodate the future Phase 3 demand and to overcome the road way leave limitations.

(4) Katugastota – Madawala Zone

a) The conversion of existing transmission pipeline from Madawala Road to Balanagala SR to a future transmission main: The existing transmission main from the ground water source near Pinga Oya to the Balanagala SR is a 225 mm dia. uPVC line. This ground water source is proposed to be abandoned after the implementation of Phase 1, and therefore, it has been decided to use this same line for the new transmission main in the above stretch, which will result in a significant saving in the cost.

b) The conversion of existing transmission pipeline from Polgolla WTP to Bangalawatte and Pihilladeniya SRs to a distribution mains: The existing 160 mm uPVC transmission main is planned to be converted to a distribution main after completion of Phase 1. Therefore, a new main of 250 mm dia. DI, 1,100 m long to Bangalawatte SR and 225 mm dia. uPVC is planned to be laid in the stretch to link Polgolla and Pihilladeniya SRs with Katugastota WTP.

(5) KMC- Kandy Four Gravets Zone

a) Transmission pipelines to Uplands, Asgiriya and Bahirawakanda SRs: A new pipeline of 700 mm and 400 mm dia. DI are planned from Katugastota WTP to Uplands SR. In addition, a 200 mm dia. DI line with an in-line booster is planned from Node No. AG' to Bahirawakande SR.

b) Bahirawakande Proposed SR: Bahirawakande, being a very steep area has limitations on the availability of land, since the available land does not permit a reservoir of more than 600 m3 capacity, as against 1,600 m^3 capacity originally planned. Therefore, a decision has been taken to provide 1,000 m^3 additional storage at Asgiriya SR, which commands an extensive service area in KMC.

(6) KMC – Uda Peradeniya Zone

Improvements to Dangolla System: The existing pumping main from KMC WTP to Dangolla

SR is comprised of a 150 mm pipeline reduced to a 100 mm pipeline. This main is as well used directly as the distribution main, and hence the flow to the reservoir is very limited. To improve the effective use of this reservoir, both JICA and ADB have proposed laying a new transmission main. As the KMC/ ADB/ JICA have considered this as a high priority need, it has been compromised that due to financial and time constraints ADB will undertake the installation of new pumps at KMC WTP and laying of 160 mm dia. uPVC new transmission main, while this Project will undertake the design and construction of a new reservoir at Dangolla.

(7) KMC- R2 Zone

Primrose SR and Pumps: The existing reservoir at Primrose is a steel tank (Braithwaite type) constructed in 1985, and has been leaking profusely over the past several years. KMC under ADB has proposed to construct a new 400 m^3 capacity concrete reservoir to replace this old unserviceable tank. Further, ADB has undertaken to replace the 300 m long, 225 mm dia. uPVC distribution main and the refurbishment of the existing transmission pumps by replacing the impellers, and thus this work has been excluded from this Project.

7.4 Demand Allocation for Each Service Zone

There is a total of 21 service reservoirs outside KMC system and 8 within KMC system including existing SRs in Phase 1 study area. The location of new SRs, which have adequate elevation by gravity flow to respective service areas were selected by NWSDB and referred to JICA F/S. The accurate elevation of each reservoir site was determined by means of topographic survey conducted afterwards in this study.

Served population forecast and water demand projection for each service zone, identified within the pressure contour boundary to guarantee the water supply for each service reservoir area by gravity was conducted as shown hereunder.

Figure 7.1 shows service area covered by each service reservoir in Phase 1.

7.4.1 Demand Allocation

In JICA F/S, the locations of new proposed service reservoirs had been tentatively decided for which further topographic surveys were carried out during this detailed design. Thus, the locations for service reservoirs were finalised, which fulfilled the two basic criteria that the hydraulic requirement of adequate pressure head for the entire distribution system, and the consent of the owners for acquisition of the lands for the proposed construction work.

SR is comprised of a 150 mm pipeline reduced to a 100 mm pipeline. This main is as well used directly as the distribution main, and hence the flow to the reservoir is very limited. To improve the effective use of this reservoir, both JICA and ADB have proposed laying a new transmission main. As the KMC/ ADB/ JICA have considered this as a high priority need, it has been compromised that due to financial and time constraints ADB will undertake the installation of new pumps at KMC WTP and laying of 160 mm dia. uPVC new transmission main, while this Project will undertake the design and construction of a new reservoir at Dangolla.

(7) KMC- R2 Zone

Primrose SR and Pumps: The existing reservoir at Primrose is a steel tank (Braithwaite type) constructed in 1985, and has been leaking profusely over the past several years. KMC under ADB has proposed to construct a new 400 m^3 capacity concrete reservoir to replace this old unserviceable tank. Further, ADB has undertaken to replace the 300 m long, 225 mm dia. uPVC distribution main and the refurbishment of the existing transmission pumps by replacing the impellers, and thus this work has been excluded from this Project.

7.4 Demand Allocation for Each Service Zone

There is a total of 21 service reservoirs outside KMC system and 8 within KMC system including existing SRs in Phase 1 study area. The location of new SRs, which have adequate elevation by gravity flow to respective service areas were selected by NWSDB and referred to JICA F/S. The accurate elevation of each reservoir site was determined by means of topographic survey conducted afterwards in this study.

Served population forecast and water demand projection for each service zone, identified within the pressure contour boundary to guarantee the water supply for each service reservoir area by gravity was conducted as shown hereunder.

Figure 7.1 shows service area covered by each service reservoir in Phase 1.

7.4.1 Demand Allocation

In JICA F/S, the locations of new proposed service reservoirs had been tentatively decided for which further topographic surveys were carried out during this detailed design. Thus, the locations for service reservoirs were finalised, which fulfilled the two basic criteria that the hydraulic requirement of adequate pressure head for the entire distribution system, and the consent of the owners for acquisition of the lands for the proposed construction work.

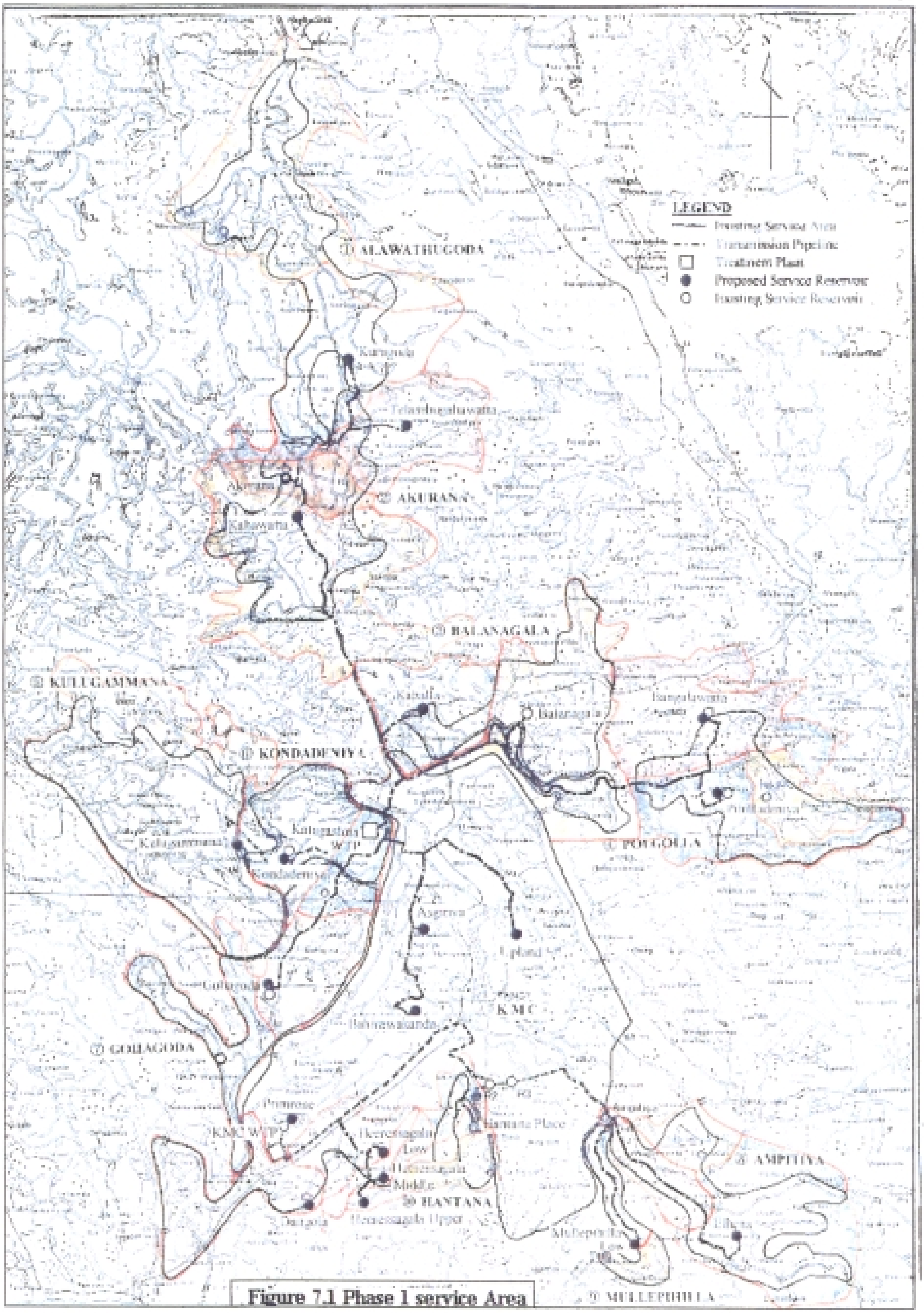


Figure 7.1 Phase 1 service Area

The next step was to identify the various service zones, which could be served by each service reservoir. To accomplish this task 1: 10,000 scale maps were prepared indicating the locations of existing and proposed service reservoirs, existing distribution systems, and demarcating the respective Grama Niladhari Division (G.N.D) boundaries. Afterwards, pressure contours were drawn in the maps to delineate the potential water supply areas by gravity flow from the service reservoirs, with a residual head of 6 m at the consumer's tap (hydraulic factor). In this manner the potential service areas under Phase 1 were decided for each reservoir.

Simultaneously, the total populations of each GND through the Divisional Secretaries, and the percentage of population, which could be physically feasible to be served (geographic factor) through the respective Officers in Charge (OIC) of the existing systems were obtained and furnished by NWSDB. As agreed by NWSDB, by making use of these three data, i.e. total population in each GND, hydraulic factor, and the geographic factor the potentially feasible population in year 2000, to be served under each reservoir was eventually determined. This population was further projected for years 2005, 2010 and 2015 with three different growth rates, identified as High (2.5 percent), Medium (2.0 percent) and Low (1.6 percent) for different areas by the respective OIC's, depending on the current and future development trends.

This exercise was applied for the 10 systems lying outside KMC area, which has produced a more accurate and realistic delineation of potential service areas in Phase 1, covering an enhanced area associated with an increased served population, than identified in JICA F/S. However, there was no need for such an exercise for KMC area since 100 percent coverage of the area was planned.

Table 7.1 tabulates water demand allocation for each service zone.

7.4.2 Features of the Proposed Service Reservoir Area

(1) Kahalla SR Area

The service area to be commanded by 600 m^3 elevated reservoir (GL: 465 m AMSL, HWL: 491.25 m AMSL, LWL: 485 m AMSL) is estimated at 2.55 km^2 with ground elevation varying between 440 to 483 m AMSL. Significant portion of the proposed service area is not covered by the existing pipe distribution system. Thus, a comprehensive pipe network system has been planned to serve the intended population within the proposed new service area and to lay reinforcement main to enhance the supply to the existing service area. Furthermore, expansion pipelines are proposed to be laid by NWSDB in future to augment supply to a small section in the existing service area and to a large area in the proposed new areas. However, certain isolated pockets of higher elevated areas will not be provided with pipe-borne water by gravity, due to hydraulic limitations.

The existing service area is presently served by Balanagala SR, which will later be isolated by an isolating valve after commissioning of the Kahalla SR. This new reservoir is capable of supplementing the supply to Balanagala SR service area via this isolating valve or vice versa if the need arises.

Table 7.1 Water Demand Allocation for Each Service Zone

Service Reservoir		Day Maximum Water Demand (m^3/d)		
No.	Name	2005	2010	2015
1. Katugastota – Uduwawala Zone				
1.1	Kulugammana	1,285	1,447	1,910
1.2	Kondadeniya	1,591	1,804	2,000
2. Katugastota – Kahawatte Zone				
2.1	Kahawatta	1,828	2,180	2,773
2.2	Kurugoda	1,894	2,226	2,773
2.3	Telambugahawatta	1,513	1,821	2,310
3. Katugastota – Madawala Zone				
3.1	Kahalla	2,092	2,331	2,773
3.2	Pihilladeniya	928	1,066	1,200
3.3	Bangalawatta	1,276	1,450	1,848
4. Polgolla – Gohagoda Zone				
4.1	Gohagoda (New)	816	1,069	1,400
5. KMC- Kandy Four Gravets Zone				
5.1	Asgiriya	10,465	14,740	15,609
5.2	Upland	7,612	10,830	11,170
5.3	Hantana Place (NWSDB)	320	366	398
5.4	Mullepihilla Low	395	449	500
5.5	Heeressagala Middle (NWSDB)	322	396	500
5.6	Heeressagala Upper	401	550	694
5.7	Elhena	826	990	1,200
5.8	Mullepihilla Low	395	449	500
6. KMC- R2 Zone				
6.1	Bahirawakanda	1,950	2,040	2,180
6.2	Primrose	1,770	1,860	1,980
6.3	Heeressagala Low	577	678	800
6.4	Heeressagala Middle (KMC)	322	396	500
6.5	Hantana Place (KMC)	190	230	260
7. KMC – Uda Peradeniya Zone				
7.1	Dangola	1,330	1,390	1,490

(2) Bangalawatte SR Area

A new service reservoir with a capacity of 300 m^3 (GL: 520 m AMSL, HWL: 521.28 m AMSL, LWL: 518.28 m AMSL) will be provided on a hillock near the exiting Bangalawatte reservoir site with the same high water level to enhance the total storage capacity to 400 m^3 from the existing 100 m^3. A narrow, steep and difficult access road is available to reach the reservoir site that is located about 1.0 km along the Bangalagedara road from Madawela town, situated on Katugastota - Wattegama highway.

This reservoir commands a service area of approximately 4.60 km^2 with ground levels varying from 445 m to 507 m AMSL. The existing distribution pipe network mostly covers the present supply area. However, in certain areas reinforcement mains will be laid to enhance the capacity of the existing system to meet the requisite future demands. However, more expansion pipelines will have to be laid in future by the NWSDB to reinforce the existing distribution system to improve the supply in the service area. Notwithstanding, certain small isolated pockets of high-elevated areas will not be provided with pipe-borne water by gravity, due to hydraulic limitations. This system is interconnected with Pihilladeniya SR service area and connected with Napana reservoir service area via an isolating valve. This reservoir is now not in serviceable condition needing repairs to be undertaken in the future in order to restore it for re-use.

(3) Pihilladeniya SR Area

At Pihilladeniya there is an existing reservoir of capacity 100 m^3, and m order to enhance the storage capacity a new reservoir of capacity 200 m^3 (GL: 519 m AMSL, HWL: 524.14 m AMSL, LWL: 522.14 m AMSL) is planned at the same site, which will increase the storage capacity to 300 m^3. Approximately, an extent of 3.18 km^2 will be served by this reservoir, primarily covered by the existing Polgolla system with varying ground levels between 484 to 505 m AMSL. Reinforcement of the system is proposed in a few areas to enhance the supply to meet the new demands and further reinstatements will as well be required in the future by the NWSDB. Adequate distribution pipe system is available in this area. This system is to be interconnected with Bangalawatte SR distribution system and linked with Napana SR service area via an isolating valve. As Napana SR is located at a low level (HWL: 502 m AMSL) lower than the surrounding area there are 2 options proposed to serve this area. The first option is to install a booster pump house from Pihilladeniya system and supply water, and the second option is to repair and restore Napana SR and connect the distribution system through a booster pump house.

(4) Kahawatte SR Area

A new elevated reservoir of 600 m^3 capacity (GL: 500 m AMSL, HWL: 522.25 m AMSL, LWL: 516 m AMSL) is planned to be constructed to serve this area, which at present receives water from Akurana SR. The service area to be commanded by this reservoir is estimated at 7.04 km^2 with ground elevation varying in the range from 440 to 488 m AMSL. Existing distribution pipe system covers greater part of the service area. However, a limited reinforcement of the existing pipelines and limited new extensions are planned under this proposal. Reinstatement of a few more pipelines is expected to be carried out by the NWSDB as well in future. This system is linked with Akurana SR service area to the north via 3 isolating valves.

(5) Kurugoda SR Area

This 600 m^3 reservoir (GL: 569 m AMSL, HWL: 573 m AMSL, LWL: 569 m AMSL) reservoir commands a service area of approximately 4.0 km^2 with ground levels varying from 475 to 557 m AMSL. A substantial segment of a new residential area is integrated into the existing Alawatugoda and Akurana schemes. An extensive distribution pipe network exists in the proposed service area, which is planned to be reinforced and extended under Phase 1 project. However, further reinforcements and extensions will have to be undertaken by the NWSDB in future to improve the service level. This SR is linked with Vilana and Owissa SR service areas to the north and with Akurana SR service area to the south by isolating valves, thereby making it possible to supply water in the high elevated areas in these service areas. Still, certain isolated pockets of areas will not be provided with pipe-borne water by gravity due to hydraulic limitations.

(6) Thelambugahawatte SR Area

The service area of this 500 m^3 capacity elevated reservoir (GL: 550 m AMSL, HWL: 566.75 m AMSL, LWL: 561.5 m AMSL) covers nearly 2.90 km^2 with ground elevations varying from 500 to 545 m AMSL. A substantial portion of a new residential area is incorporated into the existing Alawatugoda and Akurana schemes. The existing distribution pipe network in the area is grossly inadequate to serve the proposed population. As a result, supplementary distribution pipelines will be laid to supply the newly included built-up areas. Further extensions are expected to be laid by NWSDB in future to provide a wider coverage of the service area. As this reservoir is connected with Akurana SR service area via isolating valves there is the possibility of supplying water to certain high elevated areas in the latter area by this reservoir. However, certain isolated pockets of small areas will not be provided with drinking water by gravity due to hydraulic limitations.

(7) Kulugammana SR Area

A substantial area of approximately 9.45 km^2 predominantly covered by the existing SR will be served by this 100 m^3 reservoir (GL: 575 m AMSL, HWL: 583.25 m AMSL, LWL: 579.25 m AMSL) constructed by the side of the existing 300 m^3 reservoir, with varying ground levels between 488 to 571 m AMSL. Although, adequate distribution pipe system is available in this area, considerable reinforcements will be necessary to be laid by the NWSDB in future to accomplish an effective and sustainable water supply service level. Furthermore, in line boosting is planned to serve northern parts until a new reservoir proposed for Phase 2 is constructed at Nugawela.

(8) Kondadeniya SR Area

A new 200 m^3 reservoir (GL: 529 m AMSL, HWL: 535.25 m AMSL, LWL: 531.25 m AMSL) is planned to be constructed by the side of the existing 300 m^3 reservoir to augment the storage capacity to 500 m^3. This reservoir commands a service area of approximately 2.78 km^2 with ground elevations varying from 449 to 524 m AMSL. The existing distribution pipe network fully covers the proposed supply area and no extensions are needed. However, due to the prevailing topography the looping of the distribution system has not been possible resulting in some deficiencies in the supply system. It is highly recommended to reinforce almost entire distribution system by the NWSDB to improve service level in future. Certain small pockets of isolated high elevated areas will not be provided with pipe-borne water by gravity, due to hydraulic limitations.

(9) Gohagoda SR Area

A new 200 m^3 reservoir (HWL: 531.2 m AMSL, LWL: 527.2 m AMSL) is proposed to be constructed by the side of the existing 150 m^3 reservoir to augment the storage capacity to 350 m^3, and also to serve the high elevated areas which can not be served at present by the existing reservoir, which has a HWL of 524.1 m AMSL. The service area commanded by this reservoir is estimated at 2.14 km^2 with ground elevations ranging between 461 and 519 m AMSL. The existing distribution pipe network completely covers the proposed supply area, and except for a short additional distribution pipe work is planned at present no further reinforcements or extensions are required. However, certain small pockets of isolated areas will not be provided with potable water by gravity, due to hydraulic limitations. This service area is linked with Gohagoda old, Yatihelagala and Kulugammana service areas via isolating valves to the south and west and interconnected with Wegiriya SR service area to the north.

(10) Heerassagala (Middle) SR Area

This 250 m^3 reservoir (GL: 607 m AMSL, HWL: 617 m AMSL, LWL: 613 m AMSL) commands a service area of approximately 0.58 km^2 with ground levels varying from 523 to 609 m AMSL. A substantial segment of a new residential area is incorporated into the proposed service region. Furthermore, an insignificant distribution pipe network exists within the area. Hence, additional distribution pipe network system will be provided to include the newly integrated built-up areas. A booster pump house is also planned to be constructed near the reservoir to pump water to the proposed Heerassagala upper reservoir. Many more distribution lines are expected to be laid by NWSDB in future to extend the service area, and to link with Heerassagala upper to the east and Elagolla SR service area (KMC) to the south through isolating valves for a more sustainable service.

(11) Heerassagala (Upper) SR Area

The service area of this 200 m^3 reservoir (GL: 675 m AMSL, HWL: m 678, LWL: 674 m AMSL) encompasses nearly 0.48 km^2 with ground elevations varying from 598 to 660 m AMSL. The existing distribution pipe network in the area is grossly insufficient and insignificant to serve the intended population. Thus, additional distribution pipelines are planned for effective coverage. Further extensions are earmarked by the NWSDB in future to accommodate new build up areas. This service area is planned to be linked with the neighbouring Elagolla and Heerassagala (Middle) SR service areas through isolating valves.

(12) Hantana Place SR Area

The service area to be commanded by this 200 m^3 reservoir (GL: 636.8 m AMSL, HWL: 641 m AMSL, LWL: 637 m AMSL) is estimated at 0.85 km^2 with ground elevation varying between 586 and 634 m AMSL. This reservoir is proposed to serve the southwestern part of the existing Hantana upper and Hantana lower schemes to ease the burden on these two schemes in the high elevated areas. However, on a request made by the KMC some provision has been made to supply water to Kandy Hospital quarters and Nagastenna lying within KMC area. Neither extensions nor reinforcements are planned at present in this system.

(13) Elhena SR Area

This 300 m^3 reservoir (GL: 611 m AMSL, HWL: 615 m AMSL, LWL: 611 m AMSL) commands a service area of approximately 4.46 km^2 with ground levels varying from 508 to 596 m AMSL. Due to the location of the SR at a high altitude this it is proposed primarily to use to serve high elevated areas in the northern and eastern parts of Ampitiya service area. Some new mains are also proposed to be laid under Phase 1 project, while new extensions and reinforcements are expected to be carried out by the NWSDB in future to improve the service level. However, certain pockets of isolated areas will not be provided with clean water by gravity due to hydraulic restrictions. There is also provision to connect with Ampitiya SR service area via isolating valves to provide a more sustainable service.

(14) Mullepihilla (Low) SR Area

The oval shaped service area of this 100 m^3 reservoir (HWL: 713 m AMSL, LWL: 709 m AMSL) covers nearly 0.55 km^2 with ground elevations varying from 565 to 665 m AMSL. The existing reservoir has a capacity of 25 m^3 whereby the total storage capacity will thus be increased to 125 m^3. The existing distribution pipe network in the area is generally adequate to serve the intended population.

(15) Service Reservoirs within KMC Area

Six SRs namely Asgiriya (4100 m^3, HWL: 567 m AMSL, LWL: 561.5 m AMSL), Uplands (2960 m^3, HWL: 566 m AMSL, LWL: 560 m AMSL), Bahirawakanda (600 m^3, HWL: 629 m AMSL, LWL: 625 m AMSL), Dangola (500 m^3, HWL: 531.6 m AMSL, LWL: 527.6 m AMSL), Heeressagala Low (200 m^3, HWL: 570 m AMSL, LWL: 566 m AMSL), and Primrose (by ADB) are earmarked for construction in KMC area under Phase 1. As discussed earlier, Primrose SR will be undertaken by the KMC (ADB) project. There are existing reservoirs at Asgiriya, Uplands (57 m^3), Dangolla (118 m^3). Primrose (501 m^3) and Bahirawakande (91 m^3). The Asgiriya, Uplands, and Bahirawakanda SRs will supply water to the northern part of KMC area including down town, and Bahirawakanda and Primrose SRs will supply water to the high elevations in the western part of KMC. Furthermore, Dangola, Heeressagala Low, and existing R2 (3636 m^3), R3 (1136 m^3) SRs are planned to supply to the southern part of KMC area. In addition to these there are 4 more reservoirs serving KMC area namely Mapanawatura (96 m^3), Elagolla (160 m^3), Hantana (90 m3), Peiriswatte (73 m^3).

7.5 Transmission Pipeline

The hydraulic calculations of transmission pipeline analysis based on the strategy described in the previous section for the three Phases are enclosed as Data and Attachment, Volume IV. Transmission system in Phase 1, 2 and 3 are shown in Figure 7.2, Figure 7.3, and Figure 7.4, respectively. The summary of the revised transmission mains to be laid under Phase 1 is tabulated in Table 7.2.

Table 7.2 Transmission Pipelines for Phase 1

Pipe Material	Pipe Dia. (mm)	Length to be laid (m)		Total Length (m)
		KMC System	Katugastota System	
DI	800	0	415	415
	700	0	1,850	1,850
	600	0	3,272	3,272
	500	0	4,390	4,390
	400	0	2,020	2,020
	350	1,002	4,309	5,311
	300	1,782	4,605	6,387
	250	0	4,624	4,624
	200	4,539	3,940	8,479
	150	1,972	0	1,972
uPVC	225	1,457	492	1,949
	160	767	0	767
	90	149	0	149
Total		**11,668**	**29,917**	**41,585**

increased to 125 m^3. The existing distribution pipe network in the area is generally adequate to serve the intended population.

(15) Service Reservoirs within KMC Area

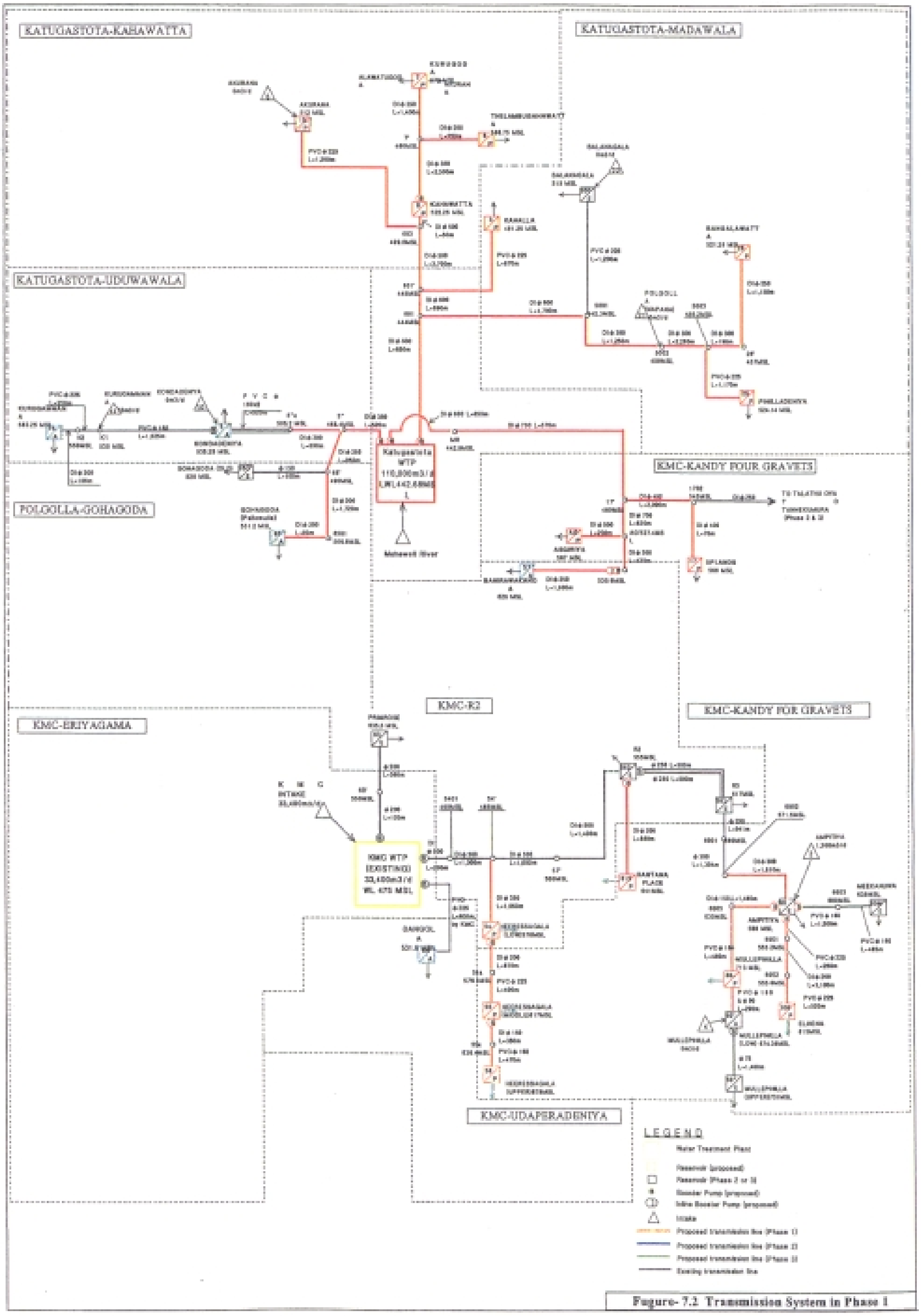
Six SRs namely Asgiriya (4100 m^3, HWL: 567 m AMSL, LWL: 561.5 m AMSL), Uplands (2960 m^3, HWL: 566 m AMSL, LWL: 560 m AMSL), Bahirawakanda (600 m^3, HWL: 629 m AMSL, LWL: 625 m AMSL), Dangola (500 m^3, HWL: 531.6 m AMSL, LWL: 527.6 m AMSL), Heeressagala Low (200 m^3, HWL: 570 m AMSL, LWL: 566 m AMSL), and Primrose (by ADB) are earmarked for construction in KMC area under Phase 1. As discussed earlier, Primrose SR will be undertaken by the KMC (ADB) project. There are existing reservoirs at Asgiriya, Uplands (57 m^3), Dangolla (118 m^3). Primrose (501 m^3) and Bahirawakande (91 m^3). The Asgiriya, Uplands, and Bahirawakanda SRs will supply water to the northern part of KMC area including down town, and Bahirawakanda and Primrose SRs will supply water to the high elevations in the western part of KMC. Furthermore, Dangola, Heeressagala Low, and existing R2 (3636 m^3), R3 (1136 m^3) SRs are planned to supply to the southern part of KMC area. In addition to these there are 4 more reservoirs serving KMC area namely Mapanawatura (96 m^3), Elagolla (160 m^3), Hantana (90 m3), Peiriswatte (73 m^3).

7.5 Transmission Pipeline

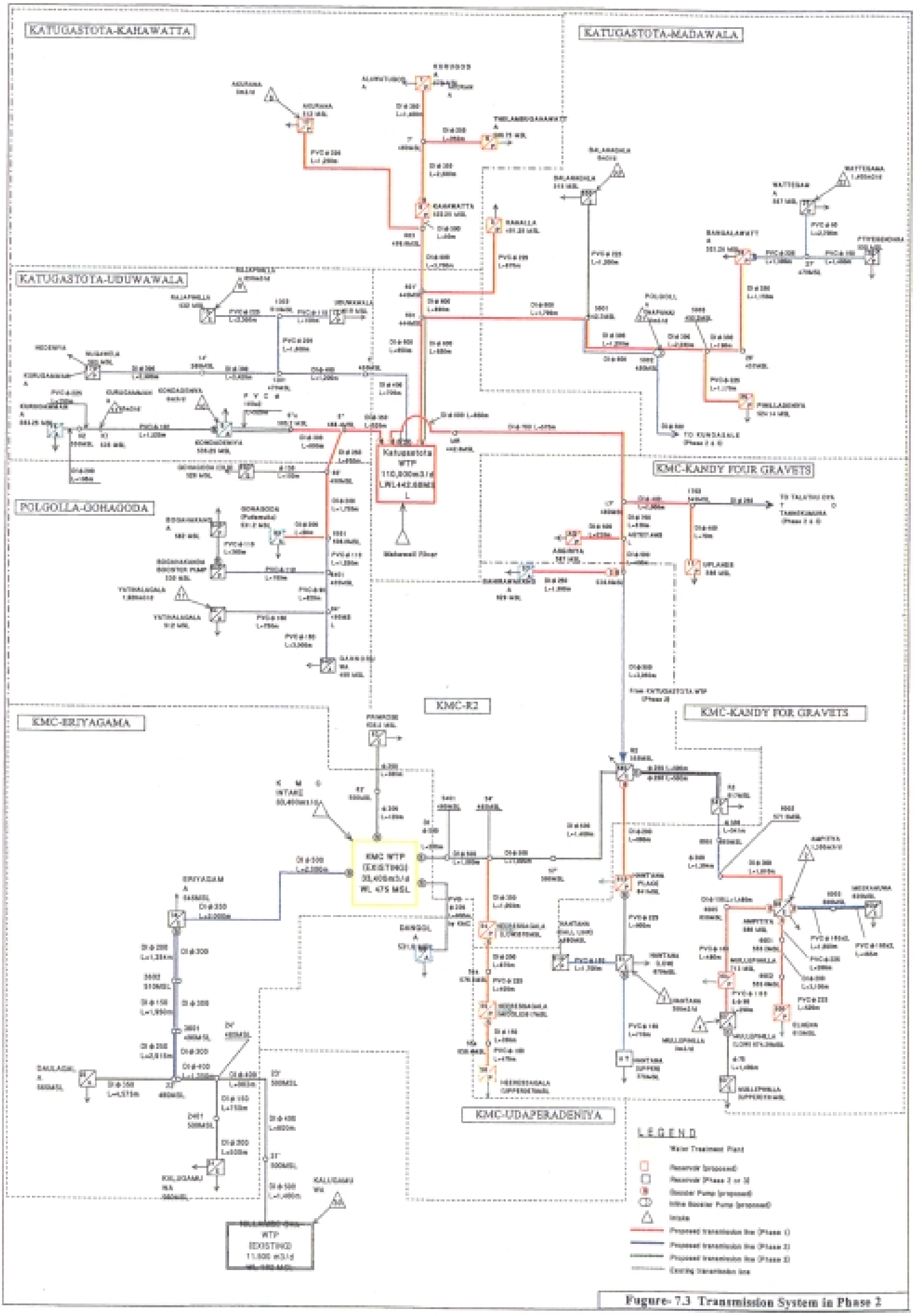
The hydraulic calculations of transmission pipeline analysis based on the strategy described in the previous section for the three Phases are enclosed as Data and Attachment, Volume IV. Transmission system in Phase 1, 2 and 3 are shown in Figure 7.2, Figure 7.3, and Figure 7.4, respectively. The summary of the revised transmission mains to be laid under Phase 1 is tabulated in Table 7.2.

Table 7.2 Transmission Pipelines for Phase 1

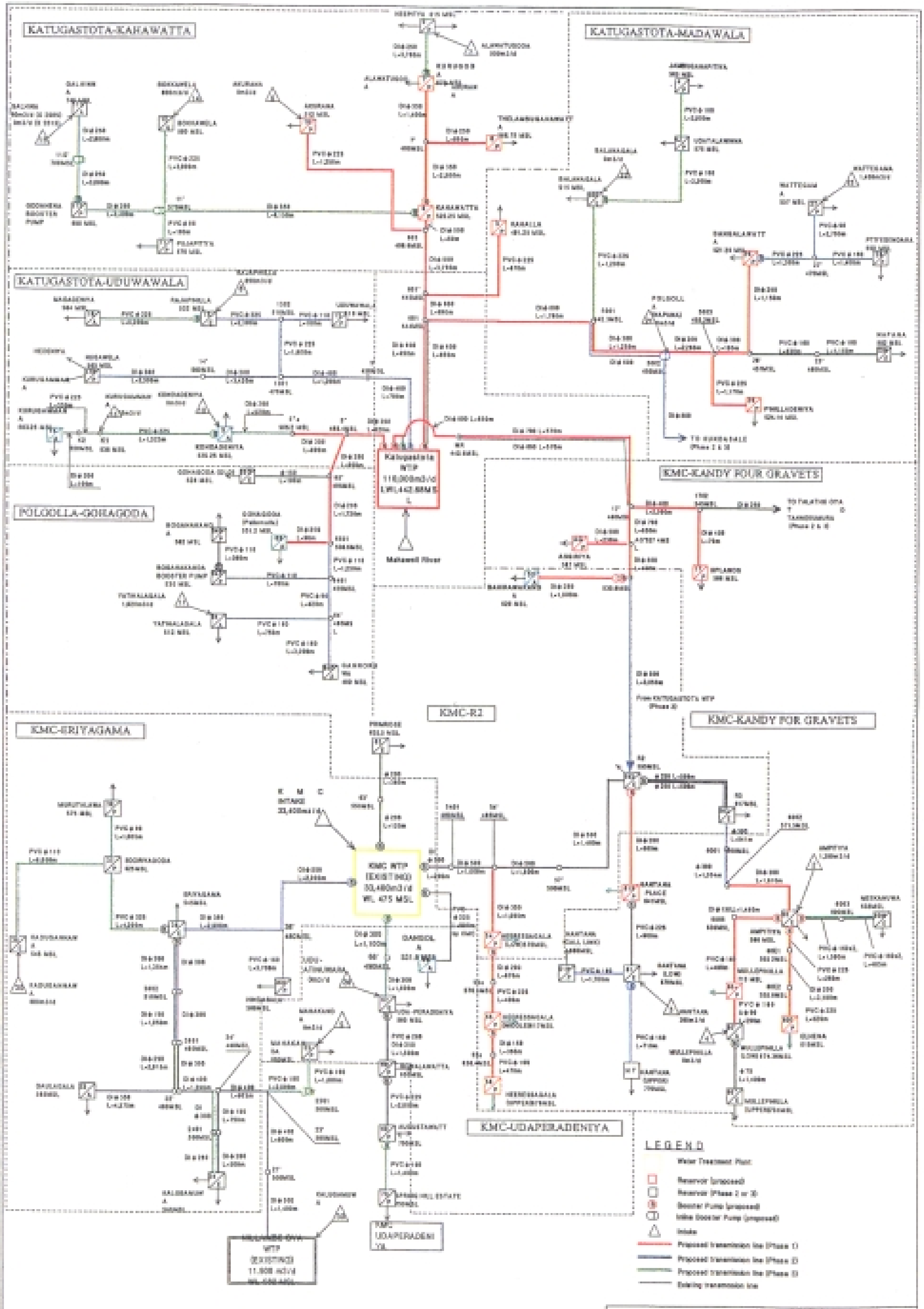
Pipe Material	Pipe Dia. (mm)	Length to be laid (m)		Total Length (m)
		KMC System	Katugastota System	
DI	800	0	415	415
	700	0	1,850	1,850
	600	0	3,272	3,272
	500	0	4,390	4,390
	400	0	2,020	2,020
	350	1,002	4,309	5,311
	300	1,782	4,605	6,387
	250	0	4,624	4,624
	200	4,539	3,940	8,479
	150	1,972	0	1,972
uPVC	225	1,457	492	1,949
	160	767	0	767
	90	149	0	149
Total		**11,668**	**29,917**	**41,585**



Fuguro- 7.2 Transmission System in Phase 1



Fugure- 7.3 Transmission System in Phase 2



Fugure- 7.4 Transmission System in Phase 3

A total length of 41.6 km of pipelines will be extended in Phase 1. Out of which, 11.7 km and 29.9 km will be constructed in KMC System and Katugastota System, respectively.

7.6 Distribution Pipelines

Based on the identified each service zone, the existing distribution pipelines are isolated by valves for making the reformed distribution network for each service zone. The feeder main from service reservoir to the existing network, additional pipeline to the existing network, reinforcements and new pipelines for unnerved area were studied by the hydraulic analysis based on the supply condition and implemented as shown Table 7.3. Details are attached in Data and Attachment, Volume IV.

Table 7.3 Phase 1 Service Zone and Type of Supply

Service Zone		Service Reservoir	
No.	Name of Reservoir	Supply Type	Remarks
1	Kahalla	Single supply	
2	Bangalawatta and Pihilladeniya	Double supply	With existing SRs
3	Kahawatta	Single supply	
4	Kurugoda	Single supply	
5	Telambugahawatta	Single supply	
6	Kulugammana	Single supply	
7	Kondadeniya	Single supply	
8	Gohagoda (New)	Double supply	With existing SRs
9	Heeressagala Middle (NWSDB)	Single supply	Also supply to KM C
10	Heeressagala Upper	Single supply	
11	Hantana Place (NWSDB)	Single supply	Also supply to KMC
12	Elhena	Single supply	
13	Mullepihilla Low	Single supply	

Distribution feeder pipe from the new SR to the connection point of the existing distribution network is of the most economical size with some allowance provided for unforeseen future water demand. Additional distribution pipes will be provided to strengthen the existing distribution network and to expand the service area to the unserved area as suggested by the OIC of the existing WSS, such as potential development area, area where ground water yields are poor, intermittent supply area, etc. Among such pipelines, high priority and hydraulically feasible area are selected and included in the detailed design.

The distribution pipelines with a total length of 27.7 km to be expanded under Phase 1 is summarised in Table 7.4.

A total length of 41.6 km of pipelines will be extended in Phase 1. Out of which, 11.7 km and 29.9 km will be constructed in KMC System and Katugastota System, respectively.

7.6 Distribution Pipelines

Based on the identified each service zone, the existing distribution pipelines are isolated by valves for making the reformed distribution network for each service zone. The feeder main from service reservoir to the existing network, additional pipeline to the existing network, reinforcements and new pipelines for unnerved area were studied by the hydraulic analysis based on the supply condition and implemented as shown Table 7.3. Details are attached in Data and Attachment, Volume IV.

Table 7.3 Phase 1 Service Zone and Type of Supply

Service Zone		Service Reservoir	
No.	Name of Reservoir	Supply Type	Remarks
1	Kahalla	Single supply	
2	Bangalawatta and Pihilladeniya	Double supply	With existing SRs
3	Kahawatta	Single supply	
4	Kurugoda	Single supply	
5	Telambugahawatta	Single supply	
6	Kulugammana	Single supply	
7	Kondadeniya	Single supply	
8	Gohagoda (New)	Double supply	With existing SRs
9	Heeressagala Middle (NWSDB)	Single supply	Also supply to KM C
10	Heeressagala Upper	Single supply	
11	Hantana Place (NWSDB)	Single supply	Also supply to KMC
12	Elhena	Single supply	
13	Mullepihilla Low	Single supply	

Distribution feeder pipe from the new SR to the connection point of the existing distribution network is of the most economical size with some allowance provided for unforeseen future water demand. Additional distribution pipes will be provided to strengthen the existing distribution network and to expand the service area to the unserved area as suggested by the OIC of the existing WSS, such as potential development area, area where ground water yields are poor, intermittent supply area, etc. Among such pipelines, high priority and hydraulically feasible area are selected and included in the detailed design.

The distribution pipelines with a total length of 27.7 km to be expanded under Phase 1 is summarised in Table 7.4.

Table 7.4 Distribution Pipelines for Phase 1

Pipe Material	Pipe Dia. (mm)	Length to be laid (m)		Pipe length (m)
		KMC System	Katugastota System	
DI	500	682	0	682
	450	1,206	0	1,206
	400	329	0	329
	300	0	873	873
	250	586	2,054	2,640
	200	0	41	41
	100	0	237	237
uPVC	225	0	7,412	7,412
	160	0	6,981	6,981
	110	0	3,454	3,454
	90	0	3,832	3,832
Total		**2,803**	**24,884**	**27,687**

7.7 Pipeline Design

7.7.1 Hydraulic Design

Pipelines will be sized using the exponential formula developed by Hazen and Williams shown below in metric units.

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

Where,
H: friction loss (m)
C: friction coefficient
D: diameter of pipe (m)
Q: rate of flow (m^3/sec)
L: Pipe length (m)

"C" value equals to 130 for the new cement lined DI and uPVC pipes.

Applied friction coefficient (C) will be as indicated in Table 7.5.

Table 7.5 Pipe Friction Coefficients

Pipe Material	Existing (old) or New	Friction Coefficient (C)
Cast Iron	Existing (old)	90
uPVC, ACP	Existing (old)	120
Ductile Iron (DI)	New	140
uPVC	New	140

The flow velocity is set at approximately 1.0 m/sec as economical and reasonable velocity. Peak factor for daily maximum demand is taken as 1.2 x daily average demand. Residual pressure of hydraulic grade line at inlet to the Service Reservoir will be more than 5 m.

In determining the peak factor 1.2, actual or estimated records of the Labugama WTP (1.10 to

Table 7.4 Distribution Pipelines for Phase 1

Pipe Material	Pipe Dia. (mm)	Length to be laid (m)		Pipe length (m)
		KMC System	Katugastota System	
DI	500	682	0	682
	450	1,206	0	1,206
	400	329	0	329
	300	0	873	873
	250	586	2,054	2,640
	200	0	41	41
	100	0	237	237
uPVC	225	0	7,412	7,412
	160	0	6,981	6,981
	110	0	3,454	3,454
	90	0	3,832	3,832
Total		**2,803**	**24,884**	**27,687**

7.7 Pipeline Design

7.7.1 Hydraulic Design

Pipelines will be sized using the exponential formula developed by Hazen and Williams shown below in metric units.

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

Where,
H: friction loss (m)
C: friction coefficient
D: diameter of pipe (m)
Q: rate of flow (m^3/sec)
L: Pipe length (m)

“C” value equals to 130 for the new cement lined DI and uPVC pipes.

Applied friction coefficient (C) will be as indicated in Table 7.5.

Table 7.5 Pipe Friction Coefficients

Pipe Material	Existing (old) or New	Friction Coefficient (C)
Cast Iron	Existing (old)	90
uPVC, ACP	Existing (old)	120
Ductile Iron (DI)	New	140
uPVC	New	140

The flow velocity is set at approximately 1.0 m/sec as economical and reasonable velocity. Peak factor for daily maximum demand is taken as 1.2 x daily average demand. Residual pressure of hydraulic grade line at inlet to the Service Reservoir will be more than 5 m.

In determining the peak factor 1.2, actual or estimated records of the Labugama WTP (1.10 to

1.15). Kalatuwawa WTP (<1.2), and Ambatale WTP (1.16) were taken into account as well as the scale of city.

A minimum service pressure of 6 bars (0.6 kgf/cm^2) above ground level is adopted for design under the peak hour demand condition for areas outside KMC.

The loss in head through friction is considered to be the predominant loss in long transmission lines. The other losses to be taken into account include those associated with elbows, fittings, valves and other pipeline appurtenances. These are usually considered minor losses in long pipelines, but may become significant in short pipelines and in pumping stations

The data such as the length, elevation of the existing and new pipelines, together with the type and diameter of the existing ones were collected during the topographical surveys and compiled. The quantity of flow to each SR, maximum day demand (m^3/d) was assessed and tabulated in Table 7.1 for each of the three Phases separately. High and Low Water Levels and Ground Levels of Service Reservoirs (existing and new) is tabulated in Table 7.1.

The distribution network analysis was carried out using KYPIPE 2 software, which is a user-friendly programme. It has the ability to analysis steady flow in complex pipeline systems and may handle pumps, regulating valves, minor loss components, multiple supplies and other features. It will also carry out extended period simulations (EPS) where conditions vary slowly over time. In addition, KYPIPE 2 calculated a variety of designs, operating and calibration parameters, which meet, stated pressure conditions.

7.7.2 Pipe Materials

In the past projects of NWSDB, several types of pipe materials have been used. Included therein are Cast Iron, Ductile Iron (DI), Mild Steel, Asbestos Cement, uPVC (Unplasticized Polyvinyl Chloride), and Galvanised Iron etc.

At present, DI pipe is used extensively for most of the medium and large diameters of 250 mm or larger pipelines. The DI pipe is an excellent pipeline material with good durability, ease of installation both in laying and jointing, and flexibility in jointing. However, the pipe should be protected from interior corrosion using a cement mortar lining and from exterior corrosion by a bituminous coating. The straight pipes and fittings are of push-in socket and spigot joints type (T type) using rubber gaskets. As necessary, restrained joints, flanged joints, flange adaptors, or couplers, are also used for installation of fittings and specials.

Application of polyethylene pipe (PEP) for the size from 250 to 400 mm was considered as an alternative material for DI pipe. The study result, however, reviled that PEP is only advantageous in the small diameter less than 250 mm in which local manufactured uPVC is more economical. The study paper of PEP is attached in Appendix 2.

For smaller diameter pipes less than 250mm uPVC pipes are then recommended in terms of cost and characteristics. uPVC pipes and fittings of diameter 110mm and larger will be of push-in type with rubber gaskets (RR joint type). The diameter 90mm and 75mm will be welded using solvent cement. The restrained joints, flanged joints, flange adaptors or couplers are to be applied for jointing of fittings and specials where necessary. A minimum working pressure is 10 kgf/m^2 or 10 bars for type 1000 pipes, at a temperature of 29 °C.

7.7.3 Structures for Pipelines

An aqueduct bridge is planned to cross the Mahaweli River near Katugastota WTP, and two pipes will be placed on that bridge, namely 800 mm pipes in Phase 1 by the year 2005 and 600 mm pipes in Phase 3 by the year 2015, to transmit clear water to the northern area of Kandy city through Bahirawakanda, Asgiriya, and Uplands service reservoirs. This transmission line will later be extended to Hantana Place reservoir and Talwatte Reservoir in Phase 2, and up to Gurudeniya, Talatu-Oya and Haragama in Phase 3.

For ease of construction, maintenance and low construction cost, the following two types are applied for bridge crossing with consent of road authorities.

- Independent U/B bridge structure without piers in the middle for spans up to 25 m and less
- Pipe bridge maintained by flanged pipes itself and supported by the concrete abutments at the both side of pipe bridge.

In case of railway crossings, it has been the practice that after obtaining approval from the Railway Authority (CGR) for a particular railway crossing, and on payment of the estimated cost, the CGR will lay a concrete pipe ducting of agreed size under the railway track in advance, to enable the water pipe to be laid through the duct by the Project at the relevant time.

For crossings under drains/culverts/streams, several types of crossings are considered taking into consideration of site investigation and topographic survey results along the entire proposed pipeline route.

- Type-A: Pipe bridge (please refer to previous item),
- Type-B: using vertical bends, (normally 45 degree) encased in concrete thrust block shall be used
- Type-C: using joints allowable for deflection, not use bend,
- Type-D: above culverts, if there is space,
- Type-E: under culverts made of stone masonry,
- Type-F: Laying of pipes through the culverts

1.0 m for both uPVC and DI of clear cover over the pipeline is applied to protect the pipelines from traffic load and to keep them from "floating" when empty. In poor ground conditions suitable beddings or geotextiles will have to be placed to provide a stable ground support for the pipes to prevent subsequent settlements and damage to the pipe lines.

Concrete thrust blocks of fittings such as bends, tees, reducers, end plugs, were designed against to the unbalanced force due to the water pressure in each pipe taking into consideration of surge pressure of 50 percent of working pressure. However, the restraint joint with corrosion protection were adopted where there is a space limitation or where the soil behind a fitting can not provide adequate support.

7.7.4 Appurtenances

At low points along the profile, washouts are provided to drain the pipeline between isolation valves for repairs or for future connections. High points are provided with air and vacuum valves to remove air from the pipe during filling and to supply air into the pipe, if a sudden release of water or a water hammer effect will produce a vacuum. Where required washout and/or air valves will be placed on either side of an isolation valve to facilitate draining of the pipeline between isolation valves for repairs or future connections. Valves, washouts, and air/vacuum connections will be protected inside concrete chambers.

Fittings within valve chambers will be flanged, while those buried and installed will be socket and spigot matching with connecting pipe. Generally, pipes will be pulled around large radius curves not exceeding the manufacturers recommendations. On bends greater than seven degrees or where pulling is not possible, standard fittings will be installed. Bends of 90 degrees will be made using multiple smaller angled bends whenever possible.

Valves of diameter 300 mm and less will be gate valves (sluice valves), and for diameters 350 mm and larger butterfly valves will be used.

Air valves will be single orifice with an isolating cock, and double orifice with an isolating gate valve for uPVC less than 225 mm dia. and DI, 250 mm dia. and larger respectively.

Washout valves are designed at the lowest elevations of the pipeline profiles with facilities to drain them fully to a nearby canal, stream, storm water drain or any other watercourse.

Generally, in-line isolation gate valves installed in long transmission mains can be one standard size smaller than the main line without causing a substantial head loss, because they are normally left open fully. Reducers are generally installed before and after each valve, to further reduce head loss. Head loss is usually expressed as $h = kV^2/(2g)$ for fittings and valves and k is normally less than 0.1 for large reducers, and 0.01 difference lies between valves one standard size lower than the pipe size. With the reduced size valves, and with velocities (max of 1.5 m/s) for this system, a head loss of only 0.03 m may occur at each valve.

7.8 Service Reservoir

7.8.1 Service Reservoirs

A total of 19 service reservoirs with a total capacity of 12, 710 m^3 will be constructed in Phase 1. 13 SRs will be located outside of KMC and remaining six SRs will be located in KMC area. The capacities of proposed service reservoirs and their respective elevations are listed in Table 7.6.

(1) Kahawatte SR

An elevated tan of storage capacity 600 m^3 is to be provided in Kahawatte site at a distance of about 800 m along Kahawatte road off Matale highway. This reservoir is located within the service area currently served by Akurana system and easily accessible. The ground elevation of the selected site is 500 m AMSL but the required high water level is over 520 m AMSL. Thus, an elevated tank with HWL at 522.25 m AMSL and LWL at 516.00 m AMSL is to be constructed.

(2) Kurugoda SR

A ground service reservoir with a storage capacity of 600 m^3 is to be provided m Kurugoda at a distance of about 200 m from the Matale main road. A narrow, steep and very difficult access road is available to reach the reservoir site. The selected reservoir site is a farmland, but within the residential area. At present this area is served by Vilana and Owissa SRs situated to the north. On commissioning of this reservoir not only the demand on these two reservoirs could be reduced significantly, but also the higher elevated areas in the northern part of Akurana service area also could be served.

(3) Thelambugahawatte SR

An elevated tank of capacity 500 m^3 is to be provided on a sound rock outcrop surface in Thelambugahawatte at a distance of about 1.0 km off Matale main highway. A narrow, sharply climbing and difficult access road is available to reach the reservoir site. To ensure the distribution to some high elevated area, an elevated tank is recommended at 11.5 m high from ground elevation. At present this area is served by Akurana SR and completion of this work will enable high elevated areas to be served by extending the distribution system to new potential areas. Currently, there is no distribution system available to serve this area. Furthermore, the supply from this SR could be extended to northern part of Akurana service area to facilitate a more sustainable supply to Akurana.

7.8 Service Reservoir

7.8.1 Service Reservoirs

A total of 19 service reservoirs with a total capacity of 12, 710 m^3 will be constructed in Phase 1. 13 SRs will be located outside of KMC and remaining six SRs will be located in KMC area. The capacities of proposed service reservoirs and their respective elevations are listed in Table 7.6.

(1) Kahawatte SR

An elevated tan of storage capacity 600 m^3 is to be provided in Kahawatte site at a distance of about 800 m along Kahawatte road off Matale highway. This reservoir is located within the service area currently served by Akurana system and easily accessible. The ground elevation of the selected site is 500 m AMSL but the required high water level is over 520 m AMSL. Thus, an elevated tank with HWL at 522.25 m AMSL and LWL at 516.00 m AMSL is to be constructed.

(2) Kurugoda SR

A ground service reservoir with a storage capacity of 600 m^3 is to be provided m Kurugoda at a distance of about 200 m from the Matale main road. A narrow, steep and very difficult access road is available to reach the reservoir site. The selected reservoir site is a farmland, but within the residential area. At present this area is served by Vilana and Owissa SRs situated to the north. On commissioning of this reservoir not only the demand on these two reservoirs could be reduced significantly, but also the higher elevated areas in the northern part of Akurana service area also could be served.

(3) Thelambugahawatte SR

An elevated tank of capacity 500 m^3 is to be provided on a sound rock outcrop surface in Thelambugahawatte at a distance of about 1.0 km off Matale main highway. A narrow, sharply climbing and difficult access road is available to reach the reservoir site. To ensure the distribution to some high elevated area, an elevated tank is recommended at 11.5 m high from ground elevation. At present this area is served by Akurana SR and completion of this work will enable high elevated areas to be served by extending the distribution system to new potential areas. Currently, there is no distribution system available to serve this area. Furthermore, the supply from this SR could be extended to northern part of Akurana service area to facilitate a more sustainable supply to Akurana.

Table 7.6 Service Reservoirs in Phase 1

Node No.	Name of Reservoir	Low Water Level	High Water Level	New Capacity (m^3)	Type	Existing Capacity (m^3)
Katugastota System						
PG	Clear Water Reservoir	442.68	445.68			
6	Kahawatte SR	516.00	522.25	600	Elevated	
7	Kurugoda SR	569.00	573.00	600	Ground	
10	Akurana SR	508.00	512.00		Ground	600
8	Thelambugahawatte SR	561.50	566.75	500	Elevated	
3	Kahalla SR	485.00	491.25	600	Elevated	
500	Balanagala SR	513.00	515.00			450
26	Bangalawatte SR	518.28	521.28	300	Ground	100
25	Pihilladeniya SR	522.140	524.14	200	Ground	100
5	Kondadeniya SR	531.25	535.25	200	Ground	300
14	Kulugammana SR	579.25	583.25	100	Ground	300
65	Gohagoda SR (new)	527.00	531.20	200	Ground	
65	Gohagoda SR (low)	524.00	528.00			150
65G	Gohagoda SR (old)	524.00	528.00			300
AG	Asgiriya SR	561.50	567.00	4,100	Elevated	
AG'	Asgiriya Pump Station		-	-		-
57	Bahirawakanda SR	625.00	629.00	600	Elevated	204
17	Uplands SR	560.09	566.00	2,960	Ground	27
KMC System						
KMC	KMC Treatment Plant	471.00	475.00			
63	Primrose	631.50	635.50	(by ADB)		501*)
582	R2	549.49	555.00			3,636
583	R3	613.00	617.00			1,136
66	Dangolla SR	527.60	531.60	500	Ground	118
54	Heerassagala (low) SR	566.00	570.00	200	Ground	
55	Heerassagala (middle) SR	613.00	617.00	250	Elevated	
56	Heerassagaa (upper) SR	674.00	678.00	200	Ground	
61S	Hantana Place SR	637.00	641.00	200	Ground	
60	Ampitiya SR	582.50	586.00			900
60M	Meekanuwa	633.00	635.00			225
60+	Mullepihilla (new) SR	709.00	713.00	100	Ground	
60'	Mullepihilla (old) SR	672.50	674.36			25
60"	Mullepihilla (high) SR	728.00	731.00			45
60E	Elhena SR	611.00	615.00	300	Ground	
			Total =	**12,710 m^3**		

Note: under the KMC (ADB) project.

(4) Kahalla SR

An elevated service reservoir with a storage capacity of 600 m^3 is to be provided in Kahalla village presently covered by the existing Balanagala system. This reservoir is located at a distance of about 800 m along Kahalla road off Katugastota - Matale main road. Access to this site from the main road is reasonably good and the reservoir is located on a flat area. The ground elevation of the land available in the area is 465 m AMSL and the required minimum water level is 485 m AMSL. Hence, an elevated tank with a 20 m high tower is planned. As the area is not adequately covered by a distribution system a substantial amount of new pipe lines also will be laid. This reservoir will be able to serve the adjacent western parts of Balanagale SR service area as well.

(5) Bangalawatte SR

A ground service reservoir with a capacity of 300 m^3 is to be provided on a hillock near the exiting 100 m^3 Bangalawatte tank with the same high water level in order to augment the existing storage capacity. A narrow, steep and difficult access road is available to reach the reservoir site that is located about 1.0 km along the Bangalagedara road from Madawela town situated on Katugastota - Wattegama highway. The proposed service area is to be interconnected with the Pihilladeniya SR service area and there is provision to link with Napana SR service area via an isolating valve. This arrangement will facilitate more extensive use of this reservoir as in many other reservoirs being constructed.

(6) Pihilladeniya SR

An additional ground service reservoir of capacity 200 m^3 is to be provided in the vicinity of the existing 100 m^3 Pihilladeniya with the same high water level with a view to supplementing the existing storage capacity. This reservoir is located at a distance of about 1.5 km along Sapugastenna road off Madawela town situated in the Katugastota - Wattegama road. A difficult, narrow and steeply climbing access road is available to reach the reservoir site. The service area is interconnected with the adjacent Bangalawatte SR service area and there is provision to connect with Napana SR service area through isolating valves.

(7) Kondadeniya SR

An additional ground service reservoir with a storage capacity of 200 m^3 is to be provided near the exiting 300 m^3 Kondadeniya tank with the same high water level in order to augment the existing storage capacity. This reservoir site is located about 1.6 km along the Kondadeniya road from Katugastota - Gohagoda road.

(8) Kulugammana SR

An additional ground service reservoir of capacity 100 m^3 is to be provided in the vicinity of the existing 300 m^3 Heenagama tank built with the same high water level to supplement the existing storage facility. This reservoir is located on the top of a sharply inclined rock at a distance of about 3.5 km along Kondadeniya road off Katugastota - Gohagoda highway.

(9) Gohagoda SR

A ground service reservoir of capacity 200 m^3 is to be provided near the exiting 150 m^3 Pallemulla tank but with a higher water level with a view to augmenting the existing storage facility and to serve higher elevated areas which could not be served by the existing reservoir. This reservoir site is located at Pallemulla along the Katugastota - Gohagoda highway. The distribution system is to be connected with service areas of adjacent existing Gohagoda SR, Kulugammana SR, Wegiriya SR and Yatihelagala SR for a more extensive usage of the reservoir.

(10) Heerassagala Middle SR

A elevated service reservoir with a storage capacity of 250 m^3 is to be provided in the middle region of Heerassagala at a distance of about 1.6 km along Heerassagala road off Kandy - Peradeniya road. Generally, the area is hilly and rapidly climbing that entails service reservoirs in close vicinity. The service area is expected to interconnect with the service areas of Heerassagala Upper SR and Elagolla SR, which falls under KMC area.

(11) Heerassagala Upper SR

A ground service reservoir with a storage capacity of 200 m^3 is to be provided along Heerassagala road at a distance of about 800 m from the Heerassagala Middle reservoir.

(12) Hantana Place SR

A ground service reservoir of storage capacity of 200 m^3 is to be provided in Hantana village covered by existing Hantana scheme. This reservoir is located at a distance of about 1.5 km along Kandy - Hantana road. The distribution system is expected to connect with Hantana Lower service area which in turn has been connected with Hantana Upper SR service area.

(13) Mullepihilla Low SR

A ground service reservoir with a storage capacity of 100 m^3 is to be provided near the existing small 25 m^3 reservoir of the Mullepihilla scheme, at a distance of about 2.8 km from Ampitiya junction along Ampitiya - Mullepihilla highway.

(14) ElhenaSR

A ground service reservoir of volume 300 m^3 is to be provided on a hillock in a farmland at Elhena at a distance of about 500 m from the Ampitiya-Thalatuoya road. A reasonably good access road is in existence except near the reservoir site. This reservoir is mainly to be utilized to serve the high elevated areas in the southwestern parts of Ampitiya SR service area.

(15) Service Reservoirs in KMC Area

a) Asgiriya SR: Located at the top of a hill, a ground service reservoir with a storage capacity of 4,100 m^3 will be provided. An access road is also planned from the public road for maintenance. A new distribution main is planned to be laid to connect city centre of Kandy town on one side and to Misty Heaven are on the other side.

b) Bahirawakanda SR: The available land which is very steep which only permits a reservoir of 600 m^3 capacity though a much larger one is required; thus an elevated tank is adopted. A slope protection is also planned to protect against land sliding.

c) Uplands SR: The location is within the protected area of a national park premises and close to the existing reservoir. A ground type of reservoir having 2,960 m^3 capacity is proposed.

d) Dangola SR: Adjacent to the existing reservoir, the new reservoir of 500 m^3 capacity will be constructed as a ground reservoir.

e) Heeressagala Low SR: This new ground type of reservoir with 200 m^3 capacity has two functions; first is to distribute to the service area and second is to transmit water to Heeressagala Middle reservoir. Thus booster pump station also will be installed.

f) Primrose SR: A storage capacity of 400 m^3 service reservoir, excluded from the scope of work for the Project, will be planned under the KMC (ADB) project.

7.8.2 Design of Service Reservoir

(1) Detention Time

They are generally designed to retain about 6-hour demand of each particular service area for absorbing demand fluctuations and any stoppage of supply from the source due to a breakdown of CEB supply, repair or maintenance.

The total water demand (max. day) projection in each service zone is exceeded or reduced from the original projection in JICA F/S. The main cause is that service area identified to be covered by gravity from each service reservoir is larger or smaller than the study area in Phase 1 in JICA F/S. Thus appropriate adjustments to keep about 6 hours retention time of Phase 3 maximum day demand, were made taking into consideration of the topographical conditions and development plan.

(2) Type Selection

The elevation of proposed service reservoir were decided based on the results of topographic survey and topographic condition of service area. The ground reservoir is adapted if the elevation of proposed service reservoir has enough elevation to distribute by gravity and to keep 0.6 bar minimum residual pressure at the furthest consumer's tap as set in the design criteria.

Elevated tank is applied where reservoir site elevation is lower than the surrounding area, thus water level is required to be raised to an additional height depending on the elevation in the service area. Maximum height contemplated is about 25 m from ground elevation to low water level.

(3) Structure

A freeboard of about 250 mm over the designed high water level is provided for inlet line, overflow line, float valve, etc, and a depth of 100 mm is available at the bottom for settlement of any remaining silt/grit not removed at the plant.

The ground reservoirs with a capacity of more than 300 m^3 are generally designed with a partition wall in the middle; such that one compartment can be isolated for cleaning, repairs, or maintenance, while the other compartment is in service and the supply thus remains uninterrupted.

The elevated reservoirs for i) Kahawatta (600 m^3), ii) Kahalla (600 m^3), iii) Bahirawakanda (600 m^3) and iv) Thelambugahawatte (500 m^3) SRs are planned are designed of one compartment. During emptying an elevated tank for cleaning, repair, etc., for maintenance, the water supply could be maintained using a bypass pipe, if necessary.

(4) Piping

For a reservoir to function effectively there are certain prerequisites to be satisfied. The incoming flow to the reservoir will be discontinued by a operation of float valve installed at the inlet line as the water level is reached at the highest.

An overflow connection, set at the high water level allows excess water to flow out of the reservoir, and is usually connected to a drain line leading to a local stream or a waterway. Similarly, a washout connection is provided at the bottom to drain the tank for emptying, for maintenance or in an emergency.

(5) Appurtenances

A local level indicator is to be installed for operators to be aware about the prevailing water level of the reservoir.

Access hatches and ladders are provided inside with safety hoops around the ladders for safety of operators climbing the ladders. Screened vents provided at the top of the reservoirs allow free air exchange to occur upon change in water level. This will also avoid accumulation of gases and building of pressures inside the reservoirs, which are detrimental and undesirable as it could lead up to even sudden explosions.

The reservoirs are covered at the top to prevent air borne dust or debris, rainwater etc., entering the tank and contaminating the water. This will also safeguard the reservoir from any act of vandalism by undesirable elements.

(6) Landscape

Most sites for service reservoirs are located on hills or on slopes, and require site access facilities since there is no access at present. At some sites, it is impracticable to construct permanent roads due to steep slopes, though the access is indispensable for purposes of checking water levels, inspection and maintaining chlorination equipment at each reservoir site. For this reason, some construction roads will be used as maintenance roads even after completion of construction, or other means of permanent access such as a flight of steps depending on the conditions of each site.

CHAPTER 8
CIVIL AND STRUCTURAL WORKS

CHAPTER 8 CIVIL AND STRUCTURAL WORKS

All structures are designed based on the following codes, standards, and criteria. The calculations are summarised in the "Design Report".

8.1 Codes and Standards

The structures will be designed according to the limit state design philosophy. The following British Standards, namely

- BS 8110: 1985 -For Framed Building structures and
- BS 8007: 1987 for water retaining structures

are used mainly in the design and calculation of civil works for the component of the Project.

Other references from British Standards or other nationally recognised standards are used for specific areas of design such as concrete mix, concrete quality, chemical attack on concrete and reinforcement. Following is a list of other standards used in general.

- BS 5950 – Structural steel
- BS 5400 – Bridges and related structures
- BS 8004 – Foundations
- BS 6399 Part 1 – Design loading for buildings-Live Loads
- BS CP3 chapter V part 2 - Basic data for the design of buildings – Wind loads
- BS 6312 – Guide to selection of constructional sealants
- BS 4449 – Hot rolled steel bars for the reinforced concrete
- BS 4461 – Cold worked steel bars for the reinforced concrete
- BS 5328 – Specification for concrete including ready-mixed concrete

Depending on the type of structure a suitable computer software package was used for the analysis and where necessary for the design of structures.

8.2 Design Criteria for Water Retaining Structures

8.2.1 Concrete

Concrete for reinforced non-prestressed, cast in place concrete construction is complied with the requirements of grade 35 of BS 12, having a characteristic strength of 35 N/mm^2 with a maximum water/cement ratio of 0.45.

Blinding concrete under footings, slabs of water retaining structure is grade 15 (15 N/mm^2) of BS 12.

The final choice of cement depended upon the results of the soil-testing programme, which indicates the chemical characteristic of the ground water. In general, the cement to be used is

"Ordinary Portland Cement (OPC)", complying with the requirements of BS12, except some places where further soil investigation should be considered during construction works.

8.2.2 Reinforcement

Non-prestressed reinforcement will be high strength deformed bars with a specified characteristic strength of 460 N/mm^2 or mild steel bars with a characteristic strength of 250 N/mm^2.

8.2.3 Design Procedure

The analysis and design was carried out in accordance with the limit state design philosophy of BS 8110 and BS 8007.

(1) Structural design:

a) The structural designs of water retaining structures are designed to satisfy Limit State of Serviceability and Ultimate limit state.

b) The partial safety factor for retained water is designed to be 1.4 for most situations at ultimate limit state (ULS) and 1.0 at serviceability limit state (SLS).

c) The structures are designed with a minimum factor of safety of at least 1.1 against flotation.

d) The maximum crack widths for reinforced concrete - All faces of liquid containing are 0.2 mm max and where aesthetic appearance is critical are 0.1 mm max.

e) Deflection – All members are checked to ensure that the deflection limitations of BS8110 are not exceeded.

f) Early age thermal and moisture shrinkage – Reinforcement is provided to ensure the early age thermal and moisture shrinkage cracking is properly controlled in accordance with the requirements of BS 8007.

(2) Structural analysis:

a) All structures required to retain liquids are designed for both the full and empty conditions and the assumptions regarding the arrangement of loading is to cause the most critical effects. Particular attention is paid to possible sliding and overturning.

b) At any given limit state the liquid level is taken to the top of the walls for design purposes assuming all outlets blocked.

c) No relief is allowed for beneficial soil pressures in designing walls subjected to internal water loading.

d) Thermal movement in roofs is minimized by appropriate means. It is noted that where a roof is rigidly fixed to a wall, forces will be generated in the wall should the roof expand or contract.

e) Earth covering roof is treated as a dead load and construction load of 5.0 kN/m^2 is considered in the design.

8.3 Design Criteria for Reinforced Concrete Framed Structures

8.3.1 Concrete

Concrete for reinforced non-prestressed, cast in place concrete construction is complied wuth the requirements of grade 25 of BS 25, having a characteristic strength of 25 N/mm^2.

Blinding concrete under footings, slabs of water retaining structure is grade 15 of BS 12, having a characteristic strength of 15 N/mm^2.

The final choice of cement depended upon the results of the soil-testing programme, which indicates the chemical characteristic of the ground water. In general, the cement to be used is Ordinary Portland Cement, complying with the requirements of BS 12. However, some locations like Bahirawakanda and Upland service reservoir sites shows aggressive in sulphates over 0.5 SO_3 percent.

8.3.2 Reinforcement

Non-prestressed reinforcement is high strength deformed bars with a specified characteristic strength of 460 N/mm^2 or mild steel bars with a characteristic strength of 250 N/mm^2.

8.3.3 Design Procedure

The analysis and design of building and frame structures are carried out in accordance with the provisions of BS 8110:1985 “Structural use of concrete”.

8.4 Steel Structures

BS 5950:1985 “The structural use of steel work in building” or other internationally recognized Standards are used for any structural steel element design.

8.5 Environmental and Loading Criteria

8.5.1 Wind Speed and Climate

The lateral loads considered in the design are due to wind forces and in the absence of a National Building Code for wind forces, the BS CP3 Chapter V in conjunction with the Report, “Design of buildings for high winds in Sri Lanka – Ministry of Local Government, Housing and Construction”, is followed in designing structures against forces due to wind.

According to this Report, the Project Area falls into Zone 3 where recommended basic wind speed is 75 mph. (34 m/s). This wind speed is therefore used to calculate characteristic wind speed, which is dependent on factors such as topology, height of structure and life of structure. The buildings and components of buildings are designed for pressures due to relevant

- Design wind speed Vs 34m/s

An enhanced wind speed of 40 m/s is, however used in designing water towers.

8.5.2 Live Load Criteria

- Inaccessible roofs : 1.5 kN/m^2
- Roof with mechanical equipment : According to actual weights and provisions of BS 6399
- Floor of mechanical rooms : Min.10.0kN/m^2 or according to actual weight of machinery whichever is higher.
- Floors accessible to trucks : BS 5400 - HA type loading
- General public access : 5.0 kN/m^2
- Offices : 3.0 kN/m^2
- Electrical rooms : Min. 12 kN/m^2 or according to actual weights of electrical equipment whichever is higher.

8.5.3 Earth Pressure Criteria

- Compacted soil density : 20.0 kN/m^3
- Active lateral soil pressure coeff. : 0.33 (to be confirmed by Geotechnical Investigation)
- Passive earth pressure coeff. : 3.0
- Surcharge on walls : 0.9m of earth or HA –uniformly distributed load where the walls can get subjected to lateral pressure due to vehicles.
- Water head at bottom of walls : groundwater level, if present
- Density of water : 10 kN/m^3
- Allowable bearing pressure : As per recommendations in soils investigation reports.

The above criteria for soil density and earth pressure generally conforms with engineering properties of soil commonly occur in the Project Area. However, where the soils investigations reveal values that lead to structures with lesser factors of safety, than the designs for that particular site was reviewed accordingly.

8.6 Soil Investigation

A result of soil investigation is reflected to design civil structures for the Project. The information collected through soil investigation is summarised hereunder.

8.6.1 Raw Water Intake and Balancing Tank

Rock edges are visible surrounding the Gohagoda Intake site. The subsurface consists of weak alluvial deposits underlain by basement rock with good core recovery and moderately good RQD values. About 3 m or more rock excavation may be required in this area. The base slab will be placed directly on the rock. The ground water level was recorded at 0.05 to 1.0 m below the ground level.

The balancing tank site is located on a fairly flat ground sloping towards the western and southern part. The subsurface consists of moderately dense soil followed by very dense weathered rock with good core recovery and moderately good RQD values. The foundation will be placed at several meters below the current ground level. No ground water table was encountered at this site.

8.6.2 Katugastota Water Treatment Plant

The treatment plant site is fairly flat area representing an alluvial flood plain of the Mahaweli River and its tributaries. The supporting layer is tend to incline according to the gradient of the ground.

The layout of structures is decided to minimise costly and time consuming piling works. The required level of each process structure is decided in consideration of the highest water level of the Mahaweli River as discussed in the previous chapter.

Around the area for the distribution chamber, flocculation/sedimentation basins, filter units, electrical sub-station building, administration building, and chemical building, bedrock is located 7 to 8 m below the base slab level so that pile foundation is considered. The clear water reservoir and transmission pump station base slab is deep enough to place its foundation directly on to the bedrock. The bearing capacity of backwash water recovery tank and the maintenance building is estimated to be 300 and 200 kN/m2, respectively as sufficient for spread foundation.

8.6.3 Service Reservoirs

Most of service reservoirs are to be constructed on virgin ground with a sufficient bearing capacity without piling foundations, even the locations are sited on sloping areas.

Gohagoda and Mullepihilla reservoirs are of pile foundations based the slope stability analysis. Individual pad footing is employed for Bahirawakande and Asgiriya reservoirs due for difficulty in carrying out earthwork on the steep slope.

Rock is exposure at the Thelambugahawatte and Kulugammana sites. Due to the designed elevation, rock excavation will be necessary for the Thelambugahawatte site and a foundation on mass concrete will be necessary for the Kulugammana reservoir.

8.6.4 Mahaweli River Crossing

The subsurface conditions at the Mahaweli River Crossing was identified as following layers.

- top layer : a weak layer of soft clay with fine sand, which is an alluvial.
- middle layer : a strong layer of dense residual soil and weathered rock in which SPT "N" value exceeds 25.
- lower layer : basement rock varies between 431.65 to 433.70 m AMSL

A centre pier foundation is to construct directly on the basement rock. Two end piers are to be supported by the required numbers of piles into the basement rock.

CHAPTER 9
MECHANICAL FACILITIES

CHAPTER 9 MECHANICAL FACILITIES

9.1 General

Based on the Preliminary Design Report submitted by the Study Team in June 2001 and data obtained from the topographic surveys, basic designs for process and mechanical facilities for the intake and water treatment plant have been conducted to reflect further design considerations. The issues described hereunder were given due consideration in preparation of the detailed design. The proposed mechanical equipment is listed in *Appendix 3*; *Proposed Mechanical Equipment*.

9.2 Raw Water Intake Pumps

A single pipe of 800 mm dia. and about 800 m long will be installed for the year 2005 flow of 38,500 m^3/d from the intake pumps to the balancing tank, which would transfer raw water to receiving well/distribution chamber in the Katugastota WTP, by gravity. The proposed specifications for the intake pumps will be as follows;

1) Number: : 2 sets (including 1 set for standby) with additional spaces provided for 1 set each for Stages 2 and 3
2) Type : Vertical double suction volute pump with dry sump
3) Capacity: : 446 l/s each (26.74 m^3/min, 1,604 m^3/hour)
4) Head : 44.0 m (operation range: 38.0 m to 44.0 m)

As illustrated in Table 9.1, horizontal double suction volute pump, vertical double suction volute pump, submersible pump station and wet well vertical mixed flow (turbine) pumps could be alternatively used for the Project. The proposed pump will have the following specific advantages;

- less installation space - the motors are located on the upper floor of the pumping station, thus the required space is minimized;
- easy access - the pumps are installed in a dry well and operators have thus easy access to monitor pumps for operation and maintenance;
- easy maintenance - NWSBD maintenance crews are familiar with the proposed type of pumps, which are of similar type as in the existing facilities. Vertical mixed flow (turbine) pumps in the wet well require the disassembly of the column pipes and the line shafts, before attending to the maintenance of the pump proper. Submersible pump motors are unlikely to be repaired at local workshops, due to lack of skills and facilities.
- high efficiency - dry well vertical double suction volute pumps have superior efficiencies than submersible pumps.

Table 9.1 Comparison of Pump Stations (1/2)

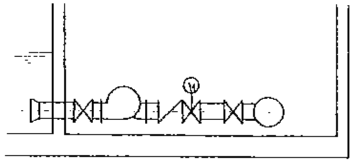
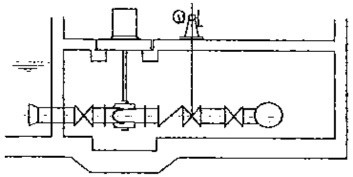
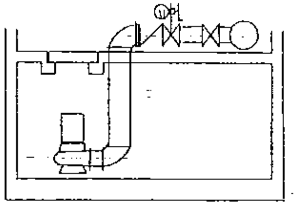
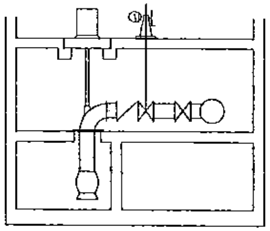
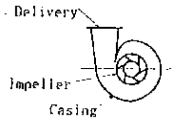
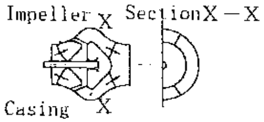
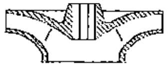
Type Item	Horizontal Double Suction Volute Pump	Vertical Double Suction Volute Pump	Submersible Pump	Vertical Mixed Flow Pump
Plan (Section)				
Structure Casing				
Impeller				
Bearing	· Impeller and shaft are supported by bearings located at both end of casing.	· Same as left	· Impeller and shaft are supported by bearings located at upper end of casing.	· Impeller and shaft are supported by bearings located at bowl case, rising pipes and bearing case.
Performance Caracteristic	· Q-H curve shows moderate pressure drop at higher flow. · Eficciency is generally high, and it is extended at wider range.	· Same as left · Same as left	· Same as left · Eficciency is comparatively low.	· Q-H curve shows steep pressure drop at higher flow, and shut-off head is relatively high.. · Eficciency is comparatively low.
Suction	· Suction head is relatively high, and the pump is safe for cavitation..	· Same as left	· Same as left	· Suction head is relatively low, and the pump is less safe for cavitation than volute pumps.

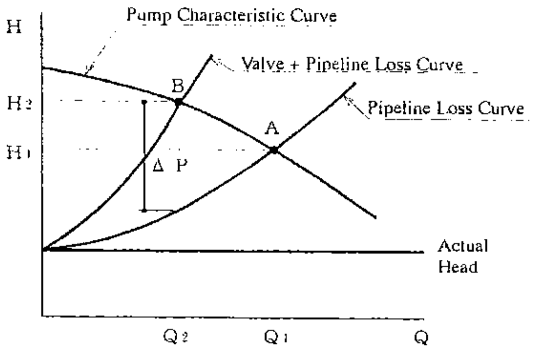
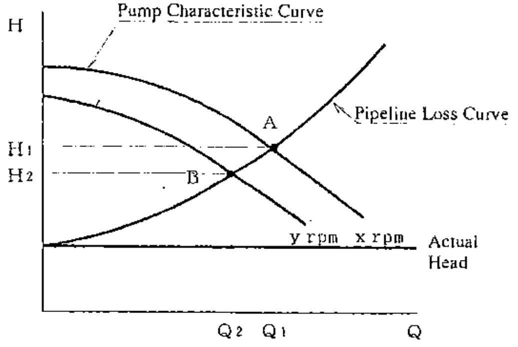
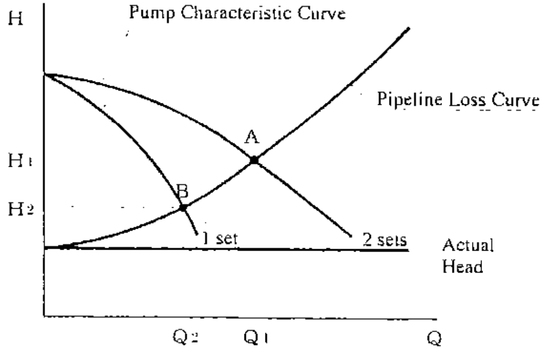
Table 9.1 Comparison of Pump Stations (2/2)

Type Item	Horizontal Double Suction Volute Pump	Vertical Double Suction Volute Pump	Submersible Pump	Vertical Mixed Flow Pump
Load	· Loads of both motor and pump are beared by pump room floor.	· Loads of motor and pump are separately beared by pump and motor room floor.	· Loads of both motor and pump are beared by pump pit floor.	· Loads of motor and pump are separately beared by pump and motor room floor.
Installation	· Easy.	· Difficult than left	· Easiest.	· Complicate.
Operation	· Priming device is not required due to psitive suction head. · Shut-off operation can be done for short period.	· Same as left · Same as left	· Same as left · Same as left	· Same as left · Same as left
Maintenance	· Easy for maintenance. Only dismount of upper casing is required for maintanance of impeller, rotor etc.	· Same as left	· Easy for maintenance. Pump and motor can be lifted from pump pit. · Submersible motor is difficult to maintain at local workshop.	· Difficult for maintenance. All motor, bearing case, rising pipe shall be disassemble to maintain pump.
Noise/Vibration	· Least noise and vibration	· Less noise and vibration	· Least noise and vibration	· Less noise and vibration
Station Area	· Largest area required.	· Larger area required than submersible pump.	· No pump room required. Smallest area required than other pumps.	· Larger area required than submersible pump.
Depth	· Positive suction head.	· Positive suction head.	· Positive suction head.	· Deepest.
Shape	· Simple. No floor for motor is required.	· Floor for motor is required.	· Simplest. No dry pit is required.	· Complicate.
Supplu Record	· Many	· Less than left	· Less than left for water supply.	· Less than horizontal type.

Table 9.2 Comparison of Control of Pump Facility Control (2/2)

Type Item	Control Valve	Speed Control	Pump Number Control
Feature	· Continuous control is available, by adjusting opening of the control valve	· Continuous control is available, by adjusting pump operating speed.	· Only stepwise is available, by control number of operating pumps.
Advantages	· Continuous flow setting is applicable. · Only one set of control valve required. · Wide range of flow control is available withoperating pump number control.	· Continuous flow setting is applicable. · Power consumption is reduced following to the decreasing of pump speed · Wide range of flow control is available with operating pump number control.	· Special devices are not required. · Lowest construction cost is required.
Disadvantages	· Cavitation can be occured at the operation withsmall opening of the control valve. · Maintenance of the control valve is required. · One control valve can hardly control small flow.	· Speed control device is relatively expensive. · Maintenance of the speed control device is required.	· Continuous flow setting is not applicable. · Round flow control cannot be Operating efficiency is low.
Maintenance	· Easy	· Easy	· Some difficulty for setting
Supply Record	· Many	· Many	· Many for small capacity

Table 9.2 Comparison of Pumping Facility Control (1/2)

Type / Item	Valve Control	Speed Control	Pump Number Control
Control Method	 • Pump is operating at A, and the flow is Q_1. If flow Q_2 is required, the operation should be shifted from A to B. However, an dditional loss is needed to this shift. Clothing the flow control valve gives the additional loss (ΔP) and the operation of the pump moves from A to B.	 • Pump is operating at A, and the flow is Q1 with pump operation speed of x rpm. If flow Q2 is required, the pump operation speed should be changed from x rpm to y rpm to change the pump characteristic curve. It reduces pumping capacity and head, and makes pumping operation at B.	 • Two pump are operating at A, and the flow is Q1. If flow Q2 is required, one of the operating two pumps should be stopped and one pump supplys flow Q2.

In order to accommodate the wide range of operating heads due to fluctuation of Mahaweli River water level, variable speed pumping is recommended. Three types of alternative flow control systems, namely i) valve control, ii) speed control and iii) operating pump number as shown in Table 9.2 are in use for the intake pump installations.

Speed control is justified for the following reasons;

- continuous setting - the pumps with speed control can be continuously operated against the varying heads within the pre-determined range. The pumps with pole change motors and valve control have the same performance, but the control system is more complicated and expensive.
- low operating cost - the pumps with speed control has a lower operating cost than pumps with pole change motor and valve control.

By providing speed control for the raw water intake pumps and monitoring flow, the flow adjustment of raw water can be accomplished automatically. Figure 9.1illustrates the proposed control system.

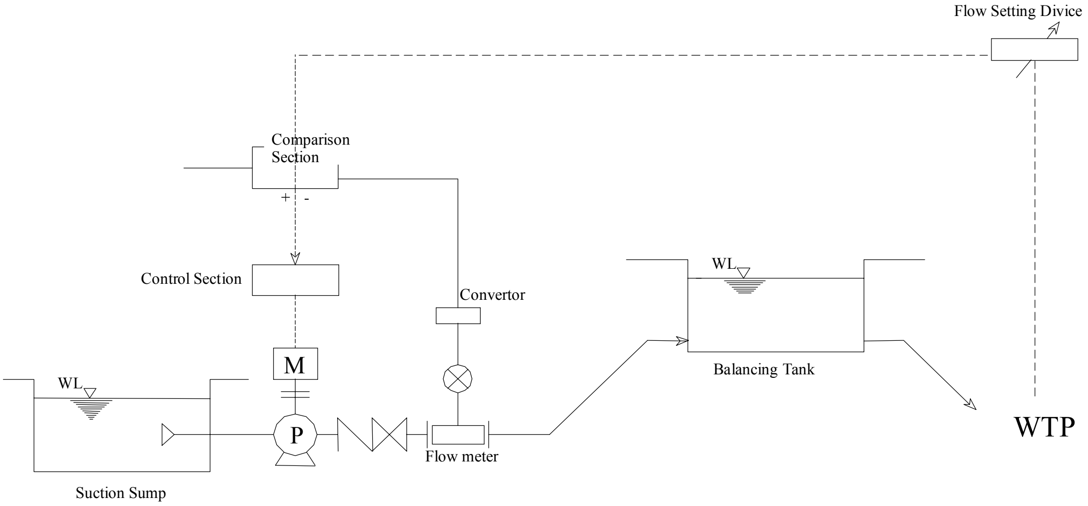


Figure 9.1 Intake Pump Control System

Surge analysis has been undertaken using the final pipeline configuration and design. No surge protection system is required for this pumping system. Result of surge analysis is shown in the Design Report.

9.3 Sludge Collection for Sedimentation

Two sedimentation basins are proposed as discussed in the previous chapter, and each will be provided with mechanical sludge collectors to ensure that sludge is effectively withdrawn automatically by means of sludge withdrawal valves.

For horizontal sedimentation basins, the following major types of sludge collectors could alternatively be used as per Table 9.3.

a) chain flight sludge collector
b) reciprocating flight sludge collector
c) travelling blade sludge collector

Travelling blade sludge collector is popular for horizontal sedimentation tanks, but it is not applicable due to troughs for intermediate collection system, which will be adopted to minimise the required space for the sedimentation basins. Submersible travelling blade, reciprocating flight, and chain flight sludge collectors are acceptable for horizontal sedimentation tanks with intermediate collection system. Reciprocating flight sludge collector has the following specific advantages;

- low cost – simple operation and structure for the collector will incur low cost;
- easy maintenance - simple operation and structure for the collector does not require special devices and materials for repair or maintenance. Local technicians could handle repairs using materials available in the local market.

9.4 Filter Control Valve

For the operation of filter gates and valves, hydraulic, pneumatic or motorized actuators are applicable. Hydraulic actuators have been used for many years, but of recently the use of pneumatic and motorized actuators has become more widespread, because of the need for cumbersome maintenance of hydraulic devices. Both pneumatic and motorized actuators are often used for operation of filter gates and valves. It is recommended that motorized actuators be used for the following reasons:

- motorized actuators can readily monitor the operation conditions such as opening, over-torque etc, and can be indicated on the control panel;
- motorized actuators can be operated manually using manual handles, when power failure occurs or the motor is damaged.

9.5 Clear Water Pump Station

9.5.1 Pump Selection

Out of the four transmission systems, A-1 (Upland/Asgiriya etc), A-2 (Gohagoda/Kondadeniya) and A-3 (Kahawatta etc) systems will be implemented in Phase 1, while A-4 (Uduwawala) system will be designed for Phase 2.

Considering Phase 2 and 3 transmission flows and heads, transmission pumps shall be designed to handle Phase 1 flows as shown in Table 9.4.

Table 9.3 Comparison of Sludge Collectors (1/2)

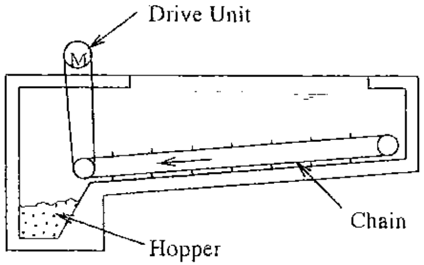
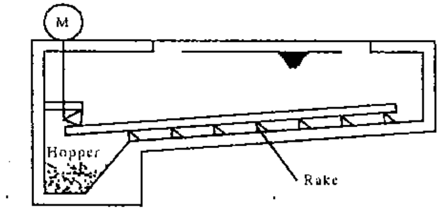
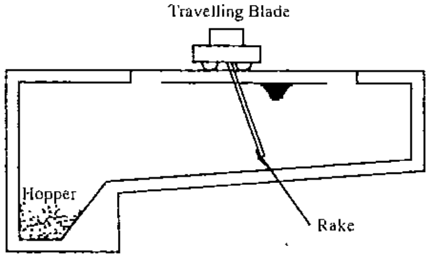
Type / Item	Chain Flight	Reciprocating Flight	Travelling Blade
Drawing			
Outline	Drive unit on the top slub rotates shafts in water by drive chains. Two main sprockets on the shafts pull two endless chains with many flights. The main chains run continuously.	Drive unit on the top slub push and pull driving rod. Vertical reciprocating motion of the rod is changed to horizontal motion by angle arm unit, and it is transferred to the rake. Many flights are equipped to the rake at right angle to the rake. The rake make reciprocating motion continuously.	Travelling blade runs forward and backward on rails installed on the top slub. The brade hangs a rake to the bottom of the tank. The travelling blrade is operated periodically.
Major Equipment	Drive Unit: motor, reduction gears Underwater: chains, sprockets, shafts, bearings, flights, shoe	Drive Unit: motor, reduction gears Underwater: rod, angle arm unit, rake, flights, guide rails	Surface: brade, motor, reduction gears, rails Underwater: rake
Operation	Two endless chains with flights runs continuously. Flights scrapes and collects settled sludge to sludge hoppers.	Rake with many flights Inatalles on the bottomruns forward and backward by reciprocating link motion. Flights on the rake scrape and collect settled sludge to sludge hoppers.	Travelling blade Inatalles on the top slub runs forward and backward. Rake hung from the brade scrapes and collects settled sludge to sludge hoppers.

Table 9.3 Comparison of Sludge Collectors (2/2)

Type / Item	Chain Flight	Reciprocating Flight	Travelling Blade
Advantages	· Inclinated plates may be installed. · Less moving parts underwater · Continuous scraping	· Inclinated plates can be installed. · Less moving parts underwater · Continuous scraping · Easy Installation · Easy operation and mainenance	· Less moving parts underwater · Easy operation and mainenance
Disadvantages	· Most of moving parts, such as cahains, sprockets, bearings etc are located underwater, and regular maintenance is required. · Main chains can be cut off. · Main chains can be loosen for long term operation.. · Breaks of the mainchain are not monitored from the top slub.	· Most of moving parts, such as rakes, flights etc. are located underwater, and regular · Maintenance is required, but less frequency.	· Inclinated plates cannot be installed. · Only periodical scraping · Top slub should bear large load.
Maintenance	· Surface - replace of gear oil: once a year - lublication of driving chains: once a month · Underwater - loosen of chain - wearing of chains/sprockets - damage of flights	· Surface - replace of gear oil: once a year - lublication of driving chains: once a month · Underwater - wearing of guiderails - damage of flights	· Surface - replace of gear oil: once a year - lublication of driving chains: once a month - wearing of wheels/sprockets: once a month - loosen of wire ropes: once a month - damage of rakes: once a month
Supply Record	· Many	· Recently increasing.	· Many

Dry well horizontal double suction volute pumps are recommended for the clear water transmission. Wet well vertical mixed flow (turbine) pumps can also be applied, but more installation space is necessary at clear water pump station in the treatment plant. The proposed pump has the same superior advantages as listed for the intake pumps above. The number of pumps is determined by the availability of low voltage motors, which are available up to approx. 500 kW, and could be locally repaired.

Table 9.4 Clear Water Pumps

No.	Service Reservoir		Daily Maximum (m^3/day)	Pump No.		Flow (m^3/min)	Head (m)
				Duty	Standby		
A-1	Upland/Asgiriya	3	17,600	1	1	12.22	134
A-2	Gohagoda Kondadeniya	3	4,710	1	1	4.08	104
A-3	Kahawatta etc	6	14,390	1	1	9.99	93
A-4	Uduwawala	-	-	-	-	-	-

Surge analysis has been executed using the final pipeline configuration and design. The results of surge analysis show surge protection is required for Upland/Asgiriya system (A1), and flywheel are proposed for the pumps for A-1 system. As for the anti-surge protection system, surge tanks with rubber bladders or pressure vessels, and flywheels are acceptable for this system. Taking into consideration of a compact area required and simple maintenance-free construction, flywheels are the preferred option for the surge protection system.

Table 9.5 Surge Protection for Clearwater Pump

System	Reservoir	Type	Size
A-1	Upland/Asgiriya	Flywheel	100 kg-m^2

9.5.2 Pump Control System

Pumps should be operated to meet water demands of service reservoirs, whereas float valves installed at the service reservoirs are operated according to the variation of water level in the reservoirs. Each transmission system contains several reservoirs (ex. four reservoirs for A-1 system). Therefore, special control devices, such as variable speed pumping are needed.

However, high initial cost of the speed control unit and less energy saving effect due to high elevation of service reservoirs, it is recommended that pumps for the clearwater pump station shall be operated without speed control, but flows and operation pressures shall be monitored.

Figure 9.2 illustrates the proposed control system.

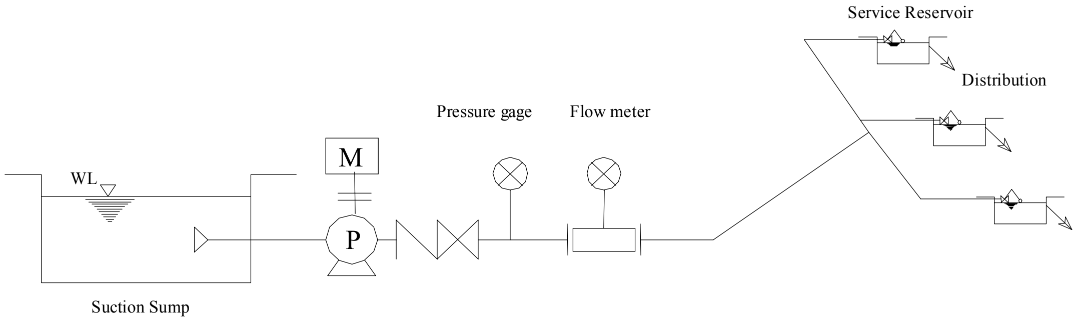


Figure 9.2 Clearwater Pump Control

9.6 Booster Pumping Station

9.6.1 Pump Selection

The booster pumping stations are designed for nine transmission systems at seven service reservoirs as shown in Table 9.6.

Table 9.6 Booster Pumps

No.	Service Reservoir	Direction		Pump No.		Flow (m^3/min	Head (m)
				Duty	Standby		
B	Heerassagala Low	Heerassagala Middle	1	1	1	1.90	68
C	Heerassagala Middle	Heerassagala Upper	1	1	1	0.49	77
D-1	Ampitiya	Elhena	1	1	1	0.83	45
D-2		Mullepihilla	1	1	1	0.68	145
D-3		Meekanuwa	1	1	1	1.49	73
E	Kahawatta	Kurugoda etc	2	1	1	2.94	65
F	R-2	Hantana Place	1	1	1	1.36	102
G	Asgiriya (In-line)	Bahirawakanda	1	1	1	1.58	68
H	Kondadeniya	Kulugammana	1	1	1	1.11	64

In the majority of these booster pumping stations, the designed flow for Phase 3 will increase by less than 200 percent from that for Phase 1. Therefore, pumping facilities will be provided for the designed flow in Phase 3, except for Systems E and G.

The above table summarises the flow and head of pumping facilities in each booster pumping station.

As for selection of pump types, Figure 9.3 is to reckon with. All pumps for booster pumping stations will have relatively small flows, and thus end suction volute pumps or multi-stage pumps are applicable in accordance with the required pump heads.

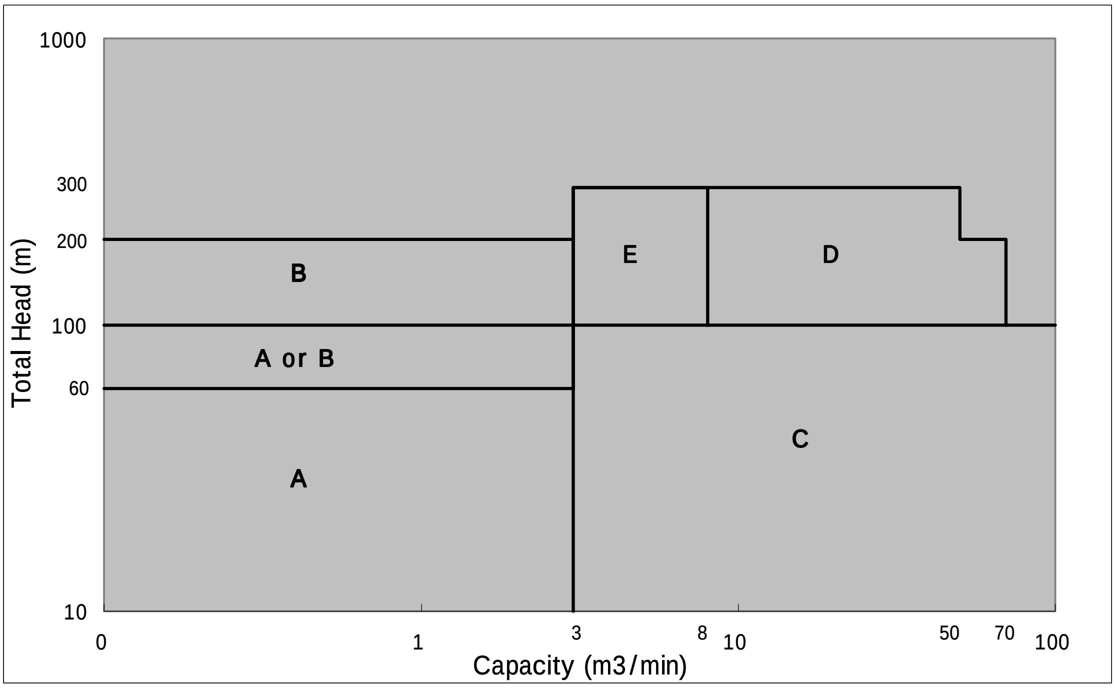


Figure 9.3 Booster Pump Selection

A: End Suction Volute Pump
B: End Suction Multi-Stage Volute Pump
C: Double Suction Volute Pump
D: Double Suction Multi-Stage Volute Pump
E: End Suction Multi-Stage Volute Pump

In principle, horizontal pumps are recommended but vertical pumps may be considered if adequate installation space is not available at the service reservoirs. Since required pump heads are relatively high 2-pole motored pumps will be fully utilised to meet the requirements and cost saving purpose.

Surge analysis has been executed using the final pipeline configuration and design. The results show surge protection shall be provided for “Ampitiya to Meekanuwa” system (D-3) and “R2 to Hantana Place” system (F). As for the anti-surge protection system, surge tanks with rubber bladders or pressure vessels, and flywheels are acceptable for this system. Taking into consideration of a compact area required and simple maintenance-free construction, flywheels are the preferred option for the surge protection system. However, surge tank with rubber blade will be applied due to the limitation of flywheel size.

Table 9.7 Surge Protection for Booster Pump

System	Reservoirs	Direction	Type	Size
D-3	Ampitiya	Meekanuwa	Flywheel	15 kg-m2
F	R-2	Hantana Place	Surge tank	(effective) 0.1 m^3

9.6.2 Pump Control System

Pumps should be operated to accomplish water demands arising at the service reservoirs, whereas float valves installed at the inflow of service reservoirs are operated according to the variation of water level in the reservoirs. Transmission flows in these systems are relatively small and each system is connected to a reservoir, except the E system. Therefore, special control methods, such as variable speed pumping, will not be required.

In order to accommodate the operation of the float valve, automatic cut-off system shall be provided for pump operation. For this purpose, a flow switch and a pressure switch will be provided on the delivery pipe of each pump station to monitor no flow or high head in the pipe. The pump will then be automatically stopped by sensing the no flow in the pipe, which takes place when the float valve in the service reservoir is closed. The pump will then be re-started by a timer or manually after the lapse of a certain period of time.

Figure 9.4 illustrates the proposed control system for booster pump stations.

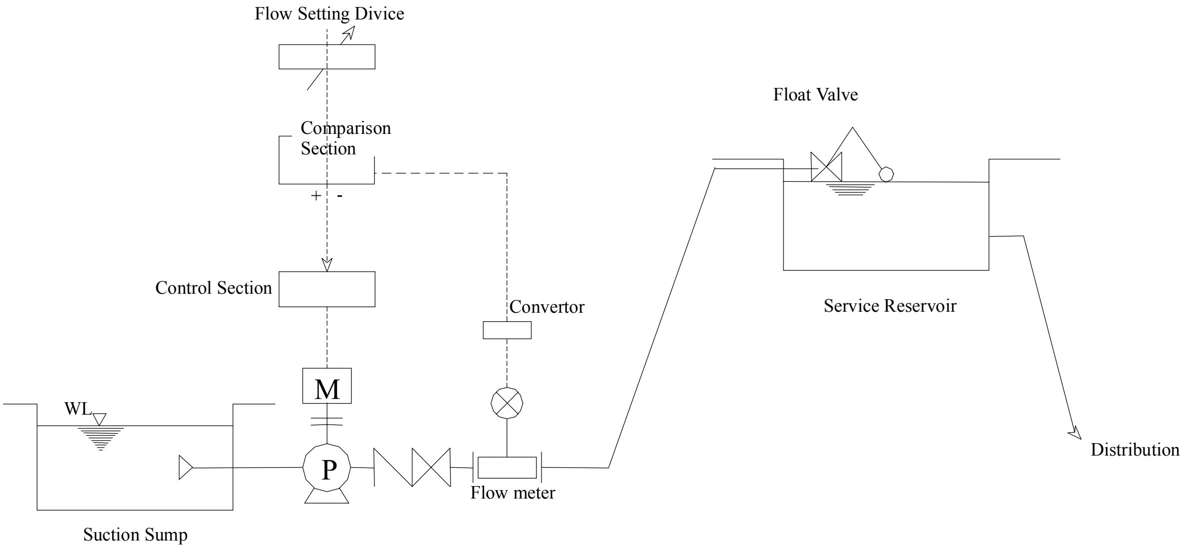


Figure 9.4 Booster Pump Control System

9.7 Chlorinator

The chlorination will be done at the proposed water treatment plant before water being transmitted to each reservoir. In addition to that, it is important, for public health concerns to disinfect the reservoirs before they are put in service. As the existing R2 and Ampitiya SRs are performing chlorination disinfections, if the reservoir is not very far away from the treatment plant chlorination may not be required, which will then act as a contact tank for chlorine.

Water to Kurugoda SR and Thelambugahawatte SR is through Kahawatta SR, thus it takes a long time for transmitting/distributing water from Katugastota WTP to consumers, and therefore additional chlorine dosing is required to secure disinfection. It is planned to install chlorination equipment and 1mg/m^3 dosage at Kahawatta SR, for which the operators are planned to be assigned to the station.

CHAPTER 10
ELECTRICAL SYSTEMS

CHAPTER 10 ELECTRICAL SYSTEMS

10.1 General

Electrical systems should adhere to the following basic requirements to accomplish a stable supply of safe and clean water.

(1) Reliability

The water supply system requires a high degree of reliability. The selection of equipment and instruments are decided on the appropriateness, high performance and high endurance. Electrical systems shall be then installed in the duplex system, complete with operation and back up system.

(2) Safety

Electrical systems prioritise the safety of life, and shall be designed to prevent any outbreak of fire or an electrification accident from taking place. The fail-safe system is adopted, if necessary.

(3) Economy

Electrical systems shall be designed by taking into account the future development plans, in order to reduce initial investments and to maximise the use of the facilities already installed in the next phases of construction. The operation and maintenance costs shall be minimized by optimising the system, with incorporating energy-saving and labour-saving devices.

(4) Control and Operation

Control and operation shall be made simple, easy, and free of operational failures. The automatic and linked operation systems shall be taken into consideration, as appropriate.

(5) Maintenance

Equipment shall be selected for easy maintenance and periodic checking. The type of equipment and instruments are unified and standardised as much as possible, and should be compatible.

Moreover, the electrical designs should be carried out in conjunction with the civil, mechanical, and other designs and be able to make the entire plant operational at any instant.

All electrical installations will be designed in accordance with the specification of Ceylon Electricity Board and the latest IEE (LONDON) wiring regulations. The equipment will comply with ISO, IEC, JIS, and BS standards.

10.2 Power Supply

10.2.1 Main Power Supply

The power supply to the intake and the water treatment plant is by the single incoming system, 3-phase 3-wire, 33kV, 50Hz from the CEB. The reservoirs are 3-phase, 4-wire, 400V, 50Hz supply from the CEB. In Phase1, the intake is provided with a 3-phase, 4-wire, 400V, 50 Hz supply.

10.2.2 Back-up Power Supply

The standby generator should be installed in view of supply interruptions caused by the CEB, in order to maintain continuous operation of the plant. The type of the generator will be a diesel engine driven, radiator cooling, battery operated, and 3-phase 400V output.

The generator should have the capacity to take the maximum demand load to operate the plant uninterrupted. The fuel tank should have capacity for 8 hours continuous operation of the generator.

750 kVA generator is installed in the intake and 2000 kVA generator is installed in the water treatment plant, respectively. These capacities cover all of electrical loads in Phase 1. However, for the reservoirs, the generators are not adopted.

Design calculations are shown in Volume IV, Data and Attachment.

10.2.3 DC Power Supply

The DC power supply is generated from the AC power supply at the low voltage distribution board. The AC power is converted to the DC power through the rectifier, and charges the storage batteries. Simultaneously, the DC power energises the DC power loads. When the main supply interruptions, the DC power from the storage batteries will be utilized, where necessary.

The DC power supplies are required for operation or control of:

- the high tension substation facilities;
- protection relays of the high tension metal-enclosed switchgear;
- air circuit breaker (ACB) of the low-tension switchboard; and
- starter of generator.

The batteries are cathode absorption seal, lead-acid battery (MSE) type, 100 V output, with 30-minuites discharge times.

10.2.4 UPS Power Supply

The UPS power supply would receive the AC power from low voltage distribution board. The AC power is converted to the DC power through the rectifier, which charges the storage batteries. When the main power supply interruption happens, the DC power from the batteries is converted to the AC power through the inverter. Thus, the UPS will continue to receive the AC power without an interruption.

The UPS power supply are for operation or control of the SCADA (Supervisory Control and Data Acquisition) system, PLCs, computers, instrumentation, etc., where even a momentary service interruption is not permissible.

The UPS is a cathode absorption seal, lead-acid battery (MSE) type, 240 V output, with 30-minute backup time.

10.3 HT System and Transformers

10.3.1 Bus Bars

The type of high-tension bus bar is the single incomer and the single bus bar type. The current capacity of the bus bar should endure the electric power demand of the whole plant.

10.3.2 Circuit Breakers

Vacuum circuit breakers (VCB) are adopted for high-tension circuit breakers for ease of maintenance. The breaking capacity at receiving point is 1000 MVA at 33 kV. The breaking current rating of VCB's should be 20 kA at 33 kV.

10.3.3 Main Transformers

In the treatment plant, the type of main transformers is the molded dry type transformer with metal enclosure for fire-proof, crack-proof, dust and moisture-proof, which is also smaller, lighter, stronger than the oil immersed transformer.

33 kV power supply from CEB should be stepped down to 415 V by 2 numbers of main transformers in Phase 2. In this case, the main transformers should run in parallel. In Phase 1, one transformer is installed in water treatment plant. A necessary capacity of the main transformers is about 1500 kVA in Phase 1. But it is installed 2000 kVA transformer, considering future expansion.

In the intake, power receiving is low voltage from CEB in Phase 1 and Phase 2. But power receiving will need HT transformer in Phase 3. So only space for future expansion is prepared in Phase 1.

Design calculations are shown in Volume IV, Data and Attachment.

10.3.4 Lightning Arrester

Indoor-type lightning arresters are installed in the power receiving panel to protect electrical equipment from lightning, surges on the CEB power line. Lighting arrester for instrumentations are installed in all outdoor instrumentation to protect from lighting induced on outdoor wiring.

10.3.5 Metering and Protection

The electricity metering device, which comprises of VCT and kWh-meter, is installed on the 33 kV side by the CEB.

An over-current relay is provided in the power-receiving panel to protect the electrical equipment from electrical faults such as over-currents.

The earthing system is the earthed neutral system, type TN-S system, in which neutral and protective functions are combined in a single conductor throughout the system. In this system, a grounding over-current relay is provided to protect the electrical equipment from electrical faults such as grounding fault.

10.3.6 Single line Diagram

The outline of single line diagram is shown in Figure 10.1 and Figure 10.2.

10.4 LV System

10.4.1 Low Voltage Distribution

The power from the transformers is distributed at 415 V, 3-phase, 4-wire to the low voltage distribution boards.

Low voltage bus bars are provided to carry the full load current of the transformers and designed to endure the full short circuit load of the transformers.

In principle, all outgoing feeders are installed with grounding over-current relays to protect the electrical equipment from faults such as grounding fault.

10.4.2 Power-factor Improvement

Power-factor improvement is achieved by static capacitor, and the compensated power-factor is 95 percent. The capacitors will be installed at the low voltage bus bars except above 55 kW loads. As for more than 55 kW load, the capacitors will be installed individually. The power-factor is adjusted automatically by APFC (Automatic Power Factor Controller), which is installed at the secondary feeder of transformer.

10.5 Motor Control Centre

Motor control centres should be installed to supply power for loads up to 55kW. Motor control centres are composed of draw-out type units that are assembled in circuit breakers, magnetic contactors and similar control devices.

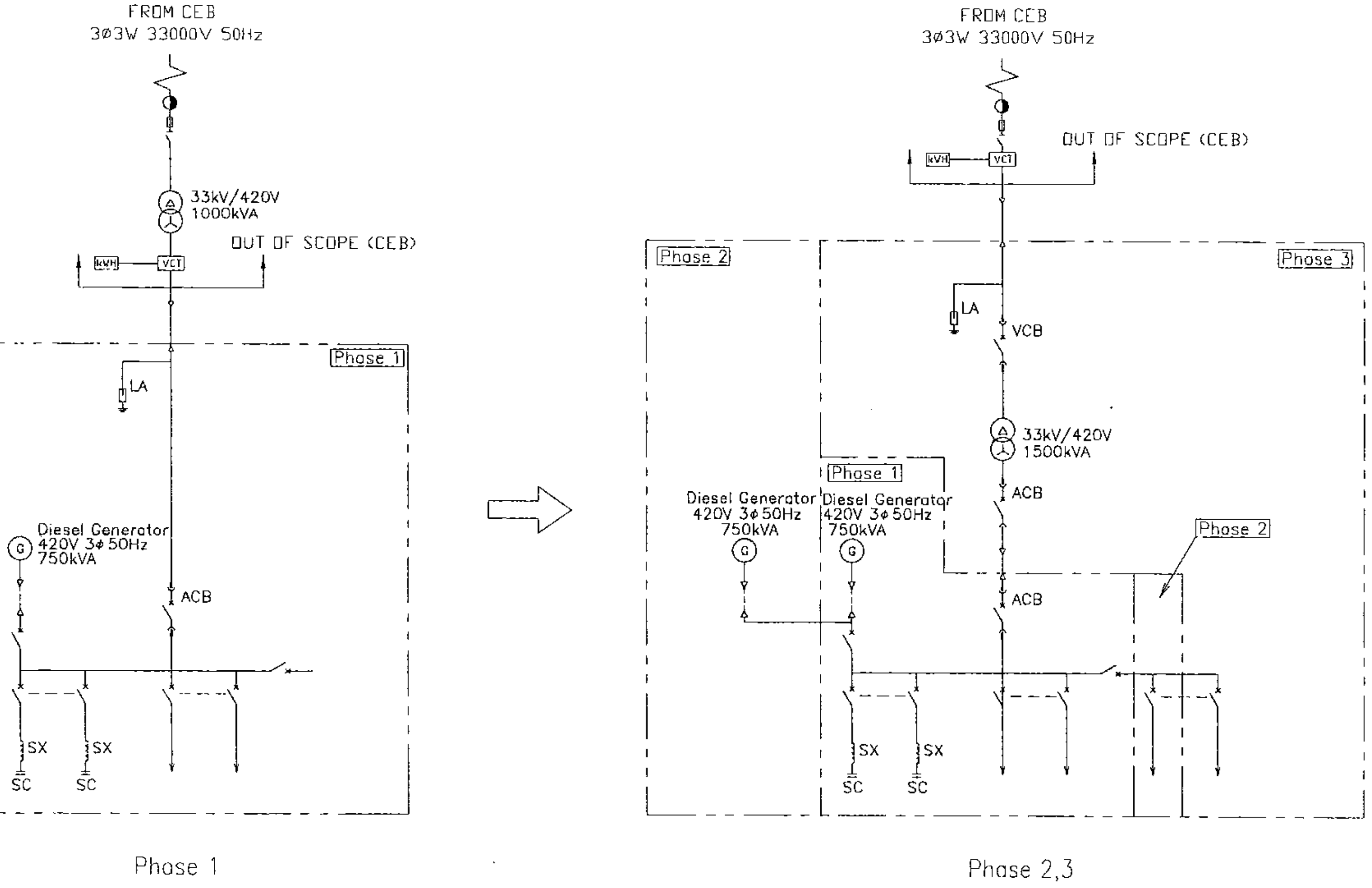


Figure 10.1
Single Line Diagram (Intake)

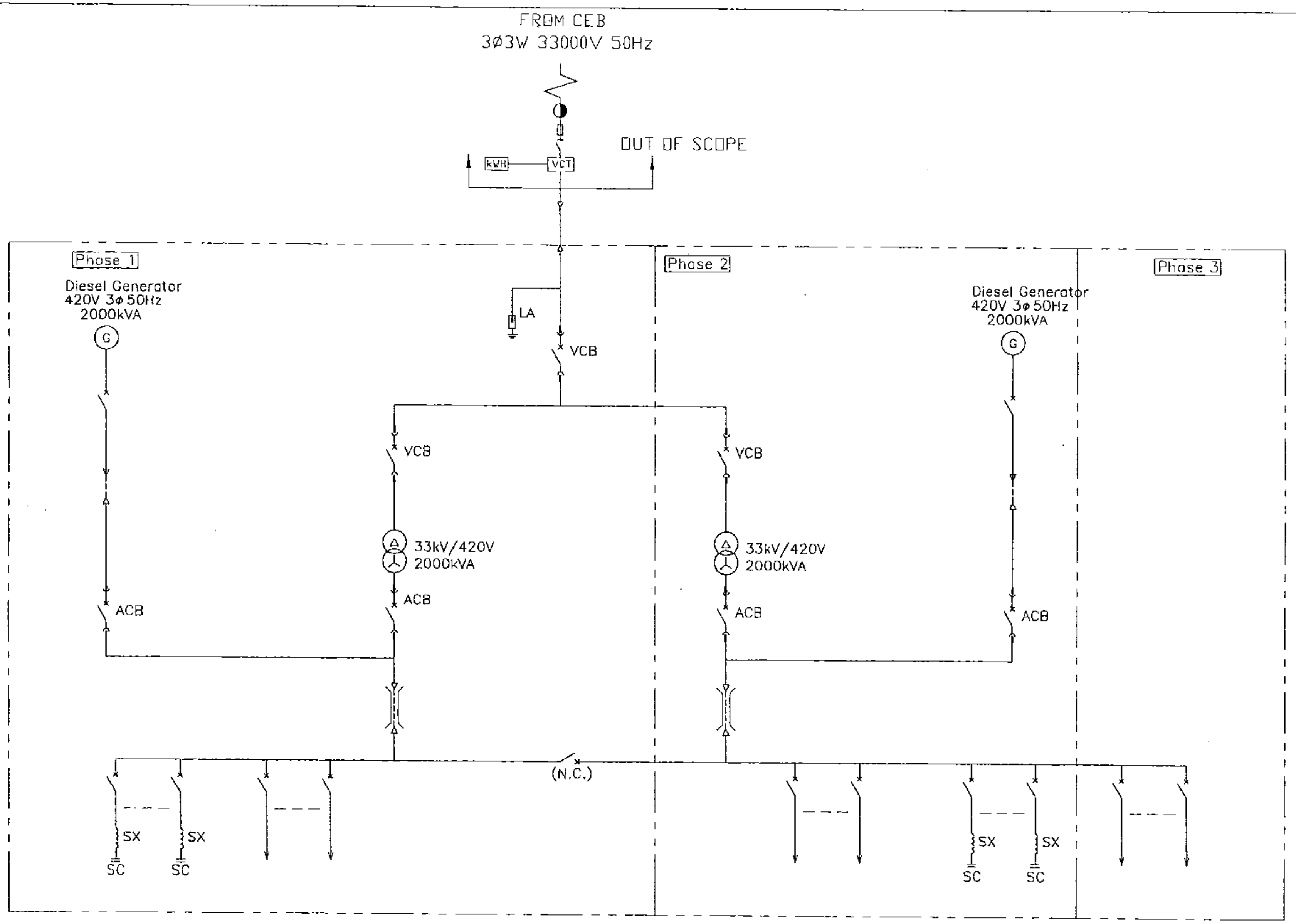


Figure 10.2
Single Line Diagram (WTP)

Motors or equipment should be controlled by auxiliary hard relays and PLCs' software. Auxiliary hard relays and PLCs have manual-mode operation, and auto-mode operation control circuits respectively.

10.5.1 Motor Voltage

Generally, motor voltages should be provided in accordance with the following specifications as shown in Figure 10.3. Motors up to 300 kW will be provided with 400 V and for motors over 300 kW, 3 kV will be provided. The maximum output power in this project is 450 kW for the high lift pumps. However, considering the eased maintenance and economy, 400 V is adopted but not 3 kV.

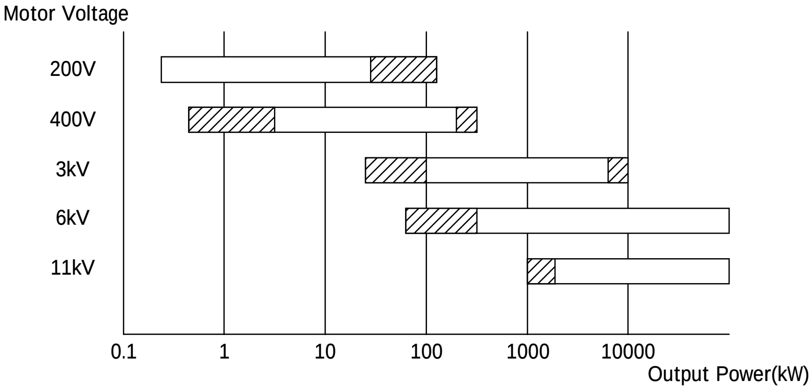


Figure 10.3 Economical Range of Every Voltage for Motor

10.5.2 Motor Starters

All motors will be provided with starting as follows:

- up to 7.5 kW	- DOL starting
- 7.5 kW to 37 kW	- star delta starting
- above 37 kW	- auto transformer starting
- raw water pump motor of 280 kW	- soft starting or VVVF starting
- transmission pump motor	- soft starting

All motor starters are installed in separate cubicles, and provided with over current protection.

10.5.3 Motor Protection

All motors are protected from damage by faults such as overload, grounding fault, lack of phase, reverse of phase, and imbalance of the three phases, which are detected by thermal relays, solid state overload relays, earth leakage relays or peak power cut relays.

10.5.4 Variable Speed Drives

To control the speed of motors, it is necessary to couple them with VVVFs (Variable Voltage

Variable Frequency). VVVF makes it possible by changing the voltage and frequency of the electricity supply with the inverter. Further, VVVF is also effective in saving energy.

As a countermeasure for higher harmonics suppression, VVVF is always installed with RNF (Radio Noise Filter).

10.5.5 Local Control Switches

Local control stations are provided adjacent to all process equipment. Each station has a key switch for “LOCAL-CENTRAL” controls or “SINGLE-LINK” controls, “ON-OFF” switch positions, etc. Local operation panels have the highest priority to operate all motors by manual. All motors can be controlled by manual at the local control stations installed by the side of motors.

10.5.6 Sub-mains Distribution and Cabling

Generally, all sub-mains cabling will be laid using multicore XLPE SWA PVC cables. When cables are wired into the ground, concrete trenches or uPVC cable ducts with concrete draw pits will be provided.

All cables are fully protected from UV degradation.

10.6 Instrumentation Equipment

10.6.1 General

The selection of instrumentations needs to adhere to the following requirements.

- The purpose of measuring and the precision of reading
  Selected subject to the consideration of the appropriateness and the cost.
- Environmental condition at measuring point
  Selected in consideration of the reliability and endurance against the adverse environmental conditions such as high temperature, high humidity, or presence of corrosive atmosphere.
- Maintenance
  The type of instrumentations should be unified and standardised as much as possible for easy maintenance.
- Measuring range

When the measuring range is smaller in Phase1 and larger in the other Phases, instrumentations will have to be altered to reflect the full operation range in each Phase.

Table 10.1 Measuring Items and Types

Measuring Items	Types
Raw water wet well level	Immersion water level (pressure) gauge
Raw water intake flow	Ultrasonic flow meter
Filter level	Ultrasonic flow meter
Back wash water flow	Ultrasonic flow meter
Air scouring flow	Orifice flow meter
Back wash return water flow	Ultrasonic flow meter
Back wash water tank level	Immersion water level (pressure) gauge
Clear water reservoir level	Immersion water level (pressure) gauge
Clear water transmission flow	Ultrasonic flow meter

10.7 Control and Supervisory System

10.7.1 Concept of System

In principle, the hierarchy system and distribution control system is adopted. The hierarchy system makes it easy to monitor due to supervision of the whole set of equipment from one location. And distributed control system improves the reliability of the control system.

The supervisory control is classified into three levels. They are the field level, electrical room level, and central monitoring room level. The detail of each level is described in the following;

The concept of a hierarchy system and horizontally distributed control system is shown in Figure 10.4.

10.7.2 Field Level

Operations such as single operations carry out unit test or, adjustment test for the load like a pump etc. Accordingly, to carry out it without failure, it is necessary to be assembled with a hard relay for the single operation, even in the event that abnormal conditions happen to the PLC of the upper class system.

The loads without direct relation to the process operations like the sump pump, ventilation fan etc., should be considered as a site operation activity only. For loads other than site operations, it is necessary to install a “LOCAL-REMOTE “ switch.

The process values, such as electric current and water level etc., that are needed for single site operation should be indicated on the site control panel. These process values are branched off from the instrumentation converter directly, without passing through the PLC.

The failure display lamps, such as over load and/or mechanical failure, should be installed on the local operation panel along with the group failure indicating lamps. Also, the condition status indicating lamps, such as high and low water level are installed on the site control panel, at the same location.

10.7.3 Electrical Room Level

The electrical room level has a function of the main control and local supervisory. In the each electrical room, there are PLC panels, hard relays panels and instrumentation panels. The distributed control system is realised to install these panels dispersively in each electrical room. This system prevents the accident of one facility from spreading to other facilities.

In principle, the PLC work for the automatic and the link operation, and the hard relays panel work for the single operation. In case of the PLC failure, it is at least possible to operate by manual by auxiliary hard relay. The instrumentation panel is composed of indiocator, controller, setting device and so on. All measuring values of instrumentation can be watched on this panel.

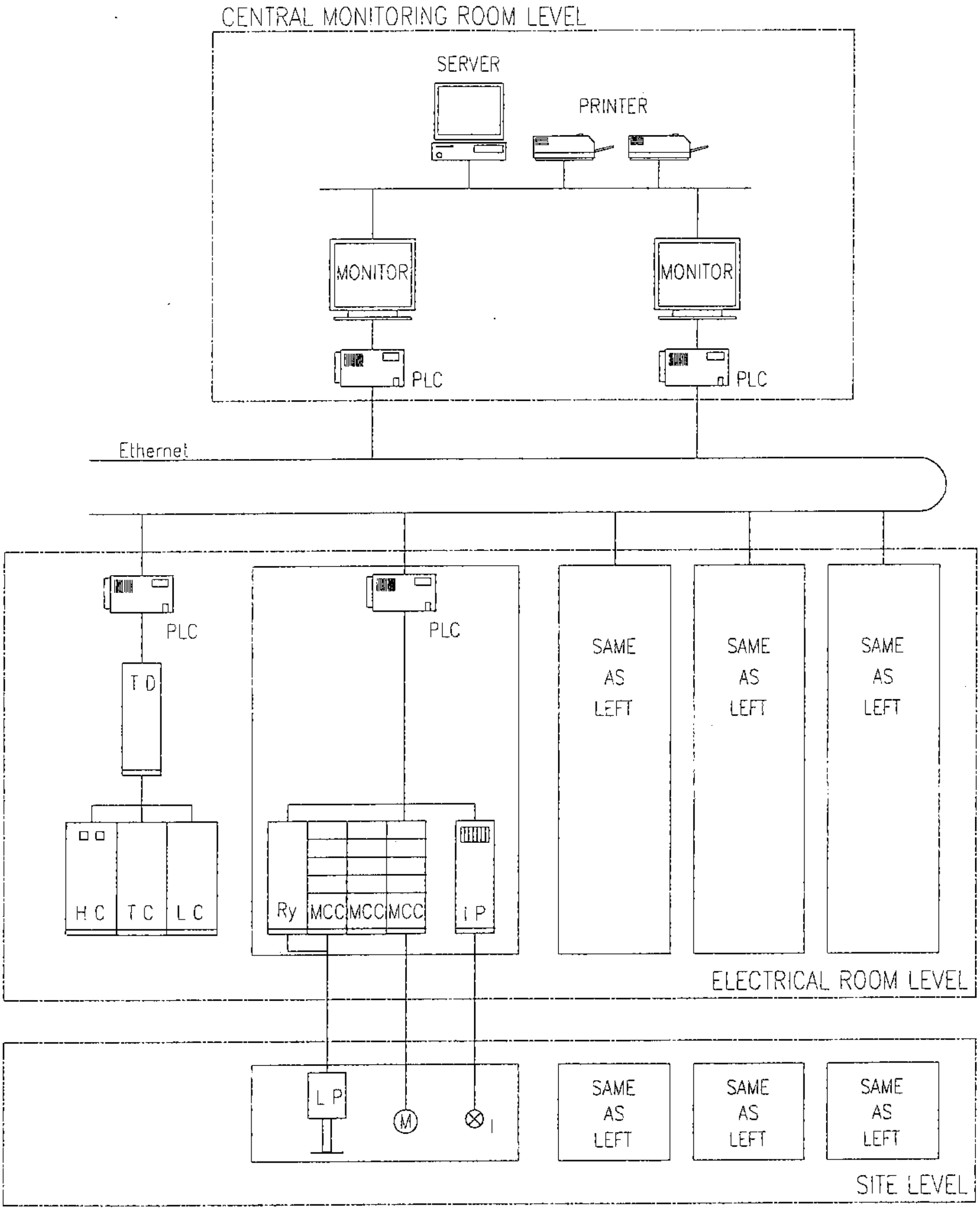
10.7.4 Central Monitoring Room Level

All of important items such as an alarm or status can be monitor comprehensively from central monitoring room. In the central monitoring room, there are two master PLCs, two computers, one server, and two printers. Two master PLCs are connected with all local PLCs by optic fiber cable and communicate each other by Ethernet protocol. Master PLC transmits the information of local PLCs to the computers. The computers are a man-machine interface to monitor the whole plant through a graphical interface. Two sets of PLC and computer have same function. This means, it is possible to monitor two sites at the same time and also mutual back up. The data, which are transmitted to the computers, are accumulated to the server. The server plays a role of data processing so that it can generate reports to the computer, such as daily, monthly and yearly report, historical trend graph, historical process running and historical alarm.

10.7.5 Principal Automations

(1) Intake flow automation

Set the target value of raw water flow, which then will control automatically the number and speed of intake pumps to keep the constant inflow flow and amount as shown in Figure 10.2. It is possible to set the target value both at the intake site, and at the central monitoring room of Administration Building in the Plant.



LEGEND:

PLC : Programable Logic Controller	T D : Transducer Panel
H C : High Tension Enclosed Switchgear	MCC : Motor Control Center
T C : Transformer Cubicle	Ry : Hard Relay Panel
L C : Low voltage Cubicle	I P : Instrumentation Panel
	L P : Local Panel

Figure 10.4
Concept of Hierarchy and Distributed Control System

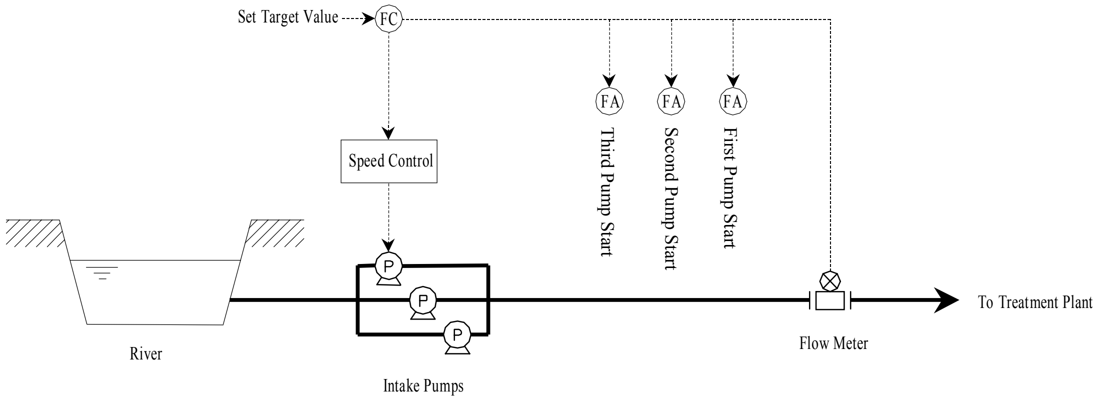


Figure 10.5 Intake Pump Operation

(2) Filter backwash automation

The sequential control of filter backwash consists of "open-close" of valves or gates and "start-stop" of pumps or blowers. This sequential control is started by pushing the button of the selected filter. Operation of the filter backwash is exclusively done on the site control panel at site level.

(3) Transmission pump automation

The operation of the transmission pumps is done at a fixed speed. Automatic control of stop and restart are schematised in Figure 10.6. The confirming timer starts to work when the transmission pressure exceeds the some settled value or the transmission flow rate below the some settled value. After the set up time passes, if pressure or flow rate is unusual continuously, the pump will stop automatically. The restart of pumps is done by the transmission pressure and timer.

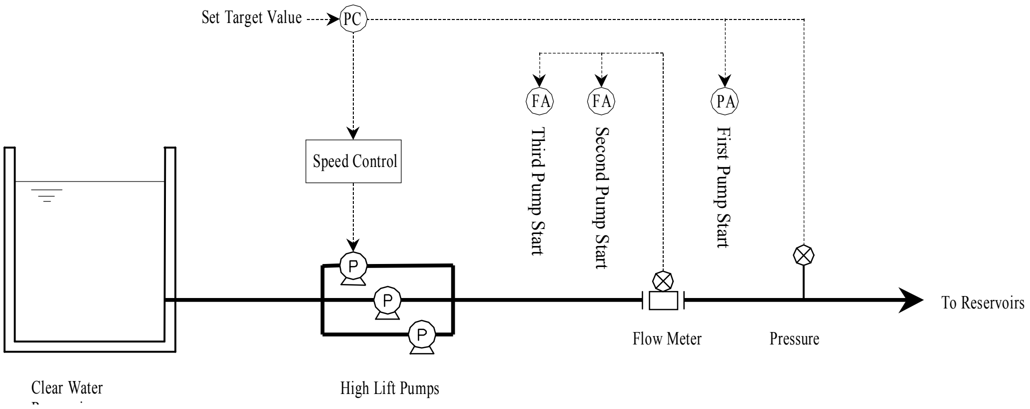


Figure 10.6 Transmission Pump Operation

10.8 Telecommunication System

10.8.1 Intake and Water Treatment Plant

The system should be geared for 24 hours extensive monitoring from the central monitoring room of the administration building in the water treatment plant. The communication between intake and water treatment plant is by a telecom dedicated line as shown in Figure 10.7.

The contents of monitoring are operation conditions, alarms, flows, etc. It is possible to monitor all of intake facilities and to set the target value of the intake flow arte from the central monitoring room in the water treatment plant

10.9 Lighting Installations

Internal lighting installations generally comprise of fluorescent fittings with diffusers providing water and dust protection to IP65, and metal halide high bay lamps. Emergency lighting is also provided in all buildings and structures, as required.

Where applicable, lighting fixtures should be suitable for use in hazardous areas, depending on the hazard level prevailing.

External lighting installations comprise of 8 metres galvanized steel columns with high-pressure mercury vapour lamps. However, flanged based columns are provided for ease of installation and maintenance.

Illumination levels are in accordance with the CIBSE codes for internal, external and emergency lighting.

10.10 General Power Outlets

General-purpose 13-amp socket outlets will be provided within the new buildings, process structures and at strategic locations outdoors for small power tools, hand lamps, etc. These units are protected against water and dust to IP65 and are suitable for installation in hazardous area, where applicable. In addition 32-amp, 3-phase outlets are provided as required. These are protected by MCB’s and RCD’s

10.11 Communications

A PABX is installed in the administration building to accomplish the entire treatment plant communication system. This exchange would take up to 10 telecom lines.

10.12 Fire Fighting System

Portable fire extinguishes are provided in the administration building and treatment plant areas, at strategic locations, as required.

10.13 Lightning Protection

Lightning protection and earthing systems will be provided as required for the buildings and structures as per BS. 6651: 1985.

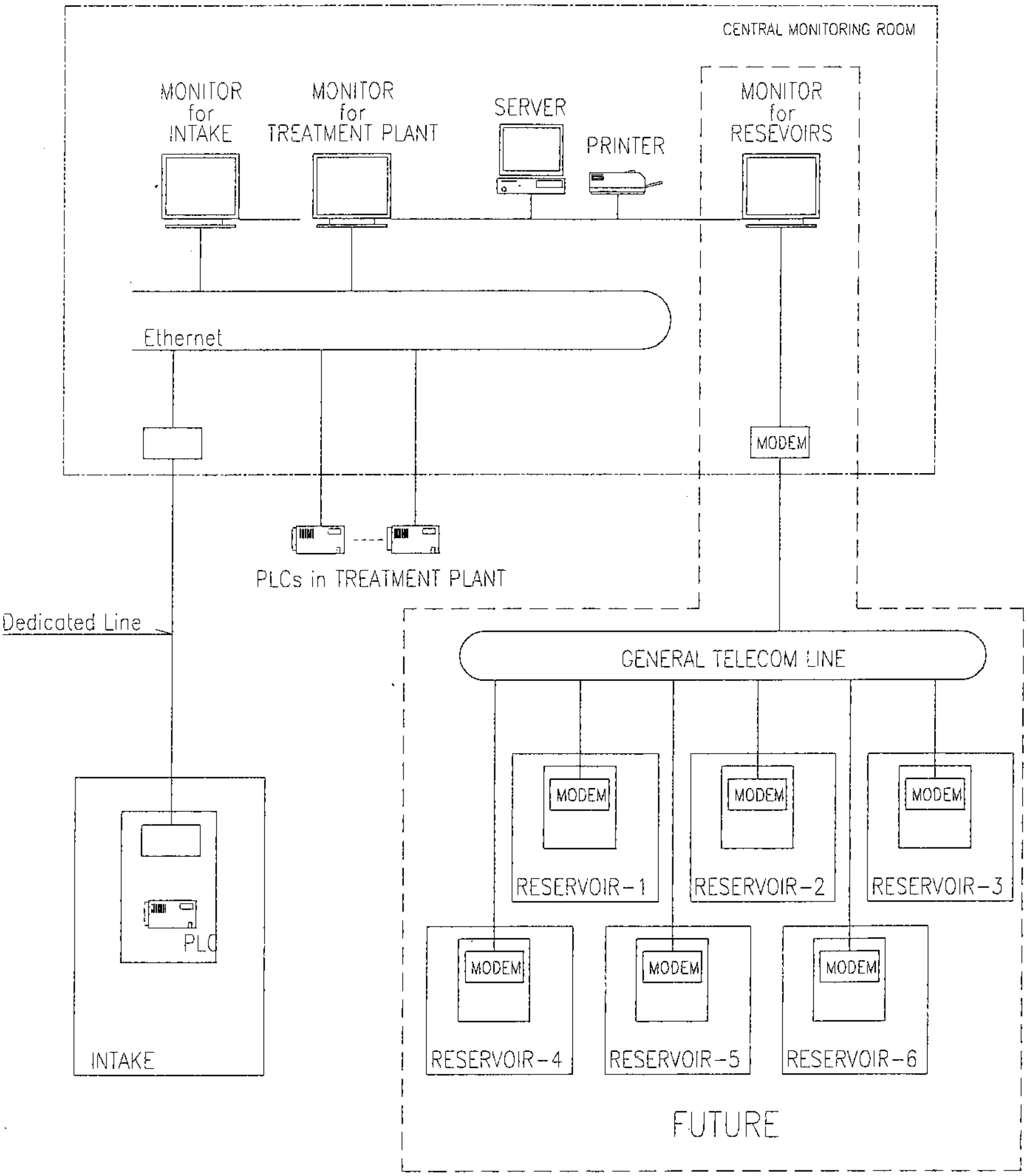


Figure 10.7
Telecommunication System

CHAPTER 11
STATEMENT OF CONSTRUCTION METHOD

CHAPTER 11 STATEMENT OF CONSTRUCTION METHOD

11.1 General

The construction methods for the Works are analysed based on the site investigation including topographic survey, level survey, soil investigation, and test excavation along the designated pipelines.

During the construction of the Works, the Contractor shall ensure that none of his activities shall cause undue hindrance to others/public in the performance of their duties. At least one lane of traffic shall be maintained over entire length of the main roads through the construction area and access shall be maintained at all times to properties adjacent to the construction areas. In case of unavoidable inconvenience area like A9 road, night work should be considered.

All utility services shall be protected and maintained to consumers during the execution of the Works. The Contractor is responsible for maintaining temporary water supplies to consumers in the case of continuation of the Contractor's work beyond the allowed shut down period.

The Contractor is expected to provide temporary site offices for his own requirements and for the Engineer. The offices should be located in the northern part, central part, and southern part of the Project area to facilitate the works divided into three zones. In each zone, the Contractor may proceed the construction works simultaneously. Those will be located near the Kahawatta Service Reservoir site, in the premises of proposed Katugastota WTP site, proposed Gohagoda Intake site, and near the Asgiriya Service Reservoir site, respectively.

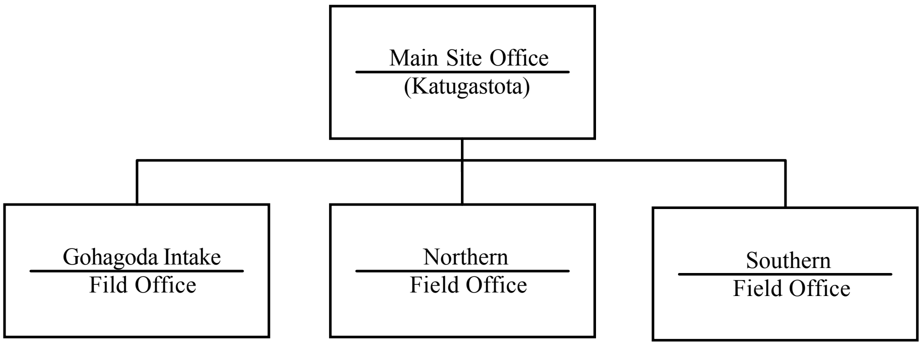


Figure 11.1 Set Up Of Site Offices

The Katugastota site office will be used as the main site office of the Engineer and ranked as a representative of project implementation for the Contractor, Consultants, and Engineer in addition to the supervision of the construction works for the treatment plant. The other field offices will control the local construction works for the Gohagoda intake facilities, northern transmission, service reservoir, and distribution facilities, and southern transmission, service reservoir, and distribution facilities, respectively.

11.2 Intake Facilities and Raw Water Conveyance Facilities

The Gohagoda field office will control the construction works for the intake and balancing tank facilities. The construction works would include removal of garbage on the route of access road to the Gohagoda intake pump station and rock excavation. A temporary road will be required to maintain the daily activities of residents around the site. The Contractor is recommended to provide a temporary filed office as mentioned in the previous section to supervise the following sophisticated construction works effectively in close collaboration with the construction works being proceeded at the Katugastota WTP site. A tentative construction schedule is referred to *Appendix 4*.

(1) General

- Construct access road to the site
- Provide temporary fencing
- Clear site and provide site office, stores, workshop, and parking area for vehicles, plant and equipment
- Establish water, electricity and telephone services
- Divert waterways as required
- Remove the garbage from the route of access road

(2) Raw Water Intake/Balancing Tank

- Place coffer dam at the construction area within the Mahaweli river
- Provide dewatering and excavate rock and soil to the required formation level
- Cast the concrete structure with openings left for pipe works, penstocks etc. (no pile works are expected.)
- Install pipes, gates, screens, valves, penstocks, ladders, pumps and other M & E works.
- Construct storm water drain channel
- Test for water tightness and repair if there are leakages.
- Remove coffer dam
- Remove surplus earth, debris etc. and dispose of at an approved location
- Test run the plant
- Provide landscaping
- Commission the plant.

11.3 Water Treatment Plant

The central site office will control the construction works in the plant site. A peculiar construction work is a large scale borrow fill of more than 50,000 m^3 at the proposed Katugastota water treatment plant site. Diversion of the existing stream flowing from southern area to the Mahaweli River is required to secure the proposed plant area. A good relation to the nearby residents and temple located in the premises of the site is vital so much so that temporary roads should be provided to maintain the daily activities of residents around the site.

(1) General

- Provide temporary access road to the site by cutting and/or filling with imported earth
- Provide the residents with casual roads with imported earth or gravel
- Clear site where necessary

- Execute earthwork for the internal roads
- Divert waterways as required.
- Provide temporary fencing
- Establish site office, toilets, stock piling area, workshops, and parking area for vehicles, plant and equipment.
- Provide water, electricity and telephone services to the site
- Protect properties of the temple

(2) Distribution Chamber/Flocculation Basin/Sedimentation Basin/Filtration Unit/Clear Water Reservoir/Transmission Pump Station/Administration Building/Chemical Building

The base rock for support the structures are located 3 to 5 m below of the planned base slabs level so that piling into the bedrock is must.

- Remove top soil and fill approximately 3 to 5 m and compact site to the base level
- Set out the structure
- Drive bored/in-situ R.C piles socketed into the bedrock (piles for filter units for future extension will be included)
- Build the structure leaving openings for pipeworks, valves, penstocks, gates, screens etc.
- Install pipeworks, valves, penstocks, instrumentation, electrical wiring and other mechanical/electrical works.
- Test the structure for water tightness and repair if there are leakages.
- Provide landscaping
- Disinfect and test run the structure
- Commission the structure.

(3) Clear Water Reservoir, Clear Water Pumping Station, Backwash Recovery Facility, and Maintenance Building

The area for these structures is expected to be of sufficient bearing capacity. The designed foundation is there a raft foundation.

- Remove top soil and level site as required
- Sheet pile, if any, and excavate to the formation level of the structure
- Arrange for dewatering system, if any
- Build the concrete structure providing openings for pipe installations.
- Install pipeworks, valves, pumps, instrumentation, electrical wiring and other mechanical and electrical works.
- Test the structure for water tightness and repair if there are any leakages.
- Provide landscaping
- Disinfect and test run the structure
- Commission the structure

(4) Sludge Lagoons

The foundation will be placed at a level of approximately 438 m, 3 m below the basement of the banks.

- Remove top soil and level site as required
- Sheet pile each lagoon area, if necessary
- Excavate to the foundation level

- Drive precast R.C piles
- Excavate the bottom 1 - 2 m below the foundation level
- Install dewatering
- Improve the ground by filling with moist compacted sand up to foundation level.
- Cast the pile cap.
- Fill and compact the interspace in between the lagoons to the shape in stages up to the top level..
- Rubble pack the walls
- Remove the sheet piles, if any, tidy up the site and landscape
- Commission the lagoons

(5) Landscaping

- Relocate the existing stream
- Construct access bridges and roads
- Complete all structures and pipe works
- Tidy up the site
- Landscape

11.4 Transmission Facilities

Transmission pipeline comprises the laying of ductile iron pipes of diameter varying from 150 mm to 800 mm for a length of approximately 38,700 m and uPVC pipes ranging from 90 mm to 225 mm diameter for a length of about 2,900 m from the proposed Katugastota WTP and existing KMC WTP at Getambe to the Service Reservoirs. Approximately 19 km, 11 km, and 11 km of transmission pipelines are shared by northern, central (main), and southern site offices, respectively as show in a tentative construction schedule, Appendix 4. The pipeline would be laid mostly along the main roads under the jurisdiction of the RDA, PRDA and Pradeshiya-Sabha.

Respective road authorities will carry out the permanent reinstatement of the roads and necessary payment shall be made for them from the project fund. However, the contractor will be required to effect temporary road reinstatement immediately after the completion of that part of work. Cost estimates submitted by these authorities for reinstatement of the roads have been included in the BOQ.

Permanent reinstatement of the recently resurfaced A9 road has to be done by the Contractor to the full satisfaction of RDA and the supervising Engineer

The detailed activities to be performed for the construction of the major transmission facilities are presented below in the sequential order.

(1) Transmission Pipes

- Obtain road authority approval for trenching and culvert/ bridge crossings
- Obtain police approval for the commencement of work and traffic control arrangements.
- Notify respective local authority, public and private transport companies etc.

- Inform public utility agencies (e.g. NWSDB, Telecom, CEB), and obtain their services to identify the locations of their underground utilities, and to assign their staff to stay with the contractor in critical areas of likely damage. Furthermore, these authorities should be kept informed to attend to any damage to the services promptly
- Notify residents/general public/traffic about the impending work and the likely inconveniences that may cause to them during the construction period by paper advertisements, electronic media, public address system and by hand bills.
- Study the road safety requirements and procure all necessary sign boards and other implements to comply with the requirements laid down by the Police.
- Investigate and decide locations where machine excavation, manual excavation, rock excavation, shoring, sheet piling, dewatering etc, will be required. The type of excavators, the suitability of excavated earth for backfilling or not etc., also could be ratified.
- Decide on the most appropriate dewatering system (e.g. well point system, sump method, direct dewatering)
- Study areas where any existing structures/properties are likely to be damaged and decide suitable methods to avoid such damages (e.g. by changing the construction method)
- Study areas where any temporary relocation of people living around is needed and take necessary measures in this regard.
- Investigate on the need to divert/relocate existing services to facilitate the pipe laying and arrange for such diversions/relocations with the respective agencies.
- Arrange a suitable borrow pit in a nearby convenient area to procure imported earth if necessary.
- Arrange a stockpiling area for bulk storage of river sand, borrow earth, bedding materials, road reinstatement materials etc., These materials should be protected from rain by covering with polythene sheets/ tarpaulins or by other approved methods.
- Arrange a tipping area for disposing of surplus/unsuitable excavated earth, excavated road materials, and debris.
- Establish site offices (mobile or otherwise) complete with water, electricity, telephone and toilet facilities.
- Carry out trial holing to identify the configuration of the existing underground utilities and to decide on the most suitable route for the pipe laying causing minimum damage/disturbance to these services.
- Barricade the site and mobilize pipe laying crews and machinery
- Barricade the sites and mobilize chamber construction/manhole construction/bridge crossing/culvert crossing crews.
- Pipe laying to be followed by earth compaction tests.
- Carry out temporary reinstatement of the road along with the progress of pipe laying bu the Contractor.
- Dispose of all surplus/unsuitable excavated earth and other debris.
- Install different types of valves.
- Flush and pressure test the main in sections and repair any leakages.
- Disinfect the main
- Carry out pressure test over the whole section in one operation
- Carry out permanent reinstatement of the road by the Contractor or respective road authorities
- Tidy up the site

(2) Water Pipe Bridge

- Inform Mahaweli Authority about the commencement of this work

- Provide temporary access road and working area for the machines (cranes, pile driving rig, concrete truck mixers, pump cars, trucks) on either side of the riverbanks by filling with imported earth.
- Provide fencing
- Set out the bridge and provide coffer damming for the pier foundations
- Drive bored piles for the end pier foundations socketed into the bedrock.
- Excavate to the bedrock for the centre pier with dewatering arrangement
- Cast the foundation of the centre pier socketed into the bedrock and continue to the top
- Backfill the foundation excavation with rock fill.
- Cast the pile caps to the two end piers and continue to the top.
- Transport and install the prefabricated bridge on the piers, by the cranes.
- Provide backfilling where necessary
- Provide painting of the bridge against corrosion (if not done before)
- Install the water main.
- Remove the sheet piles/coffer damming and tidy up the site and remove site office
- Restore the original waterway of the river.

11.5 Service Reservoirs

A total of 19 SRs will be constructed under Phase 1 within the service area. 15 SRs are of ground reservoirs and 4 SRS are of elevated type.

(1) Ground Service Reservoirs

The detailed major activities to be performed for the construction of the ground level service reservoirs are presented below in the sequential order. Gohagoda and Mullepihilla SRs will be of pile foundations.

- Construct temporary access roads, if not available at present
- Clear site
- Establish site offices stores, yards and provide fencing
- Provide water, electricity telecom and toilet facilities
- Carry out earthworks for site leveling and foundations to the specified levels.
- Drive bored/in-situ R.C piles socketed into the bedrock (piles for filter units for future extension will be included), if any
- Build the structures leaving openings for pipeworks, manholes, valves etc.
- Install pipeworks, manholes, valves and all other M & E works
- Test the structures for water tightness, where applicable
- Disinfect and test run
- Tidy up the site
- Provide landscaping
- Commission when all the other requirements are complied with.

(2) Elevated Service Reservoirs

Elevated type service reservoirs are proposed at Kahawatte, Thelambugahawatte, Kahalla and Bahirawakanda under Phase 1 of the Project. Rock excavation is expected at the Thelambugahawatte site. Bahirawakande and Asgiriya SRs are of pile foundations. The detailed major activities to be performed for the construction of the elevated level service reservoirs are presented below in the sequential order.

- Excavate for foundations
- Drive bored/in-situ R.C piles socketed into the bedrock (piles for filter units for future extension will be included), if any
- Construct the circular foundation and ring beam with reinforcement starter bars for ring wall
- Construct the ring wall
- Erect a temporary platform to support the formwork for the tank
- Form and place concrete for the tank base dome and conical section
- Form and place concrete for the tank base beam, tank wall and the beam at the top
- Construct the piping gallery within the tank area
- Form and concrete the top dome
- Construct platforms and stairs inside the tower
- Install tower piping and connect to yard piping
- Clean the tank
- Fill the tank with clean water and test for leakage
- Disinfect the reservoir
- Connect the old tank if appropriate
- Connect outlet to distribution system

11.6 Distribution Pipes

Distribution Facilities comprises the laying of ductile iron pipes of diameter varying from 100 mm to 500 mm for a length of approximately 6,000 m and uPVC pipes ranging from 90 mm to 225 mm diameter for a length of about 21,700 m from the Service Reservoirs to respective supply area. Pipeline would be laid mostly along the main roads under the jurisdiction of the RDA, Provincial RA and Pradeshiya-Sabha. Distribution Facilities have been subdivided into two main components namely Service Reservoirs and Pump Houses, and Distribution Pipelines.

The procedure will be similar to the transmission system but will be less rigorous at many locations as the roads are local roads with less traffic, except for the Asgiriya main. However, as these are narrow roads it will not be possible to provide one lane traffic wherever possible traffic diversions/re-routings may be required.

Distribution pipelines need to be connected to the existing distribution network in the service area in order to integrate the existing facilities to the new system. Permission from relevant authorities including NWSDB shall be obtained prior to these connections and perform with minimum interruption of services to the consumers. This operation shall be planned with the consent of the operators of different water supply authorities and by notifying the affected consumers. Connection to existing system shall be done with special care by closing a section of the service area at a time.

CHAPTER 12
CONTRACT PACKAGE AND PROCUREMENT PROCEDURE

CHAPTER 12 CONTRACT PACKAGE AND PROCUREMENT PROCEDURE

12.1 General

Since none of these facilities can be put into operation by itself or ahead of the other connected structures, the responsibility to complete on schedule should remain with a single contract.

Likewise, the raw water intake, water treatment plant and the service reservoirs are similar in materials and construction methods and because they are within the Greater Kandy area each other, they should be considered to be constructed under one construction package by a single contractor.

A savings in materials and supplies would also occur as, for instance, the pumps could all be procured from a single supplier. This, of course, would also reduce operation and maintenance costs and allow flexibility in allocation of spare parts for repairs. In addition, overhead and conflicting work related problems would be reduced to a minimum. Also, one contract would remove co-ordination problems caused by separate civil and M&E contracts. Such co-ordination under separate contracts is the responsibility of the Employer and could result in claims from contractors on the Employer if there are delays by the other contractors.

For these reasons, it was recommended that the raw water intake, water treatment plant and the service reservoirs be incorporated into one construction package for construction by a single contractor under financed by so called Special Yen Loan through JBIC. The clean water transmission mains comprises large diameter ductile iron pipelines and are part of the same overall water delivery system and must be completed during the same time frame.

However, RDA schedules to renovate the Wattegama Road up to September 2004 under financed by ADB, along which part of the transmission main with diameters of 300 and 600 mm is to be laid. RDA has planned to rehabilitate shortly and advised the NWSDB that this pipeline should be laid before their rehabilitation.

Approximately 6 km stretch of the pipeline should therefore be installed in close coordination with RDA project in a separate package.

12.2 Package 1: Construction Work for Greater Kandy Water Supply Augmentation Project

Contract GK/JBIC/04 includes sophisticated civil and electrical/mechanical works for:

- the intake pump station, electrical building, and balancing tank structures, screens, pumps, inlet gates, piping, cranes, electrical equipment and instrumentation. Excavation in rock, water and soil are required as well as a temporary coffer-dam, reinforcement, capacity of 115,500 m^3/d and equipment will be installed for the first phase capacity of 38,500 m^3/d;

- the treatment plant has an initial production capacity of 36,670 m^3/d and is designed to be extended to 110,000 m^3/d. The work includes construction of the distribution chamber, flocculation basins, sedimentation basins, filtration units, clear water reservoir, clear water transmission pump station, chemical building, backwash water recovery facilities, sludge lagoons, electrical substation and generator building, administration building, maintenance building, paving, yard piping for water treatment facilties and all ancillary works;
- the transmission and distribution systems includes construction of the service reservoirs, excavation, concrete, reinforcement, formwork, backfill, compaction, inlet and outlet piping, overflow, drain piping, and ancillary works;
- procurement of maintenance equipment; and
- testing, commissioning and training of NWSDB personnel for the works under the Contract.

12.3 Package 2: Construction Work for Water Transmission Main Along Wattegama Road

Due to the request of RDA, NWSDB decided to separate the construction works for transmission main along the Wattegama Road from the above main contract to be awarded under this Project by early year 2003 and carried out the tender for “Supply and Delivery of DI Pipes, Fittings, Specials, and Accessories for Laying Along Katugastota-Wattegama Road, CONTRACT No.: P&D/GK/JBIC/2001/01 in applying the Project budget in November 2001.

The tender includes mainly 600 mm and 300 mm DI push-on type pipes and its fittings with a total length of approximately 6 km. The evaluation of tender is underway to appoint a Japanese contractor.

NWSDB holds consultations on the pipe laying work with RDA to implement the work as a part of the following main package. Nevertheless no agreement is reached yet due to constraints of process of regulations.

Available options for solution of the pipe laying work are as follows:

i) NWSDB will prepare counterpart fund and will negotiate with RDA as a variation order at an agreed price for the laying work to the RDA project’s contractor to be awarded,
ii) NWSDB will contract with a Japanese contractor to make use of the part of Special Yen Loan, and
iii) NWSDB will include the laying works into the main package in case of the RDA project be delayed.

Most possible option is considered to be item i) in view of technical and financial aspect if NWSDB will be able to set up the required budget approximately 30 million rupees.

RDA also enforced certain design changes whereby the proposed pipeline route had to be rerouted along the old abandoned road in certain sections.

CHAPTER 13
MATERIAL AND EQUIPMENT PROCUREMENT PLAN

CHAPTER 13 MATERIAL AND EQUIPMENT PROCUREMENT PLAN

13.1 Conditions of Special Yen Loan

The conditions governing the procurement of material and equipment have been stipulated in the document under the title "Loan Agreement for Greater Kandy Water Supply Project – Loan Agreement No. SL-P71 dated March, 2001" prepared by GOSL. These conditions have further been highlighted in the prepared Prequalification Document for Construction of Gohagoda Intake Pump Station, Katugastota Water Treatment Plant, Service Reservoirs and Pipelines (Contract GK/JBIC/ 04) dated January 2002. Particulars is summarised as shown hereunder.

Prime contractor, Section 2 (1), Schedule 4, Procurement Procedure:
The Prime Contractors shall be nationals of Japan, or juridical persons incorporated and registered in Japan, and which have their appropriate facilities for producing or providing the goods and services in Japan, and actually conduct their business there.

Sub-contractor, Section 2 (2), Schedule 4, Procurement Procedure:
The Sub-contractors shall be (i) nationals of Japan, or juridical persons incorporated and registered in Japan, and which have their appropriate facilities for producing or providing the goods and services in Japan, and actually conduct their business there, or (ii) nationals of the Democratic Socialist Republic of Sri Lanka, or juridical persons incorporated and registered in the Democratic Socialist Republic of Sri Lanka, and which have their appropriate facilities for producing or providing the goods and services in the Democratic Socialist Republic of Sri Lanka, and actually conduct their business there.

Eligibility of services and goods, Section 2 (3), Schedule 4, Procurement Procedure:
Not less than 50 percent of the total costs of goods and services to be financed under this contract shall be procured in Japan. The goods and services procured from the eligible manufacturing company(ies) (hereinafter referred to as "the Eligible Local Manufacturing Company(ies)") invested by Japanese manufacturing companies can be regarded and counted as Japanese origin if such Eligible Local Manufacturing Company(ies) satisfy(ies) the following conditions:

- juridical persons incorporated and registered in the Democratic Socialist Republic of Sri Lanka, and which have their appropriate facilities for producing or providing the goods and services in the Democratic Socialist Republic of Sri Lanka, and actually conduct their business there;
- not less than 10 percent of shares are held by a single Japanese manufacturing company; and

- the proportion of shares held by any single company of the third country(ies), other than Japan or the Democratic Socialist Republic of Sri Lanka, is not more than that held by any Japanese manufacturing companies.

13.2 Origin of Material and Equipment

Based on the design principles adopted in this detailed design, indigenous materials and products that are easy and safe for use in construction are used to reduce costs, and to bolster the local economy and expand industrial development.

Likewise, to comply with the requirements for the procurement procedure as mentioned in the previous section, only equipment that greatly improve the reliability assuring safe and stable water supply would be imported from out of the country.

The methods of procurement of materials necessary for the Project was studied by the Study Team by comparing Sri Lankan, Japanese, and other countries' procurement methods as mentioned hereunder. The summary of procurement plan is presented in Table 13.1 and considered as a condition of const estimate and evaluation of eligibility of procurement. However, this plan does not restrain the Contractor from their procurement schedule if he satisfies the conditions of procurement procedure of the Special Yen Loan.

Table 13.1 Material Procurement Plan (sample)

Item		Procure in Sri Lanka	Procure in Japan	Procured in the Third Countries
Procure in Sri Lanka				
1)	Cement	x		
2)	Reinforcing bar	x	x*	
3)	Aggregate and bricks	x		
4)	Plywood forms	x		
5)	Architectural materials	x		
6)	uPVC pipe	x		
7)	Construction machine	x		
8)	Construction tool	x		
9)	Laboratory equipment	x		
10)	Truck with crane	x		
11)	Filter sand	x		
Procure from Japan or the third countries				
1)	Pump		x	x
2)	Ductile iron pipe		x	x
3)	Valve		x	x
4)	Water Treatment Facilities/equipment		x	x
5)	Electrical equipment		x	x
6)	Instrument		x	x
7)	Special maintenance tools		x	x

Note: * refer to the item (2) of the following section 13.2.1.

13.2.1 Locally Procured Items

(1) Cement

Several cement manufacturers are available in Sri Lanka. The price is lower than importing from the other countries. Therefore, Sri Lankan made cement is recommendable. Some imported admixtures are locally available, if necessary.

(2) Reinforcing Bar

Reinforcing bar, which conforms to worldwide standard are locally available at reasonable prices. Therefore, reinforcing bar made in Sri Lanka is recommendable.

Due to the devaluation of Japanese Yen currency recently, there is a possibility of importing Japanese products which is now competitive in price comparing with the neighbouring countries of Sri Lanka.

(3) Aggregate and Bricks

Aggregate and bricks are locally available abundantly in Greater Kandy area. Their quality is generally good and available at reasonable prices. Aggregate and bricks made in Sri Lanka will be adopted.

(4) Plywood Forms

For this Project, plywood forms will be used for the concrete structures accommodating intake pump station, water treatment plant, booster pump stations, service reservoirs, etc. Supply of plywood in the local market is stable. Therefore, plywood processed locally will be used.

(5) Architectural Materials

Such architectural materials as doors, tiles, roof covering materials, and wall/floor/ceiling finish are locally available in reasonable prices. Supply of those materials in the local market is quite stable. Therefore, architectural materials shall be locally procured.

(6) Unplasticized Polyvinyl Chloride (uPVC) Pipe

uPVC pipes are manufactured in Sri Lanka. The specifications are standardised under the Sri Lankan Industrial Standards stipulated by the Sri Lankan Standard Institution so that the quality is acceptable for the Project. Its availability in adequate quantity is nowadays stable in the market, which is widely proved in the other projects. Therefore, uPVC pipes made locally shall be adopted.

(7) Construction Machines

Construction machines, such as concrete mixers, cranes, trucks etc. are available in the local lease market and their quality is judged to be in good condition. Therefore, construction machines shall be supplied from the local market.

(8) Construction Tools

The construction tools, such as transformers, welding machines, water pumps etc. in the local lease market are not reliable. Tools shall be supplied from Japan or other counties.

(9) Laboratory Equipment

Laboratory equipment to be used in the Project is the standard ones. They are available locally through local agents who provide spare parts too, as necessary. Therefore, these equipments are to be purchased in Sri Lanka.

(10) Truck with Crane:

There are no manufacturers of truck with crane in Sri Lanka. Therefore, those made in Japan or other countries shall be adopted.

(11) Filter Sand

Good quality filter sand is available locally in Greater Kandy area. The price of sand is reasonable. Therefore, the local product of filter sand shall be adopted.

13.2.2 Locally Procured But Regarded as Japan Origin

A cement manufacturer in Trincomalee is regarded as the Eligible Local Manufacturing Company, in accordance with Section 2 (4), a, b, and c of Schedule 4; Procurement Procedure. A Japanese company holds 27.5 percent of shares, which is more than 10 percent by a single Japanese company, and the proportion of shares are not exceeded by the third countries' companies.

Therefore, cement may be counted as Japanese Product in the cost estimates.

13.2.3 Procured from Japan

To comply and make use of the system of Special Yen Loan, as per Section 2.3, Schedule 4, Procurement Procedure, which provides not less than 50 percent of the total costs and services to be financed under the Contract from Japan, pumps, DI pipes, and important electrical goods are recommended to be procured from Japan.

(1) Pumps

Intake, transmission, and booster pumps serve as the heart of the water supply system in the Project to ensure safe and stable water supply. To maximise the benefits of the conditions of "Special Yen Loan" the major pumps shall be imported from Japan. Those pumps are proven to be a good performance in the existing pumping station at the Ambatale, etc.

Small sized or general purpose type of pumps are available in Sri Lanka and such minor pumps to be used in the Project may be purchased locally.

(2) Ductile Iron (DI) Pipes

Since the time pipe borne water supply system was introduced in Sri Lanka, DI or Cast Iron pipes have been imported and extensively used for various Projects. One major country from where NWSDB imported is Japan. Therefore, DI pipes manufactured in Japan shall be adopted for this Special Yen Loan Project.

(3) Valves

The valves, most of which are imported are locally available. However, the specifications are limited and some specifications required for the Project are not available. Therefore, the valves made in Japan or other counties shall be adopted.

13.2.4 Imported from the Third Countries

(1) Water Treatment Facility/Equipment

The water treatment facilities/equipment to be used for the Project are very special and must be manufactured according to the shop drawings. There are no locally manufactured water treatment facilities available. Therefore, facilities/equipment made in Japan or other countries shall be adopted.

(2) Instrumentation

Most parts of the instrumentation are imported and have different standards. The availability is very limited in the market due to low production rate. Therefore, instruments made in Japan or other countries shall be adopted.

(3) Electrical Equipment

The electrical equipment to be used for the Project is very special and must be manufactured according to the shop drawings. Therefore, the locally available ones cannot be used so that imported materials shall be used for the Project.

(4) Special Maintenance Tools/Equipment

Special maintenance tools for the facilities/equipments to be purchased in Japan or other counties are not available in Sri Lanka. Some of these are custom-made items manufactured in accordance with the main body of facilities/equipments. Therefore, those made in Japan or other countries shall be adopted.

CHAPTER 14
OPERATION AND MAINTENANCE PROGRAMME

CHAPTER 14 OPERATION AND MAINTENANCE PROGRAMME

14.1 General

The water supply facilities/equipment should always be kept in such good condition through proper operation and maintenance to maximise the functions of the equipment, extend its useful life and save on costly repairs in the future. Namely, objective of a regular operation and maintenance program is that it provides the people in the service area with an uninterrupted, equitably distributed, and adequate amount of safe water supply with a reasonable burden on the people.

Any omission or negligence of such proper operation and maintenance may lead to the unexpected damage to not only to the consumers; but also to the water supply facilities where repairs take more time and money.

The major issues of the operations and maintenance areas are centred in and around the maintenance of facilities and equipment, and logistics of maintenance resources such as materials, spare parts, tools and equipment. This is due to a lack of planning and coordination among operations, maintenance, material control, and procurement activities. In spite of the fact that those activities are closely related, they are performed by different offices and departments and each operating unit is functioning independently from the others, thus resulting in inefficient repair and maintenance work.

Another critical issue for operations and maintenance is budget constraints despite of proper operation and maintenance. Due to the fact that the budget for O&M is limited, necessary maintenance resources are always in short supply and repair and maintenance work are not performed on time and at the optimum level of work quality, which may bring about vicious circle of lack of maintenance and improper operation.

14.2 Work Programme for Operation and Maintenance

The maintenance of each facility and equipment is composed mainly of patrol/inspection, operation and maintenance. Patrol/inspection should be done regularly, to check the normal function, working condition, etc., of each facility and equipment. Any feedback should be relayed so that maintenance work can be made to restore the normal function of each facility and equipment through cleaning, overhaul, and other preventive measures. Patrol has a shorter interval than inspection.

The relation of the operation and maintenance is shown in Figure 14.1. To get the full result out of maintenance works, procedures and methods for regular maintenance works should be standardised and systematised as shown hereunder for effectiveness and efficiency in the production of the required quality and quantity of water along with each process of intake, water treatment, clear water transmission and distribution.

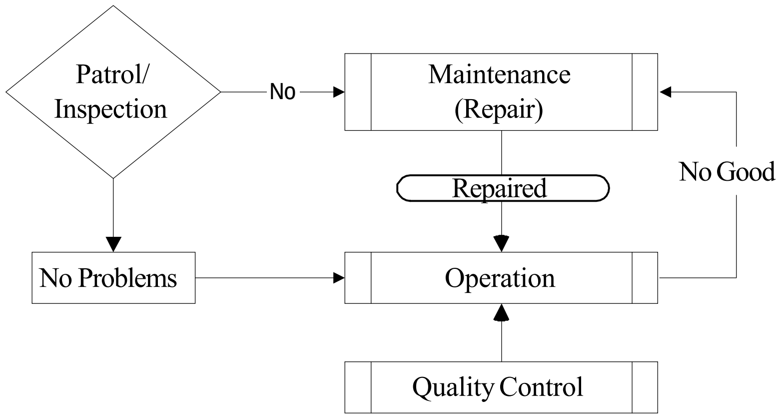


Figure 14.1 Process of Operation and Maintenance

A typical operation and maintenance programme for the proposed intake and water treatment plant is listed in Table 14.1, Table 14.2, and Table 14.3.

(1) Daily patrol/Regular Inspection

Measurements of intake and treated water quantities, as well as water levels at reservoirs, are the principal activities in order to supply water to meet demand fluctuations.

To ensure that the required quality of water is produced and efficient operation of the treatment facilities, inspection of: operation conditions at intake pump station, water treatment units and clear water transmission pump station; removal of sludge in sedimentation tanks and transfer it to the sludge lagoons; as well as water quality examination at predetermined steps of water treatment are activities to be performed daily.

The inspection of operating conditions of mechanical/electrical facilities is, as a matter of course, important to determine any defects and to take immediate countermeasures to rectify such. Likewise, transmission/distribution pipelines and civil structures should be inspected at longer intervals than mechanical/electrical facilities.

(2) Maintenance Work

O&M items mainly focus on removal/disposal of accumulated sludge and grit and more detailed examination and overhaul of mechanical/electrical facilities. Grit stored in grit chambers and accumulated sludge in sludge lagoons will be disposed of to landfill on a regular basis commensurate with accumulation. Chemical feed pipelines should be flushed regularly to avoid clogging of impurities in the chemicals and retain the designed hydraulic performance.

Table 14.1 Operation and Maintenance Programme (1/3)

Facilities	Daily Pattrol		Regular Inspection		Maintenance Work	
	Frequency	Contents to be Checked	Frequency	Contents to be Checked	Frequency	Contents to be Checked
1 Gohagoda Intake						
1-1 Intake channel/sump	once ditto ditto 3 times	a raw water quality appearance b inflow water level c condition of intake channel including equipment (gates, coarse screens, fine screens) d flow of raw water (flow meter)	3 months 1 year ditto	a leakage and moving condition of gates b working conditions of screens c concrete cracking, aging and leakage	as required everyday 3-6 months 1 year 3 years	a lubrication of gates and screens b removal of screenings c removal of grit d cleaning of intake mouth e painting of gates, screens, steel parts
1-2 Intake pumps	ditto	a condition of pumps (current, pressure, abnormal noise vibration, oil volume and leakage) b opening of valves c temperature of bearing d leakage from grand packing	1 year ditto ditto ditto ditto	a condition of gland packing b condition of lubrication c condition of pressure gauge d condition of level meter e condition of flow meter	1 year 1 year 1-5 years ditto 3 years	a adjustment of gland packing b colibration of flow meter c overhaul of bearing d overhaul of coupling e painting of steel parts
1-3 Gantry crane	once	a condition of crane	1 year	a condition of gears	5-10 years	a overhale of gears
1-4 Generator	once ditto	a fuel b condition of engine	3 months	a consume of oil	1-5 years	a overall generators/engine
2 Balancing Tank	once ditto	a water level b condition of valves	4 months 1 year	a working conditions of valves b concrete cracking, aging and leakage	1 year 3 years	a cleaning of overflow channel b lubrication of valves
3 Raw Water Conveyance Pipe/Balancing Tank	once	a condition of air-vent valves b flow of raw water at balancing tank	3 months 1 year	a leakage and moving condition of valves b concrete cracking, aging and leakage	3 years	a lubrication of valves b cleaning of dust of air vent valves
4 Water Treatment Facilities						
4-1 Receiving Well/ Distribution chamber	3 times ditto ditto	a flow of raw water b water level c raw water quality (Tu, pH, Alkalinity, etc)	1 year ditto ditto	a concrete crack, aging and leakage b moving condition of valves c concrete cracking, aging and leakage	3-6 months 3 years	a cleaning of wells b plinting of steel parts (pipes)
4-2 Rapid Mixing Tank	3 times ditto ditto ditto	a flow of raw water b water level c chemical piping and dosage (jar test) d mixing condition of chemicals	3 months 1 year	a working condition of chemical feed valves b concrete crack, aging and leakage	3-6 months 3 years as required	a cleaning of mixing tanks b painting of steel parts c replacement of chemical feed pipes
4-3 Flocculation Tank	3 times ditto	a water level b growth condition of floc	1 year	a concrete crack, aging and leakage	3-6 months	a cleaning of flocculation tanks
4-4 Sedimentation Tank	3 times ditto ditto ditto ditto ditto	a water level (detention time) b flowing condition and state of floc settling c quality of effluent (Tu, pH, Alkalinity etc) d condition of sludge valves e condition of sludge scrapers f condition of sampling pumps	1 month 1 month 2 months ditto 3 months 1 year	a working condition of sludge scrapers b working condition of sludge withdrawal valves c state of adhesive (algae, scum, etc.) d state of launders (orifice) e working condition of valves f concrete crack, aging and leakage	everyday 6 months 3-6 months 3-6 months 3 years 1-5 years	a removal of algae, scum, floating materials, etc. b grease up of spindle of sludge withdrawal valves c cleaning of sedimentation tanks d lubrication of sludge scrapers e painting of steel parts f overhaul of sampling pump
4-5 Filter Tank	3 times ditto ditto	a water level b filtration volume, filtration velocity, filtration head loss and filter run c filtered water quality (Tu, pH, Alkalinity, Residual)	2 months 1 year ditto	a state of adhesive (algae, scum etc.) on concrete walls and washing troughs b concrete cracks, aging and leakage c filter media (pollution of filter media)	6 months as required	a cleaning up of filter tanks b replenishment of filter media (at the time when the thickness of media layer is reduced by 10%)

Table 14.2 Operation and Maintenance Programme (2/3)

Facilities	Daily Pattrol		Regular Inspection		Maintenance Work	
	Frequency	Contents to be Checked	Frequency	Contents to be Checked	Frequency	Contents to be Checked
	ditto ditto monthly	Chlorine etc) d backwash volume and washing time e washing condition (carryover of filter media, trouble of washing apparatus, surface of filter media after washing) f turbidity of washed water g condition of valves (current, oil volume and leakage, vibration, valve operation system and noise)	ditto ditto	occurance of mud balls, effective particle size, filter media thickness etc) d movement of gravel layer e working condition of filtration head loss meter f condition of underdrain	1 year 3 years 5-10 years 10-15 years	c repair of control equipment and pipe insulation d painting of mechanical equipment e overhaul of motor driven valves f replacement of whole of filter media
4-6 Filter Washing Facilities	3 times	a current pressure and discharge of pumps b abnormal noise, vibration and oil leakage c temperature of bearing d leakage from gland packing e flow rate of backwash water and air	1 year ditto ditto ditto	a condition of grand packing b conditionof lubrication c condition of pressure gauge d working condition of valves	1 year 1-5 years ditto 3 years 5-10 years ditto as required	a adjustment/replacement of gland packing b overhaul of bearing c overhaul of coupling d painting of piping and steel parts e overhaul of pumps and air blowers f overhaul of motor-driven valves g fill up lubricant
4-7 Wash water Tank	as required 3 times	a water level b disinfection and pH adjustment (chlorine, lime)	monthly	a working condition of water level meter	5-10 years	a cleaning of wash water tanks
5 Chemical Building (Coagulants, pH adjustment, chlorine)	3 times ditto ditto ditto ditto ditto ditto ditto	a storage amount of chemicals b leakage of chemicals c opening of valves d storage of solution e condition of chemical feed pumps (current, pressure, abnormal noise, vibration of volume and oil leakage) f dosage and dosing rate g operation conditions h gas cylinder (leakage, pressure)	as required ditto ditto ditto ditto ditto 1 year ditto	a quality of chemicals (conc., temp.) b working condition of valves c leakage of chemicals from piping and tanks d operation conditions (temperature controller, alarm, leak test) e operation condition of crane f working conditions of weighing scale g concrete cracks, aging and leakage h condition of concrete lining	6 months as required ditto ditto 2-5 years 3 years 5-10 years	a colibration of weighing scale b lubrication of crane c cleaning up of chemical tanks and surroundings d overhaul of chlorine detector e overhaul of pumps and dust air blowers f painting of mechanical equipment g replacement of piping and valves
6 Clear Water Pump Station (Reservoir)	3 times ditto ditto ditto ditto ditto ditto	a water leval of reservoirs b condition of pumps (current, pressure, abnormal noise vibration, oilvolume and leakage) c opening of valves d temperature of bearing e leakage from grand packing f distributed water quality (Tu, pH, Alkalinity etc) g pollution control from outside (variation, manhole)	1 year ditto ditto ditto ditto ditto	a condition of gland packing b condition of lubrication c condition of pressure gauge d condition of level meter e condition of flow meter f concrete cracks, aging and leakage	1 year ditto ditto ditto 3 years 5-10 years ditto	a adjustment of gland packing b calibration of flow meter c overhaul of bearing d overhaul of coupling e painting of steel parts f overhaul of pumps g cleaning of tanks
7 Backwash Water Recovery	3 times ditto ditto ditto ditto	a water level of reservoirs b condition of pumps (current, pressure, abnormal noise, vibration, oil volume and leakage) c opening of valves d temperature of bearing e leakage from grand packing	1 year ditto ditto ditto ditto ditto	a condition of gland packing b condition of lubrication c condition of pressure gauge d condition of level meter e condition of flow meter f concrete cracks, aging and leakage	1 year ditto 1-5 years ditto 3 years 5-10 years	a adjustment of gland packing b calibration of flow meter c overhaul of bearing d overhaul of coupling e painting of steel parts d overhaul of pumps
8 Sludge Lagoons	3 lines ditto	a water level of lagoons b conditions of valves/overflow stoplogs c conditions of sludge dry	monthly	a level of sludge dried	1 year ditto ditto	a sludge removal b confirmation of sludge disposal c overhaul of valves/overflow weirs

Table 14.3 Operation and Maintenance Programme (3/3)

Facilities	Daily Pattrol		Regular Inspection		Maintenance Work	
	Frequency	Contents to be Checked	Frequency	Contents to be Checked	Frequency	Contents to be Checked
9 Transmission and Distribution Mains	daily	a leakage from pipelines	monthly	a leakage from pipe bridge	1 year	a repair of control valves/air valves
			ditto	b leakage of valves		b repair of control valves
			ditto	c leakage of air valves		
			ditto	d water quality analysis (residual chlorine)		
			1 year	e flush main		
			ditto	f patrol for unlawful occupation over the pipelines		
10 Ground Reservoirs	3 times	a water level of reservoirs	monthly	a water quality analysis (residual chlorine)	1 year	a cleaning of reservoir
	ditto	b leakage from pipes, valves, tank	ditto	b operation condition of inflow float valves	1-5 years	b overhaul of valves
	ditto	c opening of valves	ditto	c operate by-pass pipelines	ditto	c overhaul of coupling
			ditto	d working condition of valves	3 years	d painting of piping and steel parts
			1 year	e concrete cracks, aging and leakage		
11 Elevated Tanks	3 times	a Water level of reservoirs	monthly	a water quality analysis (residual chlorine)	1 year	a cleaning of reservoir
	ditto	b leakage from pipes, valves, tank	ditto	b working condition of inflow float valves	as required	b repair of chlorinator
	ditto	c opening of valves	ditto	c operate by-pass pipelines	1-5 years	c overhaul of valves
	ditto	d working conditions of chlorinator, if any	ditto	d working condition of valves	ditto	d overhaul of coupling
			1 year	e concrete cracks, aging and leakage	3 years	e painting of piping and steel parts
12 Pump Houses	3 times	a condition of pumps (current, pressure,	1 year	a condition of gland packing	1 year	a adjustment of gland packing
	ditto	abnormal noise)	ditto	b condition of lubrication	ditto	b calibration of flow meter
		b vibration, oil volume and lleakage	ditto	c condition of pressure gauge	1-5 years	c overhaul of bearing
	ditto	opening of valves	ditto	d condition of level meter	ditto	d overhaul of coupling
	ditto	c temperature of bearing	ditto	e condition of flow meter	3 years	e painting of steel parts
		d leakage from grand packing	ditto	f concrete cracks, aging and leakage	5-10 years	f overhaul of pumps
					ditto	g cleaning of tanks

Execution of maintenance guarantees the usability of equipment and facilities within or sometimes even beyond the expected life.

After expiration, however, the efficiency of equipment and facilities may decline even if they are properly maintained, some gradually while some abruptly. Any facility which has deteriorated, and whose efficient performance cannot restored by regular maintenance work, requires timely maintenance/repair after due consideration of its economical effectiveness.

The time when each facility reaches the repair limit should be ascertained through proper performance of daily and periodical checking of the facilities. A large scaled rehabilitation or renovation entails considerable expense.

(3) Water Quality Control

Quality control in the water systems aims basically to assure users of a constant supply of hygienic, safe and clean water at their service taps, free from trouble regarding the quality of water or other inconveniences.

To maintain a high level of service, the following quality measures must be implemented:

- to keep the source water as clean as possible, to effect optimal water treatment, and
- to prevent contamination of treated water as it flows through the transmission/distribution system

To achieve optimal water treatment, it is vital to analyse the quality of raw water, effluent from the coagulation/flocculation/sedimentation processes, filtered water, and chlorinated final effluent. It is also important to evaluate fully through jar tests the proper doses of coagulant or coagulant aid, as well as to assess periodically possible methods of improving the process of water treatment. A typical water quality parameters and examination frequency are listed in Table 14.1. It is recommended that NWSDB will keep its own quality test standards and quality check system, each covering the entire spectrum of tests prescribed in the National Drinking Water Standards in reference to the actual operation conditions of water supply system.

The proposed rapid sand filtration starts with coagulation, which is chemical addition process to the raw water, and is immediately followed by flocculation and sedimentation. This process entails the conditioning of the raw water such that particles contributing to turbidity can be coalesced and removed in a quiescent sedimentation basin. The success of rapid sand filtration is mostly due to the process of physical filtration.

This mode of water treatment provides excellent performance in removing suspended substances.

Coagulation, flocculation and sedimentation are greatly affected by the dosing rate of coagulant, no matter how large or small may be the dosing rate. Optimal dosing rates must be set according to the results of jar tests. The optimal dosing rate varies with the quality of raw water. Dosing rates must be adjusted when the quality of raw water changes.

Table 14.1 Typical Frequency of Water Quality Test

Parameters		Raw Water	Settled Water	Chlorinated Water	Tap Water
1	Water Temp.	A	A	A	B
2	Turbidity	A	A	A	B
3	Colour	A	B	B	B
4	pH	A	A	B	B
5	Odor	A		A	B
6	Taste			A	B
7	Alkalinity	A	A	A	
8	E.C.	A	A	A	
9	Res. Chlorine		A	A	B
10	Ammonia	B			
11	Nitrite	B			B
12	Nitrate	B			B
13	$KMnO_4$	B		B	B
14	Chloride	B		B	
15	Hardness	B		B	
16	T-Iron	B		B	
17	T-Manganese	B		B	
18	Zinc	B		B	
19	Copper	B		B	
20	Lead	B		B	
21	Bacteria	B			B
22	E. Coli	B			B
23	A-Surfactant	B		B	
24	Total solids	C		C	
25	H-Chromium	C		C	
26	Cadmium	C		C	
27	T-Mercury	C		C	
28	Arsenic	C		C	
29	Fluoride	C		C	
30	Selenium	C		C	
31	Cyanide	C		C	
32	Organic-Phosphate	C		C	
33	Phenol	C		C	
34	Tri-methane			C	C
35	Pesticide	C			
36	Sulfate	C		C	

Notes: A: Daily test, B: Monthly test, C: Twice a year test
T: total, H: hexa, Res.: residual, Tri: trihalo

After a heavy rainfall in Kandy area, the turbidity of raw water sometimes rises quickly over a short time span, thus making it difficult to set the optimal dosing rate. To cope with such cases, a “turbidity-dosing rate relation diagram” should be made in advance. This is done using jar tests wherein highly turbid sample waters are prepared by mixing raw water with different quantities of clay. The diagram above allows an operator to adjust the dosing rate quickly in accordance with the present turbidity of raw water.

Aluminum sulphate, the coagulant, chemically reacts with alkaline components dissolved in water, producing metal hydrides, and flocculation takes place with the alkaline components. When the raw water has insufficient alkalinity, lime, alkaline agent must be added to the raw water for normal flocculation to occur.

With rapid sand filtration, the turbidity of filtered water increases as the process of filtration continues. At some point - either an increase of effluent turbidity or excessive head loss through the filter - filtration must be stopped and filter must be backwashed. With this in mind, it is essential to carefully monitor the process of rapid sand filtration to ensure proper filter performance. Emergency Stop of Water Supply

Meanwhile, NWSDB is responsible to stop water supply immediately whenever the supply water is found to be polluted or is harmful to public health. Further, NWSDB is also responsible to inform users without delay not to use the water. Subsequently, appropriate measures must be taken as soon as practicable to improve the situation. NWSDB is allowed to restart the service only when absolute safety is certain. Generally, it is required to suspend the service of water supply when the following occur:

- When raw water is polluted or suspected to have been contaminated with disease-causing microbes or toxic substances, and the removal of which is impractical or unfeasible by means of conventional water treatment.
- When waters at the respective stages of filtration, transmission, and distribution are found polluted or suspected to have been contaminated with disease-causing microbes or toxic substances.
- When source water, intake water and raw water in the transmission pipeline are contaminated and there is one of the following abnormalities, intake must be stopped immediately, followed by quality checks, and water supply may have to be suspended:
- When water undergoes a conspicuous change in color and turbidity due to uncertain causes.
- When water shows remarkable change in taste and odor.
- When many fishes are found dead along the raw water source.
- When a corpse, carcass, trash, filth and other unsanitary substances are found afloat at the source of water
- When there is a failure of chlorination, either due to equipment malfunction or a shortage of chlorine, water supply must be basically suspended.

14.2.1 Intake and Water Treatment Plant

(1) Raw Water Intake Facility

Raw water enters the intake from the Mahaweli Ganga through two inlet channels. From each inlet, which is provided with stop logs for isolation during periods of maintenance, flow passes through two duplex coarse screen arrangements to remove gross solids. Screenings removed from these screens are lifted to ground level by an electrically operated hoist from the platform for screens. Screenings are deposited into a skip at ground level for ultimate disposal to landfill.

After the coarse screens, flow passes to fine screens through manually operated gates, which can isolate and empty the grit chambers. The fine screens comprise a travelling mesh screen which raise debris to the cleaning mechanism located at ground level. The cleaning mechanism works, normally, on a manually adjusted pre-set timing sequence. The screens are washed using water provided from screen wash water pumps. Debris removed from the screens is discharged in to the trough and deposited into a skip for ultimate disposal to landfill.

The grit will be removed and discharged periodically by two mobile discharge pumps.

After the grit chamber, flow passes into pump sump through manually operated gates which can isolate and empty the grit chambers incorporate with the inflow gates.

Under normal operation, both screening channels are open and the stop logs and gates are closed only for maintenance.

The pump station includes space for four vertically mounted centrifugal pumps. Two pumps are installed in Phase 1 with space left for the third and fourth pumps. Each pump system comprises a manually operated suction gate valve, check valve and electrically operated discharge butterfly valve. The suction and delivery pipework and valves for the third pump and for the fourth pump are installed in this phase and blanked off but the check valve is not included in this phase. Pressure gauges with an isolating valve and diaphragm are mounted on the discharge side of each pump.

The pumps are controlled automatically but are manually set as duty or standby at the local electrical control panel. When the third and fourth pumps are installed, three pumps will be duty and one standby. The standby pump will automatically operate on failure of the duty pump(s). Emergency stop switches are provided at each pump and each motor. The pumps have variable speed motors and speed control is effected by flow measurement from the flow meter located on the raw water transmission main in the raw water pump room. The wide variation in the levels of the Mahaweli River require speed control to provide stability of flow from the pump (s). The flow will be monitored and recorded at the instrumentation panel in the raw water pump station and at the monitors in the Administration Building. Also the required flow will be set manually at the panels and the system will automatically maintain this flow by speeding up the pumps if flow drops below the pre-set value and slowing down the pumps if flow increases.

The water level in the wet well is monitored continuously by level monitor. On manually pre-set high, or low water levels the pumps are switched off and an alarm condition initiated.

Two sump drainage pumps, check valves and manual gate valves are provided in the pump dry well for drainage and are controlled by level switch. The selection of duty/standby pump is automatically/manually determined at the local operation panel.

One manually controlled supply fan provides air to the lower level of the pump station. Three manually controlled supply fans provide air to the upper level. Three manually controlled exhaust fans extract air from high level.

A manually operated overhead crane is provided in the pump station for maintenance.

The raw water is conveyed to a balancing tank to control pressure to prevent a negative pressure along the conveyance pipe from the intake pump station to the distribution chamber. Periodical cleaning is done by manually operated drainage valve.

Two hand operated pressure control valves with orifice plates will be necessary to avoid harmful cavitations when regulates the excess pressure for the conveyance main during Phase 1. Raw water for sampling will be hydraulically tapped at the inlet to the distribution chamber to the laboratory in the administration building..

(2) Distribution Chamber

Raw water delivered to the distribution chamber from the raw water conveyance main flows over a control weir to the coagulation (rapid mixing) basin. Two weirs are provided, one for each flocculation basin for Phase 1 and four additional weirs are provided for future flocculation basins. These weirs are blocked off in this stage.

A manually operated gate valve is provided on each outlet pipe from the distribution chamber to the flocculation basins for isolation and maintenance purposes. Two interconnection pipes between the distribution chamber and flocculation basins will be installed in this Phase and four pipes will be installed in Phase 2 and 3.

Drainage facilities, controlled by manually operated gate, are provided in the receiving well.

Chemicals – alum, lime and chlorine are also dosed into the raw water at the distribution chamber. Mixing is effected hydraulically by the weirs and the dosages (in mg/l) of each chemical at the distribution chamber will be:

	Max.	Ave.	Min.
10 percent Alum ($Al_2(SO_4)_3$)	60	15	10
10 percent Pre-Lime ($Ca(OH)_2$)	30	10	5
Pre-chlorine (99 percent Cl_2)	5	2	1

Control of the chemical dosing system is described in the Chemical Building section although the relevant facilities are located at the distribution chamber.

A tapping is provided on the raw water transmission main in the meter chamber to deliver water for quality monitoring to the Administration Building through valve.

(3) Flocculation/Sedimentation Basins

From the distribution chamber the coagulated raw water flows into the flocculation basins. Two basins are provided so that in case of lower flows than the designed capacity one train may be shut down to attain a suitable flocculation intensity, or maintenance work is undertaken on any one of the two basins, the remaining one can provide adequate capacity. Flocculation intensity G-value range from 70 to 10 s^{-1}. The flocculation will be effected in vertical-flow baffled channels with three-staged tapered flocculation. From each flocculation basin flocculated water flows to the attached sedimentation tank where the solids settle out as sludge.

The solids settle in the sedimentation tanks and are moved to the inlet end of the tanks by means of sludge collectors. The collector will be continuously operated to scrape the settled sludge on the bottom of tank.

Sludge is withdrawn hydrostatically from each tank through four electrically operated desludging valves. The valves in each basin shall be manually pre-set to open and shall close automatically after a manually pre-set time interval. Valves shall be interlocked such that only those in one basin can open simultaneously. The valves discharge into the sludge header pipe which conveys the sludge to the sludge lagoons.

Each electrically operated valve has a manually operated maintenance valve upstream on the sludge withdrawal pipeline.

Intermediate chlorination is provided at the settled water effluent channel if pre-chlorination is not functioning properly.

A settled water sampling pump is provided at the settled water effluent channel. The pump with manually operated valve and check valve deliver water for quality monitoring to the Administration Building.

(4) Filters

The filtration flow rate is to be maintained and distributed into each of the four filters by an influent weir installed at the inlet to each filter from the distribution channel, which receives flow from the sedimentation tanks. The highest filtration level at which back washing will start will be controlled by means of the water level in each filter and backwashing will then run for a pre-set time period. Thus the head of water above the sand level of the filter will increase during the filtration cycle until backwashing is required.

Settled water from the sedimentation basins flows into the filter distribution channel where four electrically operated gates distribute flows to each of the four filters. Stop logs are provided upstream of each gate for maintenance purposes. Flow exits each filter into the filtered water channel through electrically operated effluent butterfly valves and then passes through the backwash water tank to the clear water reservoir. The backwash water tank is located adjacent to the filters and provides a sufficient on-line storage capacity for backwash pump operation.

The water level is monitored in each filter by level detectors. The filter backwashing requirement will be indicated on the filter backwash panel. The filter back-washing cycle will be initiated manually in one filter. Only backwashing of one filter will be undertaken at any one time.

On actuation of the backwash cycle for the first filter, the inlet gate and the effluent butterfly valve will close and the backwash drainage gate will open. The selected air blowers will start and air scour valve will open. After a manually pre-set time the backwash water pumps will start, backwash valve will open and backwashing will be effected by a combination of wash water and air scour. After a manually pre-set time the air scour blowers will stop air scour valve will close and backwashing will continue with wash water. After a further manually pre-set time the backwash pumps will stop, backwash valve will close and backwashing will cease. Backwash water drainage gate will close and inflow gate and effluent valve will open to recommence filter operation. The sequencing for the other filters will be a similar operation.

Filter drainage for maintenance purposes can be effected through the drainage valve.

The backwash pumps include three horizontally mounted centrifugal pumps. Each pump system comprises a suction valve, check valve, and discharge valve. Pressure gauges with an isolating valve and diaphragm are mounted on the delivery side of each pump.

The backwash pumps are controlled automatically with two pumps as duty and the third pump as standby. The standby pump will automatically operate on failure of one of the duty pumps. An emergency stop switch is provided at the local control panel for the three pumps/motors. Water level is monitored in the backwash water tank by level switch. On manually pre-set low water level the pumps are switched off and an alarm condition initiated.

Backwash flow measurement is effected by the flow meter. The flow will be monitored and recorded at in the filter building or the central monitoring room in the administration building. Manually operated valves will be provided both upstream and downstream of the flow meter for maintenance purposes.

The air scour system includes three air blowers each including an air filter, check valve and discharge valve.

The air blowers are controlled automatically but are manually set as duty or standby unit at the local control panel with one blowers as duty and the second as standby. The standby blower will automatically operate on failure of one of the blowers. An emergency stop switch is provided at the local control panel for the two blowers/motors.

The quantity of air for scouring is measured by orifice flow meter. The flow will be monitored and recorded at instrumentation panel in the filter building or the administration building.

Spent backwash water is discharged to the backwash recovery tank for further treatment.

Two sump drainage pumps, check valves and manual gate valves are provided in the pump dry well for drainage and are controlled from level monitor. The selection of duty/standby pump is manually determined at the local control panel.

Stop logs are provided and blanked off for future extensions to the settled water channels and the backwash water tank.

(5) Clearwater Reservoir

Filtered water from the filtered water channel in the filter complex passes through the backwash water tank and then to the clear water reservoir. At the reservoir two manually operated inflow butterfly valves are provided in the valve chambers.

Two manually operated butterfly valves are installed on the suction header pipe. Under normal operation all inter valves are open. During shut-down of either chamber of the clear water reservoir the appropriate valves are closed to isolate the chamber.

An overflow is provided from each chamber.

(6) Clearwater Pump Station

The clearwater pump station includes space for five horizontally mounted centrifugal pumps. Six pumps are installed in Phase 1; two pumps for Upland and Asgiriya, two pumps for Gohagoda and Kondadeniya and two pumps for Kahawatta with space left for six further pumps two pumps each for each directions. One unit each is standby. Each pump system comprises a suction valve, check valve and electrically operated discharge valve. The suction and delivery valves for the fourth, fifth, and sixth pumps are installed in this phase and blanked off for future extension. Pressure gauges with isolating valves are mounted on the delivery side of each pump.

The pumps are controlled automatically with three pumps as duty and the remaining three pump as standby. When the remaining six pumps are installed six pumps will be duty and other six will be standby. The standby pump will automatically operate on failure of one of the duty pumps. Emergency stop switches are provided at each pump/motor.

The pumps are stopped automatically from level sensors in both the clear water reservoir and the pre-determined flow rate which will be detected by flow meters and pressure gages with isolating valves are mounted on the delivery side of each pump. The level sensor in the clear water reservoir continuously monitors the levels in the two chambers of the clear water reservoir, which are normally operated as one unit. On pre-set falling levels at the clearwater reservoir the clear water pumps are shut down in a manually pre-determined sequence and on rising levels the pumps are started in a manually pre-determined sequence from, but subject to capacity available in the clearwater reservoir.

The pumps will be manually controlled to lower the water level and empty each chamber for maintenance of the reservoir.

Clear water from the clear water reservoir is pumped to Upland/Asgiriya, Kondadeniya, Gohagoda, and Kahawatte/Akurana/Kahalla/Bangalawatte/Philladeniya by the six pumps through a 700 mm, 300 mm, 300 mm, and 600 mm diameter pipes, respectively.

The flow rates for each direction are measured by flow meter. Maintenance of the flow meters are effected by the use of valves.

Water for in-plant use is provided by the plant water supply units.

The chlorination booster pumps are provided at the clear water pump station suction pipe manifold for chlorination motive water. The pumps and manually operated valves and check valves deliver water for chlorination to the Chemical Building Space is available for a future third pump and manually operated valves shall be provided for future connection.

Two manually controlled supply fans provide air to the lower level of the pump station and to the control area. Eight manually controlled exhaust fans extract air from high level.

Two sump drainage pumps, check valves and manual gate valves are provided in the clear water pump station for drainage controlled from the level switch.

A manually operated overhead crane is provided in the pump station for maintenance.

(7) Chemical Building

The chemical building comprises three independent sections for alum, lime and chlorine preparation and dosing facilities. An electrically operated overhead crane is provided in the alum and lime storage area for transporting bags of chemicals. Another electrically operated overhead crane is provided in the chlorine container storage area for lifting of chlorine tonne containers.

Alum Dosing System

Bagged alum will be manually transported from the storage area to the dissolving tank area using the overhead crane. Bags will be manually opened and the contents emptied into the dissolving tanks. Four dissolving tanks are provided, two for the Phase 1 operations and two for future operations.

The two storage tanks are provided with mixers to assist in dissolving the alum in water. Water is added to the dissolving tanks through manually operated valves from the plant water system. Valves are installed and blanked off for the Phase 2 and 3 expansions. An emergency stop switch is provided at the local control panel for two each mixers/motors.

Alum solution is discharged from each tank through a manually operated valve to the solution pump header pipe through alum level tank. Valves are installed and blanked off for the stage two expansions. Solution is pumped to the distribution chamber by the pumps. Each pump system comprises of a suction valve and discharge valve.

Manually operated drain valves are provided from each tank.

Plant water can be flushed through the alum suction system from valve on the plant water supply pipe and discharged to drain through valve on the drain pipe.

The pumps are manually set to discharge the required flow by speed control at instrumentation panel, and set as duty or standby at the local control panel. Emergency stop switches are provided at each pump motor.

The levels in the alum tanks are monitored by level switch.

The alum solution to the distribution chamber is measured by flow metering unit and is monitored at the local instrumentation panel installed in the chemical control room and at the central monitoring unit installed in the Administration Building monitoring room.

At the distribution chamber the alum solution discharges to alum tank containing six v-notch weirs to equalise flow to each dosing point. The tank is isolated by valves. Valves are blanked off for future use.

Lime Dosing System

Bagged lime will be manually transported from the storage area to the dissolving tank area using the overhead crane. Bags are opened and the contents emptied into the dissolving tanks. Four dissolving tanks are provided, two for the Phase 1 operation and two for future operation.

The two first stage tanks are provided with mixers to assist in dissolving the lime in water. Water is added to the dissolving tanks through manually operated valves from the plant water system. Valves are installed and blanked off for the stage two expansions. An emergency stop is provided at the local control panel for each of the two mixer/motors.

Dust is controlled by extract fan and scrubber.

Lime solution is discharged from each tank through a manually operated valve to the solution pump header pipe. Valves are installed and blanked off for the stage two expansions. Solution is pumped to the header tanks at the distribution chamber and filter building by pumps. Each pump system comprises a suction valve and discharge valve. Manually operated drain valves are provided from each tank.

The levels in the lime tanks are monitored by level switch.

The pumps are controlled automatically. The standby pump will automatically operate on failure of the duty pumps. An emergency stop switch is provided at the local control panel for the two pump/motors. The duty pumps operate when the level in the local mixing tanks drop and are shut off on manually pre-set high levels. The levels in the local mixing tanks are monitored by level switch.

Manually operated valves are provided from the plant water system to flush out the lime suction systems and which can be discharged to drain through valve.

For post lime solution is pumped to the lime mixing tank, which contains mixer at the distribution chamber and to the lime mixing tank which contains mixer at the filter building.

From the lime mixing at the distribution chamber the solution is fed to the mixing basins by lime feed pumps. Each pump system comprises a suction valve and discharge valve and common suction valve. Manually operated valve is provided from the plant water system and manually operated drain valve is provided to flush out the lime suction systems.

The lime solution to the distribution chamber is measured by the flow measuring unit and monitored at the local instrumentation panel and the central monitoring unit.

From the lime mixing tank at the filter building the solution is fed for post-lime addition by lime feed pumps. Each pump system comprises a suction valve and discharge valve. Plant water can be flushed through the lime suction system from valve and discharged to drain through valve.

The lime feed pumps are manually set for flow discharge by speed control and are set as duty or standby at the local control panel.

The lime solution to the sand filter building is measured by the flow measurement unit and is monitored at the local instrumentation panel and the central monitoring unit.

Chlorination System

Chlorine will be stored in one tonne containers and two duty containers will be coupled to the system. The duty cylinders will be placed on a weighing device using overhead crane. Change over from the duty to the other container will be effected manually.

Gaseous chlorine will be drawn off from the top of the cylinders through flexible pipes into a pipe manifold from where it will be fed to four chlorinators. Two chlorinators are manually selected as duty/standby to regulate the amount of chlorine solution delivered for pre-chlorination at the distribution chamber or upstream of the filters and two chlorinators for post chlorination at the filtered water channel prior to discharge to the clear water reservoir.

Pre chlorinators and post chlorinators can be isolated by manually operated valves.

Water will be supplied from the chlorination booster pumps water system to injectors into which chlorine will be drawn from the respective chlorinators to form a chlorine solution for pre and post chlorination respectively. The injectors can be isolated by manually operated valves.

Extract fans, which is activated by chlorine detector removes air from the chlorinator room and extract fans which are activated by chlorine detector, remove air from the chlorine drum area.

(8) Backwash Water Recovery Facility

Spent backwash water is discharged to the backwash receiving tanks. Spent backwash water is discharged to the receiving tanks through a normally open, manually operated inlet valves in each tank.

The tank contains two pumps to pump recycled backwash water to the distribution chamber. Two pumps, one for duty and another for standby, are provided. Each pump system comprises the pump, inflow valve, suction valves, check valve and manually operated discharge gate valve.

The flow to the distribution chamber is measured by flow meter. Maintenance of the flow meter is effected by valves.

The pumps are controlled automatically by level device which continuously monitor the levels in the two tanks. On manually pre-set rising levels the pumps are started and on manually pre-set falling levels the pumps are stopped from the local control panel.

An emergency stop switch is provided at the local control panel for the two pump/motors, respectively.

(9) Sludge Lagoon

Two sludge lagoons will be constructed in Phase 1 and additional two will be expanded in future. A 700 mm for inflow and a 300 mm discharge pipes will be provided with each lagoon.

Sludge is discharged from the sedimentation basins to the sludge lagoons where it is directed into the appropriate lagoon through manually operated butterfly valves. Lagoons are filled in sequence until a lagoon is full. A series of stop logs at the discharge end of each lagoon are removed to drain off supernatant water until only solids remain. The dried solids are removed from the lagoon by a loader/backhoe and truck for disposal to land fill

14.2.2 Transmission and Distribution Facilities

(1) General Pipelines

Pipelines shall be inspected regularly and well maintained. All sizes and types must be inspected for leakage or loss of pressure – outward signs of failure. To isolate and drain the pipeline sections for testing, inspection, cleaning, and repairs; a number of appurtenances or auxiliaries are installed in the line. The following appurtenances, which were designed in this project shall be operated and maintained in proper condition. To avoid faulty identification of pipes, a tape marking should be sealed on to the pipelines.

(2) Valves

Sluice valves and butterfly valves for the purposes of intercepting and controlling water flow are placed at strategic locations in the pipelines, taking into consideration of its site conditions and the configuration of pipeline/network. The opening conditions, i.e. open or close, shall be inspected and recoded. Under the normal operation, all valves on the pipeline should be fully open (100 percent open). Deteriorated coatings of valve casing and bodies shall be repaired with same coating film properties.

(3) Air Valves

The air valves are installed at the highest locations of the pipeline and on pipe bridges for release of accumulated air in the pipeline or to introduce air if a vacuum are created consequent to a sudden stoppage of supply or due to a sudden surge. Stop valves shall be left open fully under normal operation condition. During filling of water, washing and when surge occurs, air valves shall function as designed. Therefore, the condition of stop valve and air release valves shall be inspected and duly recoded before and after the maintenance work is done. The ball and rubber packing of air valve shall be checked and if they are damaged, they must be replaced or repaired promptly.

(4) Washouts

Washouts are installed at the low points of pipelines near a river, ditch, or culvert where water can be discharged. As temporary protective measures may be arranged for protection of existing utilities from discharge flow when cleaning the pipeline, draining the pipeline for construction work, or in an abnormal situation such as burst of pipe, regular inspections shall be conducted and the condition and situation of surrounding area of discharge points shall be recorded and maintained.

(5) Pipe Bridges

There are two significantly large pipe bridges namely, i) Mahaweli River Pipe Bridge and ii) Pinga Oya Pipe Bridge with truss structure. Mahaweli River Pipe Bridge has equipped an inspection corridor for checking and repair of air valve and truss members, including the centre pier and the two abutments. To prevent the corrosion of truss members, painting work must be carried out once every two years at least. Regular inspections shall be carried out and records shall be maintained as preventive measures.

(6) Chambers

Valve chamber are installed for diameters of 150 mm and more, and valve cover is installed for less than 100 mm in diameter mostly for washout valves.

For an air valve, an air valve chamber must be cleaned for elimination of expelled air and easy maintenance of the air valve and to keep dry.

Manhole cover made of cast iron, are equipped with access to inside of the chambers. For easier operation of valve from outside, a hole with cap on the cover is provided. The inside of chambers shall be kept dry.

14.2.3 Service Reservoir

(1) Operation of Pipes and Valves

The butterfly valve (toothed vane valve type) is installed on the inlet pipe for dissipation of the residual pressure to avoid the cavitation occurring at the float valve, so that incoming flow to the reservoir could be controlled.

An overflow connection, set at the high water level will allow excess water to flow out of the reservoir, and is usually connected to a drain line leading to a local stream or a waterway. Similarly, a washout connection is provided at the bottom to drain the tank for emptying for maintenance or in an emergency.

The flow meter on the inlet and outlet pipe is equipped to measure the quantity of incoming and outgoing water into the distribution system.

(2) Operation of New and Existing SRs

Bahirawakanda SRs

The elevated reservoir of 600 m^3 capacity (HWL+629.00 m AMSL, LWL+625.00 m AMSL) is planned to be built in the available land, which is very steep, and near the existing SR (V=204 m^3, HWL+620.90 m AMSL, LWL+619.10 m AMSL). The two reservoirs will be operated independently, since water levels are different and the existing SR belongs to KMC. However, to supply water from new SR to existing SR by gravity, a connection pipe with isolated valve is provided. When KMC will connect to this pipe later, a flow meter and a valve shall be installed. When KMC need water from the new SR, they should inform to NWSDB for measure the quantity of water issued to KMC. An Operator from NWSDB shall be accompanied when KMC opens the isolated valve and read flow meter.

Gohagoda SRs

A new service reservoir of volume 200 m^3 (HWL+531.20 m AMSL, LWL+527.20 m AMSL) is planned to be constructed near the exiting Pallemulla tank (V=150 m^3, HWL+524.10 m AMSL, LWL+521.90 m AMSL). The new SR will supply to the northern part, which is the high elevation area of Gohagoda service area, whilst the other existing SR will supply to the southern part, which is the low elevation area. New inlet pipe is connected to the both SRs, and discharge flows to their respective service area.

Dangola SRs

Adjacent to the existing reservoir (V=118 m^3, HWL+531.60 m AMSL, LWL+529.90 m AMSL), the new reservoir of 260 m^3 capacity (HWL+531.60 m AMSL, LWL+527.60 m AMSL) will be constructed as a ground reservoir. Both SRs have the same HWL, and the new inlet pipe to be installed by KMC is to be connected to both SRs. No interconnection pipe between the two SRs is planned due to the superannuated nature of the existing structure, but the discharge pipes from both SRs are connected together outside the premises. The incoming and outgoing quantity of water together with water level shall be measured and recorded by NWSDB and KMC.

Bangalawatte SRs

A new service reservoir with a volume of 300 cum (HWL+521.28 m AMSL, LWL+518.28 m AMSL) would be provided near the exiting Bangalawatte tank (V=100 m^3, HWL+521.28 m AMSL, LWL+519.28 m AMSL). The both SRs will have the same HWL and a new inlet pipe is planned to connect both SRs as one unit. Thus, the operator should inspect and record the water levels, incoming flow and discharge flow of the both SRs from time to time and adjust the inlet valves.

Pihilladeniya SRs

An additional service reservoir in the vicinity of the existing Pihilladeniya tank (V=100 m^3, HWL+524.14 m AMSL, LWL+522.14 m AMSL) is planned to be built with the same high and low water levels and a capacity of 200 m^3 (HWL+524.14 m AMSL, LWL+522.14 m AMSL). The new inlet pipe is planned to be connected to the both SRs, and the operation will be done as a single reservoir. The new outlet pipe will be connected to the existing distribution pipe outside the reservoir premises. Thus, the operator should inspect and record the water levels, incoming flow and discharge flow of both SRs from time to time and adjust the inlet valves.

Kulugammana SRs

An additional service reservoir in the vicinity of the existing Heenagama tank (V=300 m^3, HWL+583.25 m AMSL, LWL+579.25 m AMSL) is planned to be built with the same high and low water levels and a capacity of 100 m^3. The operation of these two SRs is similar to Pihilladeniya SRs.

Disinfection and Chlorination

SRs should be disinfected after completion and before water filling, also after cleaning. At Kahawatta SR, the chlorination disinfections shall be done, thus chlorination equipment with 1.0 mg/m^3 dosing is planned to be install. The operator should inspect and adjust the rate of chlorination based on the results of the water quality tests (residual chlorine).

Data collection

All service reservoirs would maintain a record of both quantity of incoming flow and discharge (distribution) flow together with the quality (at least residual chlorine) of the stored water. The maintenance of records relating to the quantity of water produced facilitates the utility to determine the amount of unaccounted-for water, to estimate future demands for water and to evaluate the hourly, daily, monthly and yearly fluctuations of consumption. Such records will be useful to set up a more efficient and accurate operation and maintenance system. Therefore, a record should be maintained of all meters installed, repairs carried out, and locations of installation, the size of the meter, the serial number, and the date of installation.

14.3 Organisation of Operation and Maintenance

In order to attain an efficient operation and maintenance program, it is essential to formulate a suitable organization with the necessary authority and the appropriate number of personnel.

Figure 14.1 shows the recommended organization for the operation of the proposed water supply systems. A manager who is recommended to be in the rank of an AGM will head the overall operation and maintenance of Gohagoda Intake and Katugastota WTP systems. Under him there will be 5 sections; namely production, transmission, water quality, maintenance and administration. A total numbers of staff is at least 80 excluding some shift workers, if any.

The production section will monitor and operate the production process at Intake and Water Treatment facilities. The transmission booster pumping system, transmission pipelines, service reservoirs and distribution networks will be the responsibility of the transmission section. Water quality section presently located at Sarasavi Uyana will be housed in the Katugastota WTP where water quality of raw water, process water and service water will be analysed and monitored. The maintenance section will oversee the overall maintenance work of the facilities in corporate with each section.

14.4 Operation and Maintenance Cost

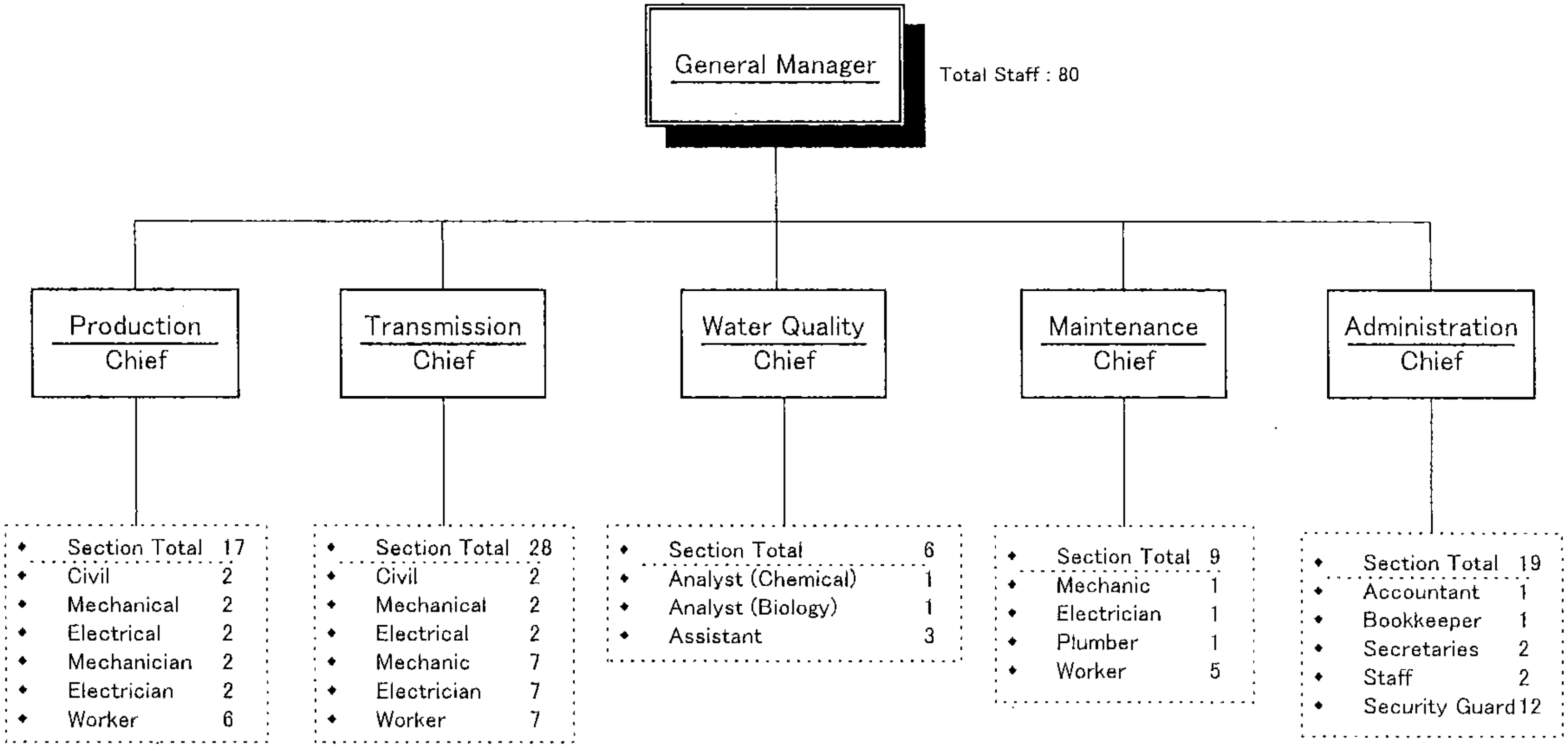
Execution of maintenance guarantees the usability of equipment and facilities within or sometimes even beyond the expected life. After expiration, however, the efficiency of equipment and facilities may decline even if they are properly maintained, some gradually while some abruptly. A large scaled rehabilitation or renovation entails considerable expense. In order to cope with such exigency, therefore, a budgetary system to ensure the availability of funds for major rehabilitation or renovation should be established.

Hereunder is the reviewed annual cost set up by the 1999 JICA F/S Study for operation and maintenance programme as described in the precedence sections.

Personnel cost is estimated based on the monthly salary data form NWSDB for the proposed number of 80 staff. Electricity cost includes Rs.270/kVA monthly meter charge and Rs. 4.4/kWh of electricity unit cost. Chemical cost is based on the NWSDB “Rate 2001”. Repair cost assumes 0.1 percent of initial facilities/equipment supply cost.

Table 14.1 Annual Operation and Maintenance Cost

Items	O&M cost in 1,000 Rps
Personnel expenses	15,240
Electricity cost	64,134
Chemical cost	6,794
Repair cost	1,472
Total	**87,640**



Note: Nr. for security guard is for 3 shifts.

Figure 14.2 Organisation for Operation and Maintenance

CHAPTER 15
PROJECT COST

CHAPTER 15 PROJECT COST

15.1 Exchange Rate

Applied exchange rate for the Project cost estimate is as follows:

-Foreign exchange rate : Sri Lankan Rs. 1.00 = Japanese Yen 1.3532, based on the average of the last 6 months' fluctuation

15.2 Basis for Cost Estimates

The Project cost is estimated on the basis of the detailed design. Unit prices and lump sum prices are established taking into considering the "Rate 2001" issued annually by NWSDB, recent awarded contracts, local conditions, sub-contractors, hiring equipment, available construction equipment and materials as well as the suitability of the construction method.

Provisional Sum is applied for the items where the work item cannot be quantified accurately. The price includes the entire Contractor's financial and administrative costs including costs of liaison with external agencies, profits, and overheads.

Items in the Bill of Quantities designated as "Provisional Quantity" in the description column indicate that the quantities for the Work covered by such items are the best possible estimates that can be made in advance of the execution of the Work, or that the provision of such facilities are described in the items, may not, in the event, be required under the Contract.

The unit rates and prices are quoted against items in the Bill of Quantities and schedule of rates separately in the following currencies:

(3) Sri Lankan Rupee (local) Portion

For those inputs to the Works which the Contractor expects to supply from within the project country including customs duty, cess, NSL, GST payable during importation, excise duty, surcharge and any other duties or levies payable by the Contractor on the items and quantities of materials and equipment stated in the Bills of Quantities for the supply of those items.

(4) Japanese Yen (foreign) Portion

For those inputs to the Works which the Contractor expects to supply from outside the project country.

15.3 Prices of Major Construction Materials

15.3.1 Construction Materials

The rates for construction materials for the Works are estimated based on the prevailing local prices in reference to the NWSDB "Rate 2000", recent awarded prices, etc. On the other hand the rate for materials such as DI pipes/Special valves are estimated based on the quotation from Japan as the Cost Insurance Freight Price. The rates include for providing drawings, samples, testing, supplying, transporting, storing, cleaning, fabricating, wastages, distributing throughout the works, fixing and supporting in position, for all testing, protection of other works, and all labour necessary.

Those items estimated as “Construction” comprises of the rate for construction materials mainly as local portion except DI pipes etc., and construction/laying works which is further broken down into local and foreign portions.

15.3.2 Equipment and Plant

The rate of supply of Equipment and/or Plant are estimated in reference to prevailing manufacturers quotations, which includes product, design, manufacturing, inspection and testing, provision of the specified accessories and spare parts, packing, shipment, expenses for custom clearance and other taxes, in-land transportation, delivery to the place at site designated by the Engineer, safeguarding and protection from inclement conditions during storage prior to, and after, installation. The rate for supply of Equipment and/or Plant to be imported is estimated as foreign portion.

The installation works of the supplied Equipment and Plant include all multiple handling necessary prior to installation, including during storage and carrying in to the site, installation including all necessary permanent and temporary supports, building in, painting, calibration, performance testing, and necessary installation supervisory services of manufacturer, any other works necessary to meet the requirements shown on the drawings and/or specified. The rate comprises of local and foreign portions, including overhead of the Contractor.

15.3.3 Reinstatement in Roads

The estimated costs (permanent reinstatement) agreed by NWSDB with the roads authority are accounted as the “Provisional Sums”, and also the reinstatement for the A9 road estimated by the Study Team which will be carried out by the Contractor directly. A temporary reinstatement is included in the item for pipe laying works.

15.3.4 Study on Overhead Rate

The overhead of the Contractor is estimated in those items for general, construction works, supply of Equipment, and installation works for the Equipment. Applied overhead is summarised below, based on the analysis of recent awarded prices and prevailing manufacturer’s quotations. The overhead covers in general the Contractor’s profit, superintendence, liabilities and insurance, use of consumable stores/utilities, cost of using/repairing/maintaining the tools necessary to each class of workmen, etc.

i) General : 8.87 -- 15 %
ii) Construction works : 31 %
iii) Installation of equipment : 67 %

15.3.5 Duty and Tax

All dues, taxes, duty and other levies which are payable by the Contractor under the Contract, or for any other cause are estimated in the rates and prices. The date considered for computation of such taxes, duties and other levies etc. is February 2002 as shown in the following:

i) Goods and services tax (GST) : 12.5 percent
ii) Surcharge : 40 percent of general duty
iii) Stamp duty : 2 percent of general duty
iv) general duty : In accordance with the "Rate 2001" issued by NWSDB
v) Defense levies : 6.5 percent

In case, the "Rate 2001" does not include the categories to be applied, the Study Team applied those items according to the "Sri Lanka Customs Tariff Guide 1999".

15.4 Project Cost

A total of Project cost for Package 1 and 2 except taxes is estimated to be approximately 4,727 million Japanese Yen as shown in Table 15.1.

Table 15.1 Project Cost in Japanese Yen (x 1,000 Yen)

	Descriptions	Local Portion	Foreign Portion	Sub total
1	General	287,198	105,348	392,546
2	Intake faculties	248,286	456,307	704,594
3	Water treatment plant	742,372	1,321,796	2,064168
4	Transmission pipelines	186,180	552,906	739086
5	Service reservoirs	307,661	285,400	593,061
6	Distribution pipelines	87,807	93,957	181,764
7	Maintenance equipment	3,431	49,009	52,440
	Total	**1,862,936**	**2,864,722**	**4,727,658**

General includes such costs as all insurances, performance bond, temporary site offices set up and operation, payment to the relevant road authorities, additional soil investigation, provisional sum for dayworks, etc. in accordance with the Conditions of Contract. This item also includes the price escalation cost in accordance with Clause 70, the Conditions of Contract.

Intake facilities include the costs for construction works for grit chamber, raw water intake pump station, intake pump motor room, electrical building, and raw water conveyance pipelines, supply and installation of the mechanical/electrical facilities/equipment including screens, raw intake pumps and motors, and appurtenances.

The cost for water treatment plant comprises of construction works for the distribution chamber, flocculation/sedimentation basins, filter units, clear water reservoirs, clear water transmission pump station, electrical building, backwash water recovery tank, chemical building, administration building, and maintenance building and supply and installation of the mechanical/electrical facilities/equipment including sludge withdrawal valves, filter control valves, filter washing equipment, chemical feeders, and other required appurtenances.

Transmission and distribution pipelines include the costs for supply and laying of DI, uPVC, and its appurtenances for the transmission and distribution systems.

Service reservoirs include the costs for construction of 19 service reservoirs and 5 booster pumping houses, and supply and installation of the required mechanical/electrical facilities/equipment including booster pumps and its appurtenances.

Maintenance equipment includes water quality analysis equipment and maintenance backhoe for the intake.

Details cost estimates are referred to the Engineers' Cost Estimates.

15.5 Eligibility for Special Yen Loan Requirements

Eligibility was evaluated based on the conditions stipulated in Section 2 (3), Schedule 4, Procurement Procedure, namely not less than 50 percent of the total costs of goods and services to be financed under the contract shall be procured in Japan, assuming that the cost estimated as foreign portion is the goods and services provided by Japanese Contractor except for those items as imported from the third countries.

The estimated cost in the previous section comprises of Rupee and Yen portions. Yen portion includes all inputs to the Works supplied from outside of Sri Lanka. Yen portion is further subdivided into procurement from Japan and the third countries as itemised below.

i)	**Total Estimated Project Cost**	:	**4,727,658**
ii)	Estimated cost for foreign portion	:	2,864,722
iii)	Estimated cost for products imported from the third countries, estimated as foreign portion	:	500,887
iv)	**Total cost regarded as eligible goods and services for the Project** = ii) – iii)	:	**2,363,836**
	Percentage of eligible goods and services (iv/i x 100)	:	**50.00 %**

(Notes) Unit in x 1,000 Japanese Yen. The cost shown above includes Package 1 and 2, but excludes taxes

As computed in the above table, the percentage for costs of goods and service procured from Japan is estimated to be 50.00 percent, which satisfies the eligibility required for the Loan Agreement.

15.5.1 Tendering

The following table summarises the allocated loan amount by JBIC and the estimated Project cost for Package 1 and 2.

	(unit in mil. J.Yen)	JBIC Loan	Estimated Cost	Balance
i)	Civil works	4,302	4,728	4
ii)	Contingencies	430	N/A	
	Total	**4,732**	**4,728**	**4**

A total of project budget to be reallocated for the Civil Works in applying Section 2, Reallocation Upon Change in Cost Estimates, Schedule 2, Allocation of Proceeds of Loan of the Loan Agreement is 4,732 million Japanese Yen, a sum of Civil Works and Contingencies. While the estimated Project cost is 4,728 million Japanese Yen which is below the available budget by approximately 4 million Japanese Yen.

15.5.2 Expected Problems and Measures

The budget available for the Project under JBIC Loan Agreement is fixed at 4,732 million Japanese Yen and the final cost of the Construction Work should be preferably kept under this ceiling unless otherwise NWSDB prepares its counterpart fund.

The estimates include Provisional Items, which by definition may not be carried out, if the Engineer decides so. In such a cost overrun situation, some of these Provisional Items may be deleted from the Scope of Work to adjust the contract price to suit the funds available.

Although the price escalation of construction materials and labour costs will be a major issue during the construction period because such changes are very common the estimates has considered the required cost as a provisional sum. Therefore, this issue will be minimised or negligible.

Soil investigations had been carried out to identify the subsoil conditions as much as possible for the civil structures and test excavations for proposed pipelines. The designs were carried out on the basis of these results and the some additional quantities of works had been addressed on a provisional basis as physical contingencies. The estimates involve all the technical possibilities that may be happened and ward off the unforeseeable surplus of costs.

There is a sharp fluctuation of Sri Lankan Rupee and the Japanese Yen due to the present trend of devaluation of both currencies. Fortunately, the relationship between these two currencies has not been significantly changed unlike the other currencies, and it is assumed that this situation would prevail in future also without much detrimental effect.

CHAPTER 16
IMPLEMENTATION PLAN

CHAPTER 16 IMPLEMENTATION PLAN

16.1 Implementation Schedule

The implementation of Project is extended using a credit from JBIC in Japanese Yen currency towards the cost of the Project and it is intended that part of the proceeds of this loan will be applied to effect payment under Contract No. GK/JBIC/04.

NWSDB will be the agency responsible for the implementation of the Project under the supervision of Ministry of Housing and Plantation Infrastructure. The implementation system is schematised in Figure 16.1.

For the smooth implementation of the Project, the Project Implementation Unit headed by the same Project Director for detailed design should continuously supervise the construction work in association with the consultants to be employed for construction supervisory services. Under the Project Director, NWSDB should provide a deputy project manager qualified for civil, structural, or pipeline work, one each of project engineers for mechanical, electrical, and civil works oriented, and 10 technical assistant officers.

The Project Implementation Unit would take charge of the following roles:

i) Management of the Project
ii) Coordination with NWSDB (Department of Planning & Design, Construction etc.)
iii) Coordination with the concerned organisation of the Government of Sri Lanka concerned
iv) Coordination of the tendering procedure.
v) Implementation of additional examination and investigation by Sri Lankan counterparts in cooperation with the Consultants and supervising engineers, if necessary.

A consultancy contract for construction supervisory services is to be concluded between NWSDB and a Japanese consulting firm in accordance with the Guidelines for the Employment of Consultants under JBIC ODA Loans dated October 1999. JBIC will check whether the selection process and consulting contract is eligible under the Loan Agreement and concurs it.

The construction contract for the Project is concluded between NWSDB and a selected Japanese construction firm in accordance with the Guidelines for Procurement under JBIC, ODA Loans dated October 1999, notwithstanding that the provisions of section 1.04 (a) of the guidelines shall be disregarded.

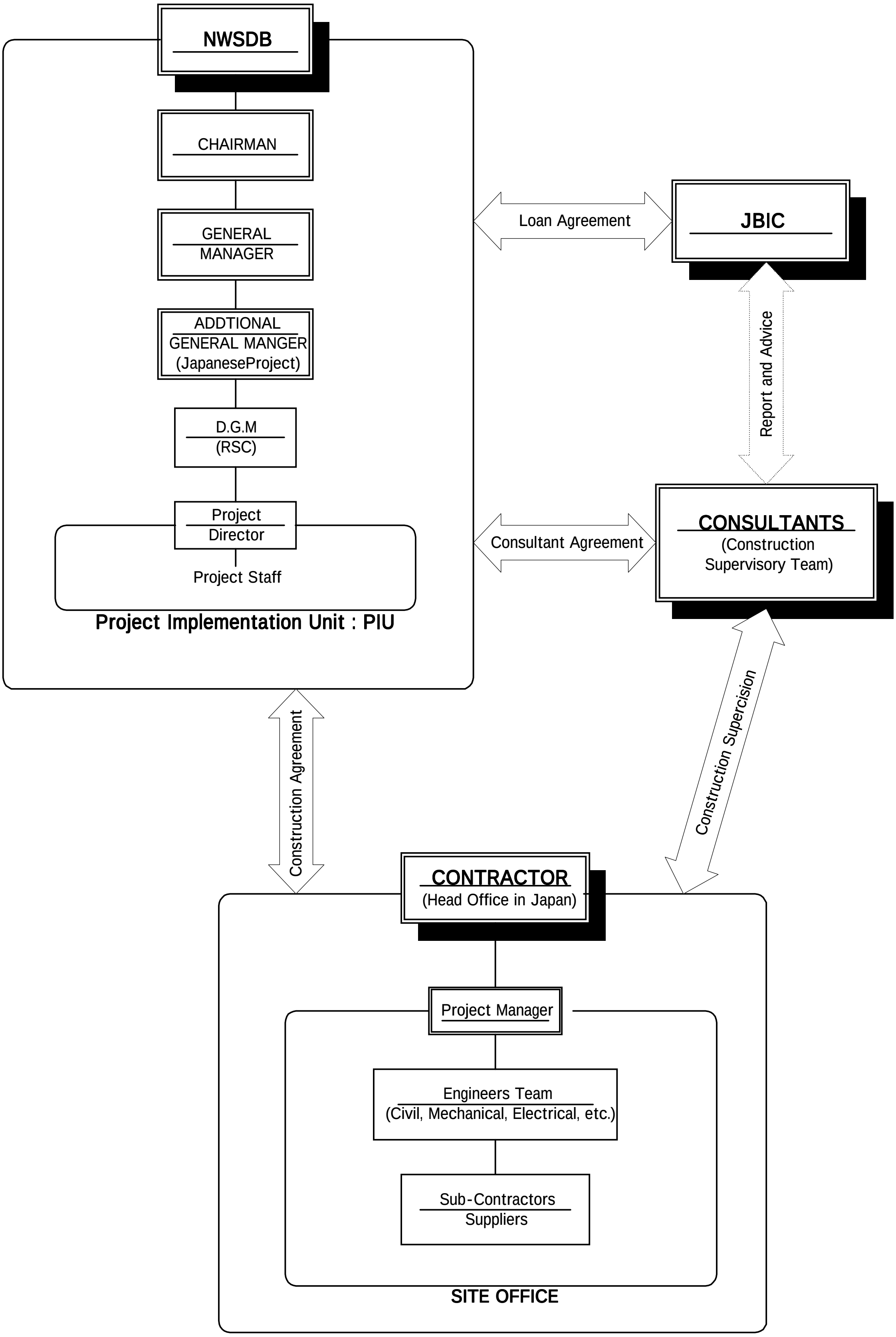


Figure 16.1 Implementation Organisation

Subsequent to the loan agreement, it is recommended that the Project construction should be undertaken by a contractor qualified as follows:

i) an individual company with civil, mechanical and electrical capabilities (nationality Japanese);
ii) a joint venture or partnership between suitably qualified civil and mechanical/ electrical contractors (nationality Japanese);
iii) a civil contractor (nationality Japanese) with a specified, and named, subcontractor to undertake the mechanical/electrical work (nationality Japanese or Sri Lankan);
iv) a mechanical/electrical contractor (nationality Japanese) with a specified, and named, subcontractor to undertake the civil work (nationality Japanese or Sri Lankan).

During the construction period, resident engineers headed by a head chief resident engineer will be fully assigned to the Japanese construction contractor to supervise the overall construction works as shown in Figure 16.1. Engineers on specific fields of expertise such as pumps, valves, electrical control panels, instrumentation and laboratory equipment will assist on a short term basis for equipment installation and test operation.

The Consultant for construction supervisory services will assist NWSDB in making the PQ evaluation, tender announcement, accepting tender applications from tenderers, and evaluating the tenders. After selecting a successful Japanese contractor as the prime contractor, NWSDB will enter into a contract agreement with him as detailed hereunder.

The Consultant will evaluate and give comments on the tender documents submitted after tendering by the selected contractor and will assist NWSDB with the procurement of Project materials and equipment in order to start the Project construction as early as possible.

The Consultant will hold a series of meetings with NWSDB officials and the contractor prior to the commencement of the Project construction works and may witness the shipments of Project materials and equipment to be transported to the Project site, and will provide the Contractor with instructions related to the construction works.

The Consultant will also supervise the Project's construction schedule, be responsible for quality control, and exert efforts to complete the Project's construction on its scheduled completion date.

16.2 Activities in Project Implementation

A construction schedule is prepared as shown in Figure 16.1, taking into account of the rainy season when monthly precipitation would be over 300 mm in October and November. Outdoor works such as earth works and concrete placing may be affected during this season. The construction period is determined to be a total of 33 months, including three month operation and maintenance assistance. The prospective commencement and completion of construction works is thus targeted for early year 2003 and for November 2005, respectively.

The various activities involved with the Tentative Implementation Schedule and the timeframe allocations are briefly explained below. Up to item (20), those activities belong to the pre-construction phase and remaining are to the post-contract and construction phases.

(1) Activity No.1: PQ Document reviewed by TEC

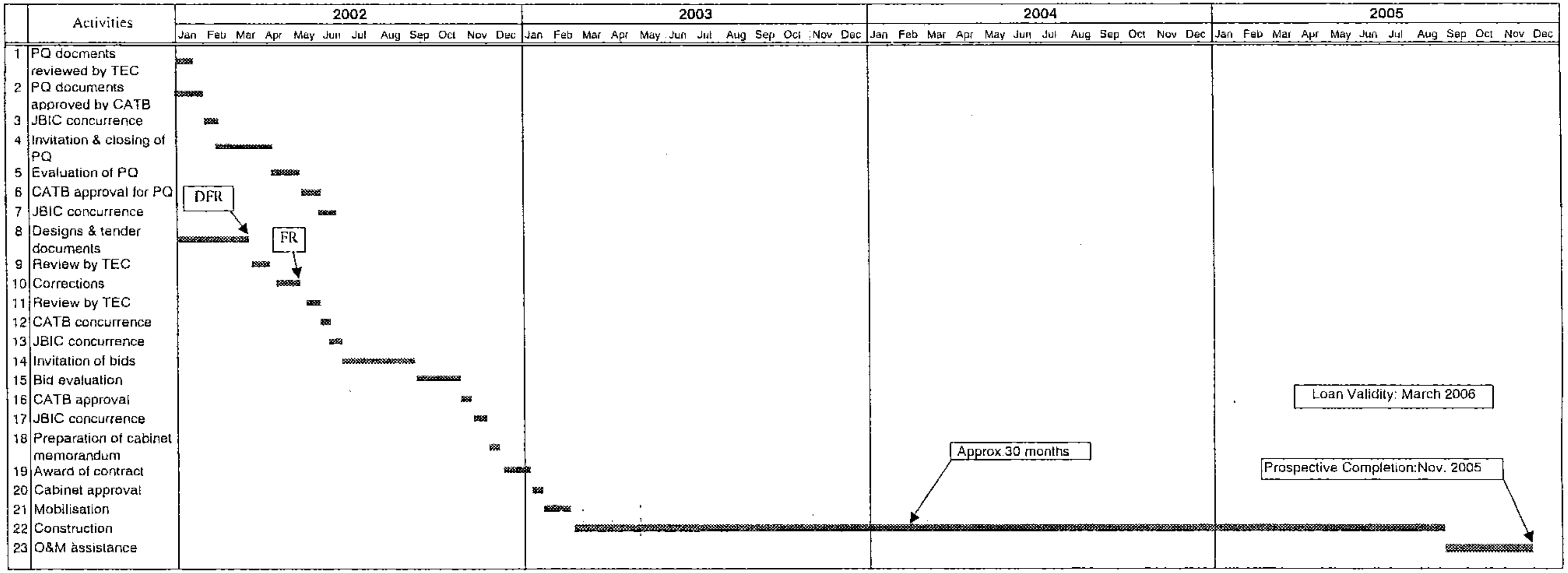
A draft Prequalification Document was submitted in the middle of March 2002 under this Project by the JICA Study Team. However, to facilitate the Project implementation, PIU should finalise the PQ documents assisted by the JICA Study Team with the concurrence of JICA. To review this document before submission to the Cabinet Appointed Tender Board (hereunder referred to as “CATB”), a Technical Evaluation Committee (hereunder referred to as “TEC”) will be appointed by the Secretary of the Treasury (hereunder referred to as “ST”) comprising of a Chairman, a Project Director who will act as Secretary/Member to TEC and one to three technical specialists on the basis of their technical knowledge and skills relevant to the particular project. They can be selected from NWSDB or from other government, semi government organisations, professional associations and private sector. In addition there will be a representative from the treasury. TEC will scrutinise the document by holding periodical review meetings with the Project Team whereby their observations, comments, agreements, and disagreements will be discussed. Two weeks are allocated for completion of this review.

(2) Activity No.2: PQ Document approved by CATB

The approval for all contracts exceeding Rs.250 million value will be granted by CATB. CATB will consist of three members of high ranking staff of Public Service nominated by ST and approved by the Cabinet. Hence, the PQ document will then be referred to CATB by TEC and it will be further scrutinized and the approval could be expected within about one week.

(3) Activity No. 3: JBIC concurrence

After receiving the CATB approval for the PQ document, it should be referred to the funding agency JBIC for its concurrence, which could be expected within a week.



Notes:
1) This schedule is prepared assuming that JICA DD will be finalised in May 2002 and during the DD study NWSDB proceeds to prepare prequalification ducments in close cooperation with the JICA Study Team.
2) DFR: Draft Final Report, FR: Final Report

Figure 16.2 Implementation Schedule for the Project

(4) Activity No. 4: Invitation and Closing of PQ

After receiving approval for the document from CATB and JBIC there will be a time lag of about 3 weeks in order to prepare copies of documents necessary for invitation to tender for prequalification. Afterwards, it is advertised for international bidding for prequalification. In this particular contract only contractors of Japanese origin are qualified to apply for prequalification. Thus a reasonable time is required for the prospective contractors to arrive in the country, study the details of work as well as local conditions and to submit their applications as an individual contractor with or without sub contractors (local or Japanese) or as partnerships. It is estimated that about 8 weeks will be required for this whole process from the time of invitation to prequalify to closing of it.

(5) Activity No. 5: Evaluation of PQ

The next task is the evaluation of the PQ applications. PIU assisted by the Consultants has to carefully scrutinise all applications for their completeness in the information furnished, substantial responsiveness and ascertaining the accuracy of information by other means, if desired so. If there are applications which are incomplete or do not satisfy the requirements stipulated those will have to be rejected. Thus, this prequalification exercise will require about 3 weeks, which includes the compilation of the evaluation report, submission to the TEC, scrutinisation of the report by TEC and the final acceptance.

(6) Activity No. 6: CATB Approval for PQ

TEC approved evaluation report will afterwards be submitted to CATB for its review and concurrence. About 3 weeks will be required for CATB to scrutinize the evaluation report, obtain further clarifications if there are any issues, or to add further amendments prior to granting approval. It is to be noted that the same members for TEC and CATB appointed originally will be involved in this exercise.

(7) Activity No.7: JBIC Concurrence for PQ

After receiving CATB approval for the prequalification it will have to be referred to the JBIC for its concurrence as stipulated in the loan agreement. This will take about 2 weeks and the above whole process will see an end in mid- June 2002 starting from January 2002.

(8) Activity No.8: Designs and Tender Documents

Apart from the prequalification of the contractors, other activities necessary for tendering for the Works also have to be pursued. The preparation of draft final report, designs and tender documents currently in hand are scheduled to be completed by the middle of March 2002.

(9) Activity No. 9: Review by TEC of Tender Documents

The tender documents so prepared have then to be forwarded to the same TEC for review, and around 4 weeks will be required to scrutinise and receive their comments on the documents.

(10) Activity No. 10: Corrections

It is likely that a substantial amount of corrections will be found by TEC on the draft documents prepared by the JICA Study Team, as they are a voluminous one. The JICA Study Team will require four weeks to attend to these corrections.

(11) Activity No. 11: Review by TEC of Tender Documents

The JICA Study Team will submit the corrected documents as the final report to NWSDB by the end of May 2002. Then TEC will review within about two weeks for their acceptance.

(12) Activity No 12:CATB Concurrence for Tender Documents:

It is afterwards forwarded to the CATB and by early June 2002 the approval is expected.

(13) Activity No. 13: JBIC Concurrence for Tender Documents:

As stipulated in the loan agreement the concurrence of JBIC is also to be sought after CATB approval and this is expected in a couple of weeks.

(14) Activity No. 14: Invitation of Tenders;

The next stage is the invitation to tender from the prequalified Japanese contractors and thus the tender documents will be forwarded to them. The completion of tender documents will involve organising site visits, discussions, tender clarifications of the contractors' inquiries on the part of PIU. The prospective contractors will have to familiarise themselves with the country, and gather a vast amount of information about site conditions, local conditions, availability of labour, materials, plant and equipment and their prices, accessibility of sites, weather conditions, prices of imported materials, plant and equipment to be incorporated, government taxes, exchange rates, shipping charges, transport facilities and charges and a host of others details to prepare competitive biddings. Thus 12 weeks are allocated for the tendering process from the time of invitation up to the time of closing of tenders.

(15) Activity No. 15: Tender Evaluation

PIU will then have to commence tender evaluation, which will involve the ascertaining the tenders of their compliance with all stipulated requirements, attending to arithmetical correction, if any, rejection of tenders which do not comply with the requirements, and selecting the most appropriate tender on the basis of lowest evaluated and the substantially responsiveness. The evaluation report so prepared with the assistance of the Consultants based on the evaluation criteria prescribed in the tender documents has to be submitted for the review by TEC and seek their approval, prior to submission for CATB approval. Six weeks are allocated for this evaluation and acceptance by TEC.

(16) Activity No. 16: CATB Approval

This selection of the suitable contractor has then to be referred to CATB and seek its approval, and a period of two weeks will be required to receive its approval, which may require further clarifications by the TEC.

(17) Activity No. 17: JBIC Concurrence

Another two weeks are allocated to refer the selection to JBIC and receive its concurrence, in conformity with the loan conditions stipulated.

(18) Activity No. 18: Preparation of Cabinet Memorandum

The Cabinet will then be informed about the decision on the award of this contract, for which a memorandum has to be prepared and forwarded by TEC, which will require two weeks.

(19) Activity No. 19: Award of Contract;

After presenting this memorandum to the Cabinet the award of the contract can proceed as approved by CATB. The successful contractor has to be informed of the award and he has to notify his acceptance promptly. Afterwards, he has to furnish necessary bonds/bank guarantees, work programmes, cash flow charts, organisation charts, etc., and also there will be a number of meetings to be held by PIU with the contractor for various matters. At the end, the contracts will be signed and this process will take about one month.

(20) Activity No. 20: Cabinet Approval

The award of the contract will then be notified to the Cabinet, and within two weeks the cabinet approval will be expected.

(21) Activity No. 21: Mobilization

The Contractor will require one month for procuring and mobilising his resources to the site, which include labour of various skills, supervising staff, vehicles, plant, equipment, materials, tools, staff accommodation etc. By then it will be the third week of January 2003.

(22) Activity No. 22: Construction

The Contractor will then commence his actual construction, work which is estimated to be completed in approximately 30 months by end of July 2004. The completion will involve successful testing and commissioning of intake, treatment plant, reservoirs, transmission and distribution mains.

(23) Activity No. 23: O & M Assistance

Within the next 12 weeks or 3 months O & M assistance will be implemented to train the NWSDB staff to operate the plant in a safe and trouble free manner under the guidance of the specialists provided by the contractor. O & M manuals for facilities/equipment will be prepared and issued by the Contractor for the operating staff to adhere to these procedures in cooperation with the Consultants. This training will be thorough and will ensure smooth and trouble free operation of the plant after taking over the system by NWSDB.

CHAPTER 17
RECOMMENDATION TOWARDS PROJECT IMPLEMENTATION

CHAPTER 17 RECOMMENDATION TOWARDS PROJECT IMPLEMENTATION

17.1 Pre-contract Phase

Pre-Construction activities for the Project involve basically coordination with the concerned agencies, including JBIC, RDA, etc to minimise or eliminate the adverse impacts on the implementation schedule. Necessary permits such as the excavation permits, permit to cut trees and Environmental Compliance Certificate (ECC) should be secured by NWSDB before selection of the Contractor. It is apparent from the schedule that the approval sequence is lengthy and involves many parties. It is therefore critical for early completion of the Project that the approval sequence is reduced to a minimum.

The works are definitely going to cause temporary inconveniences and hardships to the residents in the Project area in various ways, and will also hamper their day to day activities over short periods. This will de detrimental for the smooth progress of work, if the people will start protesting against their inconveniences/hardships. Therefore, it is prudent that at the end of the Pre-contract period a dissemination programme involving priests/local community leaders/school principles etc., be organised by NWSDB to provide awareness to the people and to seek their cooperation during the construction period for the successful completion of the Project, despite the inconveniences.

(1) JBIC Concurrence for Special Yen Loan

For smooth implementation of the Project, NWSDB should be fully aware of the Procurement Procedure, Schedule 4 of the “Loan Agreement”. During the progress of procurement of goods and services, NWSDB must submit to JBIC at deferent stages requests for review and concurrence as shown in the previous section Figure 16.1. Those submittals to JBIC are:

i) prequalification documents complete with evaluation criteria before advertisement and/or notification of prequalification,

ii) list of prequalified firms and report on the selection process applied, when the prequalified firms would be selected,

iii) tender documents with tender evaluation criteria before inviting tenders, and

iv) contract documents with report on the tender evaluation process after tender will be executed.

NWSDB had to fulfil certain requirements during the pre-contract period involving coordination with the concerned relevant authorities, securing the budget not provided in the JBIC Loan Agreement, procuring of lands for borrow fill, garbage disposal, sludge disposal, and measures for preservation of Mahaweli River water quality. These activities are discussed in detail below.

(2) RDA/ PRDA Concurrence for Pipe Laying

Many of the pipelines are designed to be laid along the Road Development Authority (RDA) and/or the Provincial Road Development Authority (PRDA) roads as it is the only option available, which is causing much annoyance to RDA /PRDA due to damage caused to the roads, despite the fact that these will be reinstated, and inconvenience to the traffic during the construction period. RDA/PRDA require all the pipelines to be laid along the verge without unnecessarily damaging the road carriageway. However, this is not practically possible in general always, as at places underground utilities such as water, telecom and electricity lines occupy the verges. Despite the fact that trial test excavations had been carried out on the verges along the roads at selected locations where pipelines are to be laid, it is impossible to identify all the location of underground services with 100 percent accuracy. The information so gathered is useful as guidelines only and therefore, the coordination with these agencies namely NWSDB itself, CEB and Telecom are also equally vital to identify the location of such utilities, but not much results may be achieved as there may not be proper as built drawings maintained by these agencies, and the memory of their respective field staff would only be helpful. It is also to be noted that there are certain minor roads owned by the Pradeshiya Sabahs (PS), and the permission for these roads will be granted by the respective PS.

(3) UDA Concurrence for Building Application Forms

Kandy having being nominated as a World Heritage City, any new building/structure to be constructed will require the approval of the Urban Development Authority (UDA), in order to prevent any structures not in conformity with traditional Kandian architecture being built. Hence, UDA approval has been necessary for the construction of the Intake at Gohagoda, Treatment Plant at Katugastota and the service reservoir at Uplands. For this a complete set of drawings had to be forwarded to UDA for their scrutiny. Any work, however small which will not be in conformity with the desired architecture will have to be amended as per the recommendations by UDA. This application is currently being pursued by UDA and seems acceptable.

In addition to these approvals, the approval of the respective local authority (e.g. KMC/PS) is also required for the proposed construction works in respect of the Intake, Treatment Plant, Pumping Stations, Service Reservoirs and Transmission and Distribution Mains (for the roads owned by PSs). In case of KMC area it is KMC which has the jurisdiction to grant approval, and in the other areas it is the relevant Pradeshiya Sabha. Completed application forms with the necessary payments have been tendered to pursue with the approval procedure. These applications for buildings/structures will be scrutinised by the local authorities (KMC/PS) to determine whether the local by-laws relating to such structures are complied with, before granting approvals.

(4) CEA Concurrence for EIA for Uplands Service Reservoir

Uplands service reservoir site is located in a preserved area within a forest reserve, where no construction work is permitted, and therefore special permission has to be sought from the Central Environmental Authority (CEA). To do so, an Environmental Impact Assessment (EIA) report has to be prepared and submitted to the Authority to substantiate that there will be no damage to the environment due to this work during or after construction. This report needs to be comprehensive and convincing in order to receive the required approval.

(5) Secure of Budget

The following five items of expenditure have been identified in the Loan Agreement as not being eligible for financing under the agreement, and GOSL shall bear such costs.

- General administration expenses
- Taxes and duties
- Purchase of land and other real property
- Compensation
- Other indirect items

It is herewith intended to discuss these matters in brief to understand their implications on the GOSL financing.

i) <u>General Administration Expenses:</u> NWSDB has to maintain PIU for the management of the Contract provided with office facilities, transport, overtime, allowances in addition to the assistance provided by the counterpart Consultant's staff. If adequate staff having the requisite experience could not be found or released from NWSDB, such staff will have to be engaged on contract basis at higher salary levels than the established NWSDB salary structure of similar categories. Consequently, all expenses incurred in maintaining this unit including all staff remunerations, office facilities etc., will have to be borne by GOSL

ii) <u>Taxes and Duties:</u> It is agreed that payment of all custom duties and taxes on imported items, and all forms of GST, NSL etc., will be borne by using counterpart fund. This condition will apply for the payment of the contractor's monthly payment certificate as well.

iii) <u>Purchase of Land and Other Real Property:</u> The construction of almost all structures (intake, treatment plant, service reservoirs, booster pump houses, access roads to the intake and treatment plant) require acquisition of land for which compensation has to be paid to the owners of these lands according to the government valuations, or at mutually agreed prices. This will be the responsibility of NWSDB.

iv) <u>Compensation:</u> Any loss or damage caused to a third party not covered under the contract, and outside of insurance cover and contractor's risks will become a subject of compensation. For an example, if the construction works require relocation of certain families temporarily or permanently it will be a compensation event. Such costs will have to be borne by NWSDB.

v) <u>Other Indirect Items:</u> It is not easy to precisely identify such costs at this stage, and there can be numerous ways these can arise. For example, there can arise litigation by a certain person or a party against the some loss or inconvenience caused by the works, or the contractor may decide to apply for arbitration over a certain dispute, which could not be amicably settled. Such situations will cause expenditures, which will have to be borne by NWSDB.

Likewise, NWSDB may need to allocate own counterpart fund to fulfil the Project costs if tender result is not successful, or the scope of work may be adjusted and carry out tender again to meet the budget.

(6) Borrow Fill

The construction works especially at the Treatment Plant involve large quantities of earthwork, and it is likely that there will be a significant amount of imported earth arising out of these works. This imported earth will have to be borrowed on time to facilitate preparation works for construction. Hence, suitable borrow fill areas will have to be identified and arranged during the pre-construction phase.

(7) Garbage Removal from the Proposed Gohagoda Site

One of the serious issues was garbage removal form the vicinity of the Gohagoda Intake since the previous JICA Study had conducted. NWSDB should, in collaboration with KMC and other authorities concerned, secure a suitable dumping site.

(8) Sludge Disposal Sites

At the proposed Katugastota Treatment Plant a considerable amount of grit/sludge will be generated continuously. NWSDB should take action for selection of sludge disposal site immediately, further to the selection of garbage dumping site.

(9) Preservation Programme for Mahaweli River Water Quality

Although the studies carried out under the detailed designs have confirmed that the present water quality of the Mahaweli River is acceptable as a source of drinking water with the type of treatment adopted, there is a potential risk of the river water quality deteriorating in the future due to increase in population, unsanitary living conditions, and various other human activities as well as the increased water supply. This situation may be aggravated further during dry seasons when the river flow drops considerably. Hence, it is recommended that implementation of the preservation programme including the proposed Sewerage Treatment Plant Project for Kandy too will be considered as an urgent need and given highest priority, if necessary.

17.2 Activities During Construction Phase

(1) Effective Construction Supervision

In order to achieve the Project completion as designed in quality and on time as scheduled, it is recommended that NWSDB will vest the selected Consultants with authority to exercise their technical expertise on the Project.

(2) Organization Set Up and Participation for Training on O & M

The Project is an extensive one and requires well-experienced and responsible personnel who are familiar with the intricacies of operation and maintenance. When selecting staff for this Project their qualifications, knowledge and skills in the O & M field should be given the highest priority for selection. It may also become necessary to transfer some experienced in-house staff from other places like Ambatale, who have the necessary know how to operate the project with confidence.

Notwithstanding, all selected staff should be given a thorough training in their respective operational activities, as their previous experiences alone will not be sufficient to operate this project efficiently. The method of training, duration etc. remains to be decided. Their training should cover not only the operation of the project in a trouble free and efficient manner, but also should ensure that the plant will function its full life time without any hindrance by implementing proper preventive maintenance procedures.

(3) Secure O & M Cost

On completion of the Project NWSDB will have to take over and operate it, which will require annually over 80 million Rupees of funds for staff payments, chemicals, transport, power supply, repairs, general maintenance and a host of other expenses. Hence, it is necessary that all these different cost components are identified and the annual O & M cost is evaluated, in order to allocate the necessary funds for the operation of this Project. This costing will also reflect whether the current water tariff system would be adequate to meet the annual O & M expenses of the Project, and if not the tariff system may have to be revised upwards to make it sustainable.

17.3 Post Construction Phase Activities

(1) Implementation of Preventive Maintenance

Preventive maintenance as detailed in the previous chapter plays a major role in ensuring the smooth and trouble free operation of the Project over its full designed lifetime. The O & M manuals prepared by the Consultants will provide the necessary guidelines in this regard possibly in chart forms towards the end of Construction Phase, and these measures will have to be strictly adhered to. In addition, during the training periods provided to various categories of staff these measures and their importance will be explained.

Reduction of Non Revenue Water, which is still at a very high level, is one of the first problems to be looked into. NWSDB should be the sole agency responsible for operation and maintenance of the water supply systems including leakage detection and correction.

It is advisable to maintain registers for each item/equipment so that details of preventive maintenance carried out could be recorded to guarantee that every item/equipment needing preventive maintenance is not left in abeyance. Mapping and records are a vital part of any water transmission and distribution system, as without them no utility can operate efficiently and the utility will be dependent upon the memories of long-time employees, which will result in a loss of much valuable information with the retirement of each employee. To arrest such a situation monitoring system built in the Administration Building should be utilised effectively. Comprehensive maps should always be made available complete with the national grid lines. This will facilitate the accurate location of all points. As-built drawings of all pipelines shall be properly maintained as drawings and in the computer as electronic files. In addition, it is often necessary to modify or to relocate the pipelines, and these drawings should then be updated accordingly.

(2) Adjustment of Water Demand

NWSDB should identify the areas to be served by the each service reservoir, and should analyse the water demand in every year. The planned demand in the served area set in the detailed design and actual demand should be monitored regularly and compared. If there is a discrepancy, demand allocation should be modified based on the actual findings.

(3) Update Master Plan

In Greater Kandy area outside KMC limits, large-scale development plans are earmarked in accordance with the Development Plan for Kandy (1997). Such proposed future developments will have a major impact on the water supply the Greater Kandy areas. Therefore, NWSDB should coordinate with the related authorities concerned and update the 1999 Master Plan every five to ten years to achieve its mission effectively and sufficiently to encourage the potential future growth in Greater Kandy area.

APPENDICES

APPENDIX 1

KMC WTP OPERATION IN THE YEAR 2000

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
					Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
	Intake Rate		Tu	pH	Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Jan	1,409	33,816	12	6.9						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
2-Jan	1,413	33,905	10	7.0	1.8	2.5	7.1	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
3-Jan	1,408	33,791	8	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.4	1.0	1.0	2.0	1.4
4-Jan	1,464	35,134	10	6.9	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
5-Jan	1,458	34,982	12	7.0	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
6-Jan	1,449	34,785	8	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
7-Jan	1,458	35,002	8	7.0	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
8-Jan	1,466	35,176	8	6.8	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
9-Jan	1,458	34,987	30	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.2	2.5	1.8
10-Jan	1,486	35,671	50	6.8	1.7	2.5	6.7	10.0	8.4	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.2	2.5	1.8
11-Jan	1,448	34,755	20	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.2	2.5	1.8
12-Jan	1,418	34,028	18	6.9	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	0.8	2.0	1.4
13-Jan	1,469	35,249	9	6.9	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.8	1.5	1.0	2.0	1.8
14-Jan	1,435	34,444	20	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.8	1.5	1.0	2.0	1.8
15-Jan	1,451	34,827	23	7.0	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.8	1.5	1.0	2.0	1.8
16-Jan	1,384	33,222	28	6.9	1.8	2.5	7.2	10.0	9.0	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.2	2.0	1.8
17-Jan	1,401	33,628	55	7.0	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
18-Jan	1,412	33,885	18	6.9	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
19-Jan	1,408	33,794	14	6.8	0.9	1.25	3.6	5.0	4.4	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
20-Jan	1,390	33,360	9	6.8	0.9	1.25	3.6	5.0	4.5	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
21-Jan	1,375	32,996	8	6.8	1.8	2.5	7.3	10.0	9.1	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.2	2.0	1.8
22-Jan	1,407	33,757	12	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
23-Jan	1,364	32,747	10	6.9						0.4	0.5	0.4	0.5	0.8	0.8	1.5	1.0	2.0	1.8
24-Jan	1,395	33,488	8	7.0	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.8	1.5	1.0	2.0	1.8
25-Jan	1,389	33,328	8	6.9						0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
26-Jan	1,376	33,029	8	6.9	1.8	2.5	7.3	10.0	9.1	0.8	1.0	0.8	1.0	1.5	0.8	1.5	1.0	2.0	1.8
27-Jan	1,423	34,163	8	6.8	1.8	2.5	7.0	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
28-Jan	1,407	33,779	9	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
29-Jan	1,430	34,312	13	6.9	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
30-Jan	1,428	34,267	12	7.0						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
31-Jan	1,337	32,085	8	6.8	1.9	2.5	7.5	10.0	9.4	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
Max	1,486	35,671	55	7.0	1.9	2.5	7.5	10.0	9.4	0.8	1.0	0.8	1.0	1.6	0.8	1.5	1.2	2.5	1.8
Ave	1,420	34,077	15.3	6.9	1.7	2.4	6.8	9.6	8.5	0.7	0.9	0.7	0.9	1.3	0.6	1.1	1.0	2.0	1.7
Min	1,337	32,085	8.0	6.8	0.9	1.3	3.6	5.0	4.4	0.4	0.5	0.4	0.5	0.7	0.4	1.0	0.8	2.0	1.4

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
	Intake Rate		Tu	pH	Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
					Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Feb	1,410	33,837	12	6.9	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
2-Feb	1,404	33,696	25	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
3-Feb	1,425	34,192	33	6.9	1.8	2.5	7.0	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
4-Feb	1,377	33,051	16	6.8						0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
5-Feb	1,403	33,667	8	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
6-Feb	1,432	34,361	26	6.8						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
7-Feb	1,395	33,491	80	6.9	3.6	5.0	14.3	20.0	17.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
8-Feb	1,393	33,433	67	6.8	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
9-Feb	1,430	34,316	25	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
10-Feb	1,426	34,226	70	6.7	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
11-Feb	1,340	32,157	26	6.8	1.9	2.5	7.5	10.0	9.3	1.2	1.6	1.2	1.6	2.3	0.6	1.0	1.0	2.0	1.6
12-Feb	1,384	33,221	18	6.8	1.8	2.5	7.2	10.0	9.0	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
13-Feb	1,344	32,249	12	7.0	1.9	2.5	7.4	10.0	9.3	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
14-Feb	1,438	34,518	9	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
15-Feb	1,220	29,271	8	6.9	2.0	2.5	8.2	10.0	10.2	0.4	0.5	0.4	0.5	0.9	0.6	1.0	1.0	2.0	1.6
16-Feb	1,396	33,494	10	7.0	1.8	2.5	7.2	10.0	9.0	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
17-Feb	1,432	34,365	7	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
18-Feb	1,408	33,783	10	6.9						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
19-Feb	1,425	34,202	7	6.9	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
20-Feb	1,435	34,442	13	6.9	2.0	2.9	8.2	11.7	10.2	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
21-Feb	1,435	34,436	160	6.7	2.0	2.9	8.2	11.7	10.2	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
22-Feb	1,466	35,190	240	6.8	4.3	6.3	17.1	25.0	21.3	1.4	2.1	1.4	2.1	2.8	0.6	1.0	1.0	2.0	1.6
23-Feb	1,407	33,775	200	6.9	4.4	6.3	17.8	25.0	22.2	1.5	2.1	1.5	2.1	3.0	0.6	1.0	1.0	2.0	1.6
24-Feb	1,434	34,425	80	6.8	3.5	5.0	13.9	20.0	17.4	1.5	2.1	1.5	2.1	2.9	0.6	1.0	1.0	2.0	1.6
25-Feb	1,453	34,864	60	6.8	1.7	2.5	6.9	10.0	8.6	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
26-Feb	1,423	34,160	20	6.7	1.8	2.5	7.0	10.0	8.8	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
27-Feb	1,442	34,607	12	7.2	1.7	2.5	6.9	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
28-Feb	1,316	31,588	13	6.9	1.9	2.5	7.6	10.0	9.5	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
29-Feb	1,402	33,652	12	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
Max	1,466	35,190	240	7.2	4.4	6.3	17.8	25.0	22.2	1.5	2.1	1.5	2.1	3.0	0.6	1.0	1.0	2.0	1.6
Ave	1,403	33,678	44	6.9	2.1	3.0	8.6	12.1	10.7	0.8	1.1	0.8	1.1	1.6	0.6	1.0	1.0	2.0	1.6
Min	1,220	29,271	7	6.7	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
	Intake Rate		Tu	pH	Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
					Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Mar	1,367	32,798	35	6.8	1.8	2.5	7.3	10.0	9.1	1.1	1.6	1.1	1.6	2.3	0.6	1.0	1.0	2.0	1.6
2-Mar	1,364	32,744	16	6.9	1.8	2.5	7.3	10.0	9.2	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
3-Mar	1,451	34,820	13	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
4-Mar	1,408	33,789	10	6.9						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
5-Mar	1,269	30,465	9	6.8	2.0	2.5	7.9	10.0	9.8	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
6-Mar	1,384	33,216	30	7.1	1.8	2.5	7.2	10.0	9.0	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
7-Mar	1,397	33,519	30	6.8	3.6	5.0	14.3	20.0	17.9	1.5	2.1	1.5	2.1	3.0	0.6	1.0	1.0	2.0	1.6
8-Mar	1,386	33,268	34	6.9	1.8	2.5	7.2	10.0	9.0	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
9-Mar	1,401	33,619	140	6.8	3.9	5.4	15.5	21.7	19.3	1.5	2.1	1.5	2.1	3.0	0.6	1.0	1.0	2.0	1.6
10-Mar	1,453	34,862	62	6.8	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
11-Mar	1,425	34,194	79	6.8	3.5	5.0	14.0	20.0	17.5	1.5	2.1	1.5	2.1	2.9	0.6	1.0	1.0	2.0	1.6
12-Mar	1,440	34,568	20	7.2	2.3	3.3	9.3	13.4	11.6	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
13-Mar	1,410	33,830	15	6.9	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
14-Mar	1,459	35,008	12	6.9	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
15-Mar	1,377	33,044	13	6.9	1.8	2.5	7.3	10.0	9.1	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
16-Mar	1,415	33,963	14	6.9	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
17-Mar	1,417	33,999	15	6.9	1.8	2.5	7.1	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
18-Mar	1,414	33,927	8	6.8						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
19-Mar	1,395	33,486	10	6.9	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
20-Mar	1,420	34,081	6	6.9	1.8	2.5	7.0	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
21-Mar	1,401	33,627	8	6.9						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
22-Mar	1,416	33,973	7	7.0	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
23-Mar	1,370	32,874	8	6.8	1.8	2.5	7.3	10.0	9.1	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
24-Mar	1,427	34,247	12	6.9						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
25-Mar	1,351	32,417	8	6.8	1.9	2.5	7.4	10.0	9.3	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
26-Mar	1,351	32,426	70	6.8	4.6	6.3	18.5	25.0	23.1	2.3	3.1	2.3	3.1	4.6	0.6	1.0	1.0	2.0	1.6
27-Mar	1,372	32,927	42	6.8	2.8	3.8	10.9	15.0	13.7	1.5	2.1	1.5	2.1	3.0	0.6	1.0	1.0	2.0	1.6
28-Mar	1,366	32,785	52	6.8	1.8	2.5	7.3	10.0	9.2	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
29-Mar	1,397	33,522	20	6.8	1.8	2.5	7.2	10.0	8.9	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
30-Mar	1,400	33,608	12	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
31-Mar	1,395	33,487	8	6.9	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
Max	1,459	35,008	140	7.2	4.6	6.3	18.5	25.0	23.1	2.3	3.1	2.3	3.1	4.6	0.6	1.0	1.0	2.0	1.6
Ave	1,397	33,519	26.4	6.9	2.2	3.0	8.6	12.0	10.8	0.8	1.1	0.8	1.1	1.6	0.6	1.0	1.0	2.0	1.6
Min	1,269	30,465	6.0	6.8	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate															
	Intake Rate		Tu	pH	Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
					Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Apr	1,420	34,079	10	6.9	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.2	0.5	1.0	2.0	1.2
2-Apr	1,412	33,887	35	7.0	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.2	0.5	0.9	2.0	1.1
3-Apr	1,404	33,692	14	6.9	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.2	0.5	0.9	2.0	1.1
4-Apr	1,386	33,264	200	6.8	3.0	4.2	12.0	16.6	15.0	1.1	1.6	1.1	1.6	2.3	0.4	1.0	0.9	2.0	1.3
5-Apr	1,316	31,576	128	6.9	4.4	5.8	17.8	23.4	22.2	1.6	2.1	1.6	2.1	3.2	0.6	1.0	1.0	2.0	1.6
6-Apr	1,424	34,175	70	6.9	1.8	2.5	7.0	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
7-Apr	1,349	32,385	104	6.8	3.1	4.2	12.3	16.6	15.4	1.2	1.6	1.2	1.6	2.3	0.4	1.0	1.0	2.0	1.4
8-Apr	1,432	34,372	198	6.8	2.9	4.2	11.6	16.6	14.5	1.1	1.6	1.1	1.6	2.2	0.4	1.0	1.0	2.0	1.4
9-Apr	1,417	34,004	70	6.8	4.1	5.8	16.5	23.4	20.6	1.5	2.1	1.5	2.1	2.9	0.6	1.0	1.0	2.0	1.6
10-Apr	1,426	34,227	40	7.0	1.8	2.5	7.0	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
11-Apr	1,444	34,658	29	7.0	3.5	5.0	13.8	20.0	17.3	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
12-Apr	1,407	33,766	23	6.9	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
13-Apr	1,421	34,100	40	7.0	3.5	5.0	14.1	20.0	17.6	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
14-Apr	1,454	34,901	31	7.1						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
15-Apr	1,357	32,560	15	7.0	1.8	2.5	7.4	10.0	9.2	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
16-Apr	1,402	33,650	17	7.0	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
17-Apr	1,417	34,010	18	7.0	1.8	2.5	7.1	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
18-Apr	1,312	31,499	34	6.8	1.9	2.5	7.6	10.0	9.5	0.4	0.5	0.4	0.5	0.8	0.4	1.0	1.0	2.0	1.4
19-Apr	1,368	32,828	300	6.8	4.9	6.7	19.5	26.7	24.4	1.5	2.1	1.5	2.1	3.0	0.6	1.0	1.0	2.0	1.6
20-Apr	1,385	33,235	327	6.9	4.8	6.7	19.3	26.7	24.1	1.9	2.6	1.9	2.6	3.8	0.6	1.0	1.0	2.0	1.6
21-Apr	1,410	33,846	132	6.8	3.8	5.4	15.4	21.7	19.2	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
22-Apr	1,421	34,108	70	6.8	1.8	2.5	7.0	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
23-Apr	1,304	31,305	49	6.8	1.9	2.5	7.7	10.0	9.6	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
24-Apr	1,459	35,005	50	6.9	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	0.8	2.0	1.4
25-Apr	1,434	34,421	30	6.9	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
26-Apr	1,454	34,901	23	6.8	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
27-Apr	1,421	34,096	24	7.0	1.8	2.5	7.0	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
28-Apr	1,452	34,842	20	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
29-Apr	1,421	34,099	18	6.8	3.5	5.0	14.1	20.0	17.6	1.5	2.1	1.5	2.1	2.9	0.6	1.0	1.0	2.0	1.6
30-Apr	1,441	34,592	14	6.9	1.7	2.5	6.9	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
Max	1,459	35,005	327	7.1	4.9	6.7	19.5	26.7	24.4	1.9	2.6	1.9	2.6	3.8	0.6	1.0	1.0	2.0	1.6
Ave	1,406	33,736	71	6.9	2.5	3.6	10.1	14.2	12.7	0.8	1.1	0.8	1.1	1.5	0.5	1.0	1.0	2.0	1.5
Min	1,304	31,305	10	6.8	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.2	0.5	0.8	2.0	1.1

Date	Raw Water				Chemical Dosage / Feeding Rate														
Year	Intake Rate		Tu	pH	Alum					Pre Lime		Post Lime		TTL	Pre Cl2		Post Cl2		TTL
2000					Aerator		Pulsator		TTL	Aerator		After Pulsation		Lime					Cl2
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-May	1,398	33,557	19	6.9	3.6	5.0	14.3	20.0	17.9	1.1	1.6	1.1	1.6	2.2	0.8	2.0	1.0	2.0	1.8
2-May	1,430	34,327	19	6.8	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.8	2.0	1.0	2.0	1.8
3-May	1,397	33,539	20	6.9	3.9	5.4	15.5	21.7	19.4	1.1	1.6	1.1	1.6	2.2	0.8	2.0	1.0	2.0	1.8
4-May	1,397	33,539	35	6.8	3.6	5.0	14.3	20.0	17.9	1.5	2.1	1.5	2.1	3.0	0.8	2.0	1.0	2.0	1.8
5-May	1,412	33,893	52	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.8	2.0	1.0	2.0	1.8
6-May	1,446	34,709	18	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.8	2.0	1.0	2.0	1.8
7-May	1,445	34,688	40	6.8	3.7	5.4	15.0	21.7	18.8	1.4	2.1	1.4	2.1	2.9	0.8	2.0	1.0	2.0	1.8
8-May	1,390	33,348	24	7.0	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.8	2.0	1.0	2.0	1.8
9-May	1,443	34,629	14	7.0	1.7	2.5	6.9	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.8	2.0	1.0	2.0	1.8
10-May	1,412	33,884	32	6.9	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.8	2.0	1.0	2.0	1.8
11-May	1,436	34,462	48	6.8	3.5	5.0	13.9	20.0	17.4	1.1	1.6	1.1	1.6	2.2	0.8	2.0	1.0	2.0	1.8
12-May	1,441	34,590	15	6.9	1.7	2.5	6.9	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.8	2.0	1.0	2.0	1.8
13-May	1,450	34,811	15	6.8	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.8	2.0	1.0	2.0	1.8
14-May	1,347	32,336	14	6.8	1.9	2.5	7.4	10.0	9.3	0.8	1.0	0.8	1.0	1.5	0.8	2.0	1.0	2.0	1.8
15-May	1,365	32,760	10	6.8	1.8	2.5	7.3	10.0	9.2	0.8	1.0	0.8	1.0	1.5	0.6	1.0	0.8	2.0	1.4
16-May	1,405	33,710	8	6.9	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
17-May	1,414	33,934	10	6.9	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
18-May	1,396	33,498	13	6.8	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
19-May	1,378	33,067	9	6.8	1.8	2.5	7.3	10.0	9.1	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
20-May	1,366	32,784	12	6.9	1.8	2.5	7.3	10.0	9.2	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
21-May	1,404	33,706	13	6.9	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
22-May	1,394	33,452	15	6.8	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
23-May	1,390	33,361	8	6.8	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
24-May	1,414	33,933	8	6.9	1.8	2.5	7.1	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
25-May	1,396	33,495	9	6.8	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
26-May	1,392	33,414	10	6.8						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
27-May	1,437	34,494	15	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
28-May	1,420	34,078	12	6.8	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
29-May	1,395	33,472	7	7.0	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
30-May	1,430	34,323	9	7.0	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
31-May	1,426	34,216	318	6.8	2.7	3.8	10.5	15.0	13.2	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
Max	1,450	34,811	318	7.0	3.9	5.4	15.5	21.7	19.4	1.5	2.1	1.5	2.1	3.0	0.8	2.0	1.0	2.0	1.8
Ave	1,409	33,807	27.5	6.9	2.1	3.0	8.5	11.9	10.6	0.7	1.0	0.7	1.0	1.5	0.7	1.5	1.0	2.0	1.7
Min	1,347	32,336	7.0	6.8	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	0.8	2.0	1.4

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate																
	Intake Rate		Tu	pH	Alum					Pre Lime Aerator		Post Lime After Pulsation		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
					Aerator		Pulsator		TTL										
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Jun	1,465	35,166	220	6.8	4.5	6.6	18.2	26.7	22.7	1.4	2.1	1.4	2.1	2.8	0.6	1.0	1.0	2.0	1.6
2-Jun	1,290	30,957	90	6.8	2.2	2.9	9.1	11.7	11.3	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
3-Jun	1,389	33,334	60	6.7	3.6	5.0	14.4	20.0	18.0	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
4-Jun	1,391	33,386	42	6.9	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
5-Jun	1,414	33,930	52	6.8	3.8	5.4	15.3	21.7	19.2	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
6-Jun	1,371	32,910	80	6.7	2.1	2.9	8.5	11.7	10.6	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
7-Jun	1,408	33,781	72	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
8-Jun	1,436	34,459	39	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
9-Jun	1,293	31,026	53	6.8	3.9	5.0	15.5	20.0	19.3	1.2	1.6	1.2	1.6	2.4	0.6	1.0	1.0	2.0	1.6
10-Jun	1,422	34,116	46	6.8	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
11-Jun	1,358	32,588	42	6.9	1.8	2.5	7.4	10.0	9.2	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
12-Jun	1,303	31,272	68	6.8	1.9	2.5	7.7	10.0	9.6	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
13-Jun	1,442	34,619	42	7.0	1.7	2.5	6.9	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
14-Jun	1,413	33,906	30	6.8	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
15-Jun	1,378	33,070	22	7.0	1.8	2.5	7.3	10.0	9.1	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
16-Jun	1,455	34,925	10	6.9	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
17-Jun	1,430	34,319	13	6.9	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
18-Jun	1,340	32,158	10	7.0	1.9	2.5	7.5	10.0	9.3	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
19-Jun	1,362	32,681	50	6.8	3.7	5.0	14.7	20.0	18.4	1.1	1.6	1.1	1.6	2.3	0.6	1.0	1.0	2.0	1.6
20-Jun	1,397	33,523	22	6.9	1.8	2.5	7.2	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
21-Jun	1,381	33,154	24	6.9	1.8	2.5	7.2	10.0	9.0	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
22-Jun	1,383	33,183	33	6.9	1.8	2.5	7.2	10.0	9.0	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
23-Jun	1,406	33,734	20	7.0	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
24-Jun	1,411	33,860	10	6.9	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
25-Jun	1,391	33,381	10	6.9	1.8	2.5	7.2	10.0	9.0	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
26-Jun	1,417	34,000	10	6.8	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
27-Jun	1,438	34,506	15	6.8	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
28-Jun	1,363	32,708	32	6.9	3.4	4.6	13.4	18.3	16.8	1.1	1.6	1.1	1.6	2.3	0.6	1.0	1.0	2.0	1.6
29-Jun	1,434	34,417	40	6.7	3.5	5.0	13.9	20.0	17.4	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
30-Jun	1,414	33,944	48	6.8	1.8	2.5	7.1	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
Max	1,465	35,166	220	7.0	4.5	6.6	18.2	26.7	22.7	1.4	2.1	1.4	2.1	2.8	0.6	1.0	1.0	2.0	1.6
Ave	1,393	33,434	44	6.9	2.3	3.2	9.1	12.7	11.4	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
Min	1,290	30,957	10	6.7	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
	Intake Rate		Tu	pH	Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
					Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Jul	1,362	32,694	60	6.8	2.1	2.9	8.6	11.7	10.7	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
2-Jul	1,405	33,710	93	6.8	1.8	2.5	7.1	10.0	8.9	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
3-Jul	1,439	34,545	68	6.8	1.7	2.5	6.9	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
4-Jul	1,417	34,011	22	6.9	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
5-Jul	1,395	33,484	32	6.8	1.8	2.5	7.2	10.0	9.0	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
6-Jul	1,402	33,645	20	6.9	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
7-Jul	1,452	34,857	29	6.9	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
8-Jul	1,416	33,984	30	6.8	1.8	2.5	7.1	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
9-Jul	1,433	34,393	12	7.1	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
10-Jul	1,411	33,863	15	7.0	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
11-Jul	1,449	34,770	14	6.9	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
12-Jul	1,390	33,369	14	6.8	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
13-Jul	1,455	34,929	13	6.8	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
14-Jul	1,442	34,616	14	6.8	1.7	2.5	6.9	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
15-Jul	1,432	34,366	12	6.7	1.7	2.5	7.0	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
16-Jul	1,447	34,723	14	6.9	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
17-Jul	1,503	36,081	14	6.8	1.7	2.5	6.7	10.0	8.3	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
18-Jul	1,439	34,536	13	6.9	1.7	2.5	6.9	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
19-Jul	1,440	34,552	14	6.7	1.7	2.5	6.9	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
20-Jul	1,428	34,271	10	6.9	1.8	2.5	7.0	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
21-Jul	1,439	34,524	10	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
22-Jul	1,447	34,731	12	6.8	0.9	1.25	3.5	5.0	4.3	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
23-Jul	1,430	34,330	11	6.9	0.9	1.25	3.5	5.0	4.4	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
24-Jul	1,411	33,862	10	6.9	1.8	2.5	7.1	10.0	8.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
25-Jul	1,462	35,098	12	6.9	1.7	2.5	6.8	10.0	8.5	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
26-Jul	1,432	34,367	12	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
27-Jul	1,401	33,629	13	6.9	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
28-Jul	1,409	33,808	60	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
29-Jul	1,426	34,234	35	6.9	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
30-Jul	1,437	34,492	19	6.9	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
31-Jul	1,453	34,869	16	7.0	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
Max	1,503	36,081	93	7.1	2.1	2.9	8.6	11.7	10.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
Ave	1,429	34,301	23.3	6.9	1.7	2.4	6.8	9.7	8.5	0.6	0.9	0.6	0.9	1.2	0.6	1.0	1.0	2.0	1.6
Min	1,362	32,694	10.0	6.7	0.9	1.3	3.5	5.0	4.3	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
					Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
	Intake Rate		Tu	pH	Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Aug	1,431	34,351	20	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
2-Aug	1,402	33,641	24	7.0	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
3-Aug	1,343	32,222	14	6.8	1.9	2.5	7.4	10.0	9.3	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
4-Aug	1,397	33,531	30	6.8	1.8	2.5	7.2	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
5-Aug	1,384	33,215	12	6.9	0.9	1.25	3.6	5.0	4.5	1.1	1.6	1.1	1.6	2.3	0.6	1.0	1.0	2.0	1.6
6-Aug	1,297	31,117	13	7.0	1.0	1.25	3.9	5.0	4.8	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
7-Aug	1,436	34,460	22	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
8-Aug	1,409	33,824	24	6.9	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
9-Aug	1,428	34,282	23	6.8	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
10-Aug	1,415	33,966	37	6.9	1.8	2.5	7.1	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
11-Aug	1,451	34,823	15	6.9						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
12-Aug	1,431	34,337	13	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
13-Aug	1,454	34,904	20	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
14-Aug	1,420	34,068	96	7.1	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
15-Aug	1,441	34,580	70	6.8						0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
16-Aug	1,332	31,963	30	6.8	1.9	2.5	7.5	10.0	9.4	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
17-Aug	1,377	33,048	13	6.8						0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
18-Aug	1,471	35,301	33	6.8	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
19-Aug	1,436	34,458	44	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
20-Aug	1,438	34,515	50	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
21-Aug	1,427	34,258	32	6.8						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
22-Aug	1,457	34,973	52	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
23-Aug	1,404	33,704	42	6.8	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
24-Aug	1,180	28,331	34	6.8	2.5	2.9	9.9	11.7	12.4	1.3	1.6	1.3	1.6	2.6	0.6	1.0	1.0	2.0	1.6
25-Aug	1,343	32,220	150	6.9	2.2	2.9	8.7	11.7	10.9	1.2	1.6	1.2	1.6	2.3	0.6	1.0	1.0	2.0	1.6
26-Aug	1,359	32,605	170	6.8	4.0	5.4	16.0	21.7	19.9	1.5	2.1	1.5	2.1	3.1	0.6	1.0	1.0	2.0	1.6
27-Aug	1,398	33,554	98	6.8	1.8	2.5	7.2	10.0	8.9	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
28-Aug	1,429	34,292	48	6.8	3.5	5.0	14.0	20.0	17.5	1.5	2.1	1.5	2.1	2.9	0.6	1.0	1.0	2.0	1.6
29-Aug	1,432	34,376	65	6.8	1.7	2.5	7.0	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
30-Aug	1,421	34,102	40	6.8	1.8	2.5	7.0	10.0	8.8	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
31-Aug	1,443	34,637	32	7.0	1.7	2.5	6.9	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
Max	1,471	35,301	170	7.1	4.0	5.4	16.0	21.7	19.9	1.5	2.1	1.5	2.1	3.1	0.6	1.0	1.0	2.0	1.6
Ave	1,403	33,666	44.1	6.9	1.9	2.6	7.6	10.6	9.4	0.8	1.2	0.8	1.2	1.7	0.6	1.0	1.0	2.0	1.6
Min	1,180	28,331	12.0	6.8	0.9	1.3	3.6	5.0	4.5	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
					Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
	Intake Rate		Tu	pH	Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Sep	1,414	33,933	23	6.8						0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
2-Sep	1,344	32,252	12	7.0	1.9	2.5	7.4	10.0	9.3	1.2	1.6	1.2	1.6	2.3	0.6	1.0	1.0	2.0	1.6
3-Sep	1,397	33,516	9	7.2	1.8	2.5	7.2	10.0	9.0	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
4-Sep	1,333	31,983	15	7.0						0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
5-Sep	1,414	33,934	14	6.9	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
6-Sep	1,405	33,718	16	7.1	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
7-Sep	1,421	34,108	17	7.0	0.9	1.25	3.5	5.0	4.4	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
8-Sep	1,428	34,275	15	6.9	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
9-Sep	1,281	30,744	19	6.8	2.0	2.5	7.8	10.0	9.8	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
10-Sep	1,337	32,099	13	6.8						0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
11-Sep	1,424	34,175	14	6.9	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
12-Sep	1,415	33,955	12	6.9	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
13-Sep	1,410	33,831	13	6.9						0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
14-Sep	1,418	34,030	10	6.8	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
15-Sep	1,437	34,498	12	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
16-Sep	1,415	33,966	13	7.0	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
17-Sep	579	13,901	9	6.9						0.9	0.5	0.9	0.5	1.8	0.6	1.0	1.0	2.0	1.6
18-Sep	684	16,404	10	6.8						1.5	1.0	1.5	1.0	3.0	0.6	1.0	1.0	2.0	1.6
19-Sep	1,387	33,294	50	6.8	1.8	2.5	7.2	10.0	9.0	1.1	1.6	1.1	1.6	2.3	0.6	1.0	1.0	2.0	1.6
20-Sep	1,425	34,191	80	6.8	2.3	3.3	11.5	16.4	13.8	1.5	2.1	1.5	2.1	2.9	0.6	1.0	1.0	2.0	1.6
21-Sep	1,409	33,807	82	6.8	1.8	2.5	7.1	10.0	8.9	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
22-Sep	1,422	34,116	48	6.8	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
23-Sep	1,426	34,220	32	6.9	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
24-Sep	1,467	35,197	196	6.8	3.1	4.6	12.5	18.3	15.6	1.4	2.1	1.4	2.1	2.8	0.6	1.0	1.0	2.0	1.6
25-Sep	1,474	35,379	142	6.8	3.4	5.0	13.6	20.0	17.0	1.8	2.6	1.8	2.6	3.5	0.6	1.0	1.0	2.0	1.6
26-Sep	1,472	35,339	73	6.9	1.7	2.5	6.8	10.0	8.5	1.1	1.6	1.1	1.6	2.1	0.6	1.0	1.0	2.0	1.6
27-Sep	1,513	36,310	40	6.9	1.7	2.5	6.6	10.0	8.3	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
28-Sep	1,460	35,030	25	6.8	1.7	2.5	6.9	10.0	8.6	1.1	1.6	1.1	1.6	2.1	0.6	1.0	1.0	2.0	1.6
29-Sep	1,424	34,187	38	6.9	1.8	2.5	7.0	10.0	8.8	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
30-Sep	1,428	34,279	48	6.9	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
Max	1,513	36,310	196	7.2	3.4	5.0	13.6	20.0	17.0	1.8	2.6	1.8	2.6	3.5	0.6	1.0	1.0	2.0	1.6
Ave	1,362	32,689	37	6.9	1.9	2.7	7.6	10.8	9.5	0.9	1.3	0.9	1.3	1.9	0.6	1.0	1.0	2.0	1.6
Min	579	13,901	9	6.8	0.9	1.3	3.5	5.0	4.4	0.7	0.5	0.7	0.5	1.4	0.6	1.0	1.0	2.0	1.6

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
	Intake Rate		Tu	pH	Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
					Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Oct	1,450	34,795	48	6.8	1.7	2.5	6.9	10.0	8.6	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
2-Oct	1,430	34,308	52	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
3-Oct	1,394	33,446	30	6.7	1.8	2.5	7.2	10.0	9.0	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
4-Oct	1,375	33,009	22	6.9	1.8	2.5	7.3	10.0	9.1	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
5-Oct	1,408	33,798	20	6.7	1.8	2.5	7.1	10.0	8.9	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
6-Oct	1,430	34,331	80	7.0	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
7-Oct	1,268	30,424	60	6.9	2.0	2.5	7.9	10.0	9.9	1.2	1.6	1.2	1.6	2.5	0.6	1.0	1.0	2.0	1.6
8-Oct	1,330	31,930	28	6.8	1.9	2.5	7.5	10.0	9.4	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
9-Oct	1,462	35,094	25.	6.9	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
10-Oct	1,418	34,035	18	6.8	1.8	2.5	7.1	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
11-Oct	1,447	34,724	15	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
12-Oct	1,463	35,119	23	6.9	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
13-Oct	1,377	33,055	120	6.7	2.1	2.9	8.5	11.7	10.6	1.1	1.6	1.1	1.6	2.3	0.6	1.0	1.0	2.0	1.6
14-Oct	1,434	34,425	160	6.8	3.5	5.0	13.9	20.0	17.4	1.5	2.1	1.5	2.1	2.9	0.6	1.0	1.0	2.0	1.6
15-Oct	1,064	25,527	60	6.9	2.4	2.5	9.4	10.0	11.8	1.0	1.0	1.0	1.0	2.0	0.6	1.0	1.0	2.0	1.6
16-Oct	1,418	34,031	30	7.0	1.8	2.5	7.1	10.0	8.8	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
17-Oct	1,425	34,208	72	6.8	1.8	2.5	7.0	10.0	8.8	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
18-Oct	1,407	33,777	70	6.8	1.8	2.5	7.1	10.0	8.9	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
19-Oct	1,452	34,850	58	6.9	1.7	2.5	6.9	10.0	8.6	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
20-Oct	1,444	34,664	36	6.8	1.7	2.5	6.9	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
21-Oct	1,440	34,557	14	7.0	1.7	2.5	6.9	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
22-Oct	1,435	34,447	14	7.2	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
23-Oct	1,405	33,731	15	7.0						0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
24-Oct	1,400	33,605	88	6.8	1.8	2.5	7.1	10.0	8.9	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
25-Oct	1,466	35,178	64	6.8	2.6	3.8	10.2	15.0	12.8	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
26-Oct	1,500	36,008	30	6.8	1.7	2.5	6.7	10.0	8.3	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
27-Oct	1,451	34,818	14	7.0	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
28-Oct	1,504	36,104	13	7.0						0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
29-Oct	1,454	34,903	12	6.9	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
30-Oct	1,470	35,274	12	7.1	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
31-Oct	1,410	33,831	13	6.9	1.2	1.7	4.7	6.6	5.9	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
Max	1,504	36,104	160	7.2	3.5	5.0	13.9	20.0	17.4	1.5	2.1	1.5	2.1	2.9	0.6	1.0	1.0	2.0	1.6
Ave	1,414	33,936	42.5	6.9	1.9	2.6	7.4	10.5	9.3	0.9	1.2	0.9	1.2	1.8	0.6	1.0	1.0	2.0	1.6
Min	1,064	25,527	12.0	6.7	1.2	1.7	4.7	6.6	5.9	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
					Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
	Intake Rate		Tu	pH	Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Nov	1,373	32,957	30	6.9	1.8	2.5	7.3	10.0	9.1	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
2-Nov	1,434	34,406	40	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
3-Nov	1,419	34,048	50	6.8	1.8	2.5	7.0	10.0	8.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
4-Nov	1,384	33,205	75	6.8	2.7	3.8	10.8	15.0	13.6	1.5	2.1	1.5	2.1	3.0	0.6	1.0	1.0	2.0	1.6
5-Nov	1,375	33,001	28	6.8	1.8	2.5	7.3	10.0	9.1	0.4	0.5	0.4	0.5	0.8	0.6	1.0	1.0	2.0	1.6
6-Nov	1,418	34,035	22	6.8	1.8	2.5	7.1	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
7-Nov	1,442	34,618	15	6.9	1.7	2.5	6.9	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
8-Nov	1,442	34,617	120	6.8	3.5	5.0	13.9	20.0	17.3	1.4	2.1	1.4	2.1	2.9	0.6	1.0	1.0	2.0	1.6
9-Nov	1,436	34,453	100	6.7	1.7	2.5	7.0	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
10-Nov	1,430	34,310	40	6.9	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
11-Nov	1,436	34,457	20	6.9	1.7	2.5	7.0	10.0	8.7	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
12-Nov	1,432	34,378	60	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
13-Nov	1,446	34,698	45	6.8	1.7	2.5	6.9	10.0	8.6	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
14-Nov	1,000	23,990	20	6.8	2.5	2.5	10.0	10.0	12.5	0.5	0.5	0.5	0.5	1.0	0.6	1.0	1.0	2.0	1.6
15-Nov	1,457	34,961	18	7.0	1.7	2.5	6.9	10.0	8.6	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
16-Nov	1,488	35,708	8	7.2	1.7	2.5	6.7	10.0	8.4	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
17-Nov	1,337	32,093	28	6.9	1.9	2.5	7.5	10.0	9.3	0.8	1.0	0.8	1.0	1.6	0.6	1.0	1.0	2.0	1.6
18-Nov	1,495	35,879	200	6.7	3.3	5.0	13.4	20.0	16.7	1.7	2.6	1.7	2.6	3.5	0.6	1.0	1.0	2.0	1.6
19-Nov	1,480	35,515	92	6.9	1.7	2.5	6.8	10.0	8.4	1.1	1.6	1.1	1.6	2.1	0.6	1.0	1.0	2.0	1.6
20-Nov	1,471	35,302	86	6.9	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
21-Nov	1,434	34,411	65	6.8	1.7	2.5	7.0	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
22-Nov	1,446	34,705	30	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
23-Nov	1,455	34,908	80	6.9	1.7	2.5	6.9	10.0	8.6	1.1	1.6	1.1	1.6	2.1	0.6	1.0	1.0	2.0	1.6
24-Nov	1,446	34,715	38	6.8	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
25-Nov	1,454	34,901	26	6.8	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
26-Nov	1,437	34,477	95	6.7	3.5	5.0	13.9	20.0	17.4	1.8	2.6	1.8	2.6	3.6	0.6	1.0	1.0	2.0	1.6
27-Nov	1,481	35,553	15	6.9	1.7	2.5	6.8	10.0	8.4	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
28-Nov	1,442	34,619	16	6.9	1.7	2.5	6.9	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
29-Nov	1,418	34,021	14	6.8	1.8	2.5	7.1	10.0	8.8	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
30-Nov	1,433	34,389	16	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
Max	1,495	35,879	200	7.2	3.5	5.0	13.9	20.0	17.4	1.8	2.6	1.8	2.6	3.6	0.6	1.0	1.0	2.0	1.6
Ave	1,421	34,111	50	6.8	2.0	2.8	7.9	11.2	9.8	0.8	1.2	0.8	1.2	1.7	0.6	1.0	1.0	2.0	1.6
Min	1,000	23,990	8	6.7	1.7	2.5	6.7	10.0	8.4	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
					Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
	Intake Rate		Tu	pH	Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
1-Dec	1,469	35,265	15	6.8	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
2-Dec	1,428	34,272	14	6.8	0.9	1.25	3.5	5.0	4.4	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
3-Dec	1,428	34,279	12	7.2	0.9	1.25	3.5	5.0	4.4	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
4-Dec	1,419	34,063	12	6.9	1.8	2.5	7.0	10.0	8.8	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
5-Dec	1,473	35,343	11	6.9	1.7	2.5	6.8	10.0	8.5	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6
6-Dec	1,483	35,580	13	6.8	1.7	2.5	6.7	10.0	8.4	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
7-Dec	1,424	34,170	14	6.8	1.8	2.5	7.0	10.0	8.8	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
8-Dec	1,462	35,091	12	6.9	1.7	2.5	6.8	10.0	8.5	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
9-Dec	1,425	34,202	12	6.8	1.8	2.5	7.0	10.0	8.8	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
10-Dec	1,424	34,171	15	6.8	1.8	2.5	7.0	10.0	8.8	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
11-Dec	1,455	34,929	11	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
12-Dec	1,437	34,482	13	6.8	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
13-Dec	1,443	34,627	14	6.8	1.7	2.5	6.9	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
14-Dec	1,446	34,696	15	6.8	1.7	2.5	6.9	10.0	8.6	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
15-Dec	1,451	34,821	13	6.9	1.7	2.5	6.9	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
16-Dec	1,445	34,681	12	6.8	1.7	2.5	6.9	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
17-Dec	1,439	34,530	10	6.9	1.7	2.5	7.0	10.0	8.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
18-Dec	1,433	34,395	18	6.8	1.7	2.5	7.0	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
19-Dec	1,418	34,036	25	6.7	2.0	2.9	8.3	11.7	10.3	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
20-Dec	1,435	34,436	42	6.9	1.7	2.5	7.0	10.0	8.7	1.1	1.6	1.1	1.6	2.2	0.6	1.0	1.0	2.0	1.6
21-Dec	1,405	33,725	24	6.9	1.8	2.5	7.1	10.0	8.9	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
22-Dec	1,425	34,211	18	7.0	1.2	1.7	4.6	6.6	5.8	0.7	1.0	0.7	1.0	1.5	0.6	1.0	1.0	2.0	1.6
23-Dec	1,446	34,709	20	6.8	1.2	1.7	4.6	6.6	5.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
24-Dec	1,373	32,956	24	6.8	1.8	2.5	7.3	10.0	9.1	0.8	1.0	0.8	1.0	1.5	0.6	1.0	1.0	2.0	1.6
25-Dec	1,442	34,607	50	6.8	1.2	1.7	4.6	6.6	5.8	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
26-Dec	1,322	31,738	55	6.9	2.9	3.8	11.3	15.0	14.2	1.2	1.6	1.2	1.6	2.4	0.6	1.0	1.0	2.0	1.6
27-Dec	1,234	29,619	78	6.7	4.1	5.0	16.2	20.0	20.3	1.2	1.5	1.2	1.5	2.4	0.6	1.0	1.0	2.0	1.6
28-Dec	1,461	35,055	50	7.0	1.7	2.5	6.8	10.0	8.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
29-Dec	1,485	35,641	39	6.9	1.1	1.7	4.4	6.6	5.6	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
30-Dec	1,445	34,670	30	6.8	1.2	1.7	4.6	6.6	5.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
31-Dec	1,463	35,122	22	6.7	1.2	1.7	4.5	6.6	5.7	0.7	1.0	0.7	1.0	1.4	0.6	1.0	1.0	2.0	1.6
Max	1,485	35,641	78	7.2	4.1	5.0	16.2	20.0	20.3	1.2	1.6	1.2	1.6	2.4	0.6	1.0	1.0	2.0	1.6
Ave	1,430	34,327	23.0	6.8	1.7	2.4	6.7	9.6	8.4	0.8	1.2	0.8	1.2	1.7	0.6	1.0	1.0	2.0	1.6
Min	1,234	29,619	10.0	6.7	0.9	1.3	3.5	5.0	4.4	0.4	0.5	0.4	0.5	0.7	0.6	1.0	1.0	2.0	1.6

Date Year 2000	Raw Water				Chemical Dosage / Feeding Rate														
					Alum					Pre Lime		Post Lime		TTL Lime	Pre Cl2		Post Cl2		TTL Cl2
	Intake Rate		Tu	pH	Aerator		Pulsator		TTL	Aerator		After Pulsation							
	(m3/h)	(m3/day)			(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)	(mg/l)	(kg/h)	(mg/l)	(kg/h)	(mg/l)
Year Ave.	1,407	33,777	37.1	6.9	2.0	2.8	8.0	11.2		0.8	1.1	0.8	1.1		0.6	1.0	1.0	2.0	

APPENDIX 2

STUDY ON POLYETHYLENE PIPE

Study on Polyethylene Pipe

This working paper presents the study results of polyethylene pipes to be applied for the water pipelines for the phase 1 development of Greater Kandy Water Supply Augmentation Project. In this Project, uPVC for nominal diameters of 75 mm to 225 mm and DI for larger than 250 mm in diameter were originally adopted. However, as advised by NWSDB, for pipes of 250 mm to 400 mm in diameter, polyethylene pipe shall be considered as an alternative pipe material for DI, since material cost of polyethylene pipe appears to be cheaper than the cost of DI.

1. GENERAL

Polyethylene Pipes have been used in water pipeline systems since the 1950's. In Europe, the polyethylene pipe is standardized with a nominal diameter (outside diameter) according to ISO standard and differs from the outside diameter of JIS standard. In the U.S.A., AWWA (Ac901) standard is adopted for manufacturing polyethylene pipes for nominal diameter (the inside of nominal value). The outer diameter is almost the same as that of JIS standard.

In Japan, in one hand, the polyethylene pipe for water service is specified by JIS standard, up to 50mm (the inside of nominal value) of diameters, and moreover, it is manufactured by the manufacturers standard to 150mm of diameter according to JIS standard.

2. MATERIAL

Base material for polyethylene is thermoplastic resin representing petrochemistry, and is widely used for films, electric wire coverings, automobile parts, lamp-oil cans, daily necessities, etc. As regards density, polyethylene has low density (LDPE), medium density (MDPE), and high density (HDPE) varieties, and have different properties according to the manufacture method and each molecular structure.

Polyethylene resin currently being used for the polyethylene pipes for water service is roughly divided into low-density polyethylene (L-LDPE or MDPE) manufactured by low/medium pressure method and high-density polyethylene (HDPE). In general, gas industry has been using two kinds of polyethylene pipes, PE80 a medium density polyethylene (MDPE) and PE100 high-density polyethylene (HDPE)..

2.1 Standards and References

The high-density polyethylene or equivalent quality shall be applied with the following reference standards.

(1) ISO
- ISO 3607 – 1997 (E)

Polyethylene pipes – tolerance on outside diameter and wall thickness

- ISO/DIS – 427 DRAFT INTERNATIONAL STANDARD

  Polyethylene pipes for water supply Specifications

(2) Britain

- BS 6572

  Blue Polyethylene pipes up to nominal size 63 for below ground use for portable water
- BS 6730

  Black polyethylene pipe up to nominal size 63 for above ground use for portable water
- BS 791 (3)

  Cross-linked polyethylene pipes & fittings and for hot & cold water and heating installations
- WRC 4-32-03 (*1)

  Specification for black-polyethylene pressure pipe for cold portable water (nominal size 90 to 1000 for underground or protected use)
- WRC 4-32-09

  Specification for black polyethylene Pressure pipes for portable water above ground or average (nominal size 90 to 1000)
- WRC 4-32-13

  Specification for blue higher performance Polyethylene, HDPE/PE100, pressure pipes, nominal size 90 to 1000, for underground or protected use for the conveyance of water intended for human consumption

(3) U.S.

- AWWA C901-88

  Polyethylene pressure pipe and tubing, 1/2 in. through 3 in., for water service
- AWWA C906-90

  Polyethylene pressure pipe and fittings, 4 in. through 63 in., for water distribution

(4) Japan

- JIS K 6762:1998

  Double wall polyethylene pipes for water supply
- JWWA K144 (Pipe) and JWWA K145 (Fittings)

Note: (*1) WRC is the abbreviation for the WATER RESERCH CENTRE in England performing water services, pollution prevention, and activities related to environmental preservation not only in Britain, but widely known as an independent investigation body and a consulting company in the world.

2.2 Features of Polyethylene Pipe (PEP)

The typical features of the polyethylene pipe (PEP) for water service are as follows:

(1) Advantages

a. It is lightweight hence easy to handle at the time of conveyance
b. PEP has excellent corrosion resistance and is not corroded by natural soil and stray electric currents.
c. PEP has shock resistance, and a shockproof property does not fall significantly even at low temperature, since it excels in cold resistance
d. PEP has flexibility, thus pipe can be installed along the planned route with geographical features and a few bending installations without bends are being used.
e. Cutting of PEP can be simply performed by the pipe cutter, and can also ensure easy jointing by welding, and its construction workmanship is good.

(2) Disadvantages

a. PEP is deteriorated by sunlight, therefore, should be stored indoors and is not suitable for above ground piping.
b. Chemicals may intrude polyethylene, such as the organic solvent of benzene, toluene, etc., gasoline, lamp oil, and white and extermination, or smell may be intruded, thus caution is required.
c. PEP is easily deformed by external load, and therefore not suitable for piping under main (heavy traffic) roads.
d. PEP is not suitable for high-pressure pipelines because of its inferior strength. (Less that 0.75 MPa in static pressure is preferable.)
e. Skilled labours for PEP are required to ensure the cutting surface accuracy and proper welding using the special equipment.

3. INSTALLATION WORK

3.1 General Installation

The dimensions of trench width should never be less than the outside diameter of pipe plus 250 mm to allow for correct compaction of sidefill. Normal minimum depth of cover for mains should be 900 mm from ground level to the top of pipe. Stones and other hard objects should be removed from trench, and a minimum of 100 mm sand bedding is required. Jointing holes shall be excavated wider than normal width for fusion joint equipment space and workers.

3.2 Jointing

There are two jointing methods of fusion, butt fusion and electro fusion. The outline of both methods is as follows:

(1) Butt fusion

In butt fusion, the pipe ends to be joined are brought together in a dedicated butt fusion machine. The end faces are squared up by planning with a mechanical trimmer, then heated with a thermostatically controlled non-stick heater plate. When molten, the faces are pushed together and allowed to cool.

(2) Electro fusion

This joint method uses socket-type fittings with integral heating elements to construct a pipe system. Couplers are used to join mains pipe. Within an electro fusion fitting there is a resistive heating wire connected to surface terminals. An electrical current passed through the wire melts the polymer and fuses the fitting to the pipe wall. The pipe to be prepared by scraping away the outer surface layer, then pipe and fitting are clamper together to restrain movement. An electrical current is applied across the terminals from a generator via a control box (generally 40 V). After welding, the assembly is allowed to cool thoroughly before unclamping.

(3) Safe handling of molten material

Gloves must be worn if there is any risk of skin contract. Great care should be taken where there is a risk of PEP residues adhering to heated surfaces such as heating plates used for welding. Some ventilation is important in ensuring safe working conditions.

(4) Welding equipment

The following equipment and tools are required for welding.

- Generator
- Welding machine of suitable size, including clamp frame, clamp shells, trimmer, controller and hydraulic pump
- Pipe support rollers
- Pipe end covers
- Welding tent
- External/internal debeading tool
- Bead gage
- Calibrated digital thermometer and probe
- Timer

4. DESIGN CONDITION

Considering the features of PEP as described in the previous section, and the planned transmission system and distribution network systems in this project under the topographical condition of Kandy area, the following design conditions are established.

1) PEP is applicable for 250 mm to 400 mm diameter as requested by NWSDB.

2) PEP should be able to subject to a static pressure of 0.75 MPa or less.
3) PEP should be laid under general roads (less traffic load) and footpath.
4) PEP shall not be laid above ground.
5) PE 100 high-density polyethylene pipe should be applied on this project to the following specification.

Diameter	SDR (*)	Pressure Rating
250-400 mm	11	16 bar

Note: (*) means Standard Dimensional Ratio (SDR) = Outside diameter/wall thickness.

6) Electro fusion joint method shall be used for larger diameter (250-400 mm), since the wall thickness is high as shown below.

Diameter (mm)	Thickness (mm)
225	No standard
250	25.2
315	31.7
355	35.7
400	40.2

5. COST COMPARISON

The price quotations (CIF Colombo) of PEP and DI taken from Durapipe, UK and Kubota, Japan, as at end of August 2001 are as follows:

(1) PEP (PE 100, electro fusion method)

Straight Pipe Dia. x Length	Pipe Price (Yen)	EF Coupler (Yen)	Equipment (Yen)	Shipment (Yen)	Total Price (Yen)
225 x 6000	12,236	12,887	502	5,125	30,750
250 x 6000	15,059	18,788	676	6,905	41,428
315 x 6000	23,910	31,132	1,100	11,228	67,370
355 x 6000	30,318	45,974	1,526	15,564	93,382
400 x 6000	38,553	55,386	1,878	19,163	114,980

Note: Equipment cost is estimated 2 % of (pipe + EF coupler).

(2) DI (push-on type with rubber ring)

Straight Pipe Dia. x Length	Pipe Price (Yen)	Equipment (Yen)	Shipment (Yen)	Total Price (Yen)
200 x 6000	27,485	275	4,164	31,924
250 x 6000	36,452	365	5,523	42,340
300 x 6000	46,290	463	7,013	53,766
350 x 6000	59,441	594	9,005	69,040
400 x 6000	71,376	714	10,814	82,904

Note: Equipment cost is estimated 1.0 % of pipe price.

The above tables reveal that PEP is more economical than DI for small diameter (smaller than 250 mm) and DI is advantageous for the larger diameters (larger than 300 mm). UK and the study reports in Japan also establish almost the same tendency.

6. RECOMMENDATION AND COMMENTS

Consequent to the above study, the Study Team recommends the use of DI for pipes larger than 250 mm in diameter in the original design criteria, due to the following reasons:

- DI has been used in the water supply field for a long time in Sri Lanka, including in Kandy and outside Kandy water supply schemes, thus NWSDB is very familiar with DI.
- According to the cost comparison, DI is almost same
- To limit the use of several types of pipe materials in the pipeline systems, (e.g. DI, uPVC, ACP and steal pipes) taking into consideration of maintenance and repair aspects of pipelines, lesser kinds of pipe materials are preferable.
- Many kinds of jointing equipment and special skills are required for welding joints, thus more complicated jointing work for PEP than DI.
- PEP shall be used for small diameters (for instance, house connections) in the Phase 1 Project, and thereafter larger size PEP will be used in Phase 2 and 3.

However, if NWSDB is still desirous to use PEP on this project, the followings are our recommendations as this is the first introduction of PEP in Kandy and outside Kandy water supply schemes.

- Additional stocks of welding equipment and tools shall be kept for repair or maintenance of PEP, at the warehouse of NWSDB.
- Spare parts and repair materials of PEP shall be stored.
- As build drawings for PEP shall be kept properly at the NWSDB office.
- Catalogues and technical instruction manuals submitted by manufacturers shall be kept at the NWSDB office.
- The skilled workers for PEP installations need to be trained.
- It is recommended that smaller than 180 mm in nominal diameter PEP may be applied for the Phase 1 project, because of butt fusion (easier and cheaper than electro fusion method) is the suitable jointing method for such small diameter range and transportation or handling is easy by coils or drums.

When PEP is applied, the PEP manufacturers shall dispatch several skilled labours (supervisors) to the work site for about 2 – 3 months during the installation stage. The PEP manufacturers should undertake installation supervision and the technical transfer to the local staff of NWSDB, since the installation work of such large size PEP is the first ever experience for NWSDB.

APPENDIX 3

PROPOSED MECHANICAL EQUIPMENT

Greater Kandy Water Supply Augumentation Project

Mechanical Equipment List

Facility/Equipment	Tag	Phase		Specification		Motor
	No.	Duty	St'd-by			(kW)
01-Raw Water Intake Facility						
Coarse Screen	01 CS 11/21	2	0	Bar Screen	2.0mW x 5.0mH x 50mm	-
Screening Hoist	01 MH 01	1	0	Elecrtically Operated	0.5 t	0.8 + 0.4
Inflow Gate	01 HG 11/21	2	0	Hand Operated Sluice	1.5mW x 1.5mH, L= 6.2m	-
Fine Screen	01 FS 11/21	2	0	Motorized Net Screen	2.0mW x 7.0mH x 15mm	2.2
Screen Wash Pump	01 SW 01/02	1	1	Submersible	0.6m3/min x 42.0m	11
Outflow Gate	01 HG 12/22	1	0	Hand Operated Sluice	1.5mW x 1.5mH, L= 6.2m	-
Raw Water Pump	01 RP 11/21	1	1	Vertical Centrifugal	26.74 m3/min x 44.0m	280
Discharge Valve	01 MV 11/21	2	2	Motorized Butterfly	400mmdia.	0.2
Sump Drainage Pump	01 DP 01/02	1	1	Submersible	0.1 m3/min x 15.0m	1.5
Overhead Hoist	01 HC 01	1	0	Manual Operated	3.0 t x 14 mH	-
05-Distribution Chamber						
Distribution Valve	05 HV 11/21	2	0	Hand Operated Sluice	500mm dia. , L= 5.51m	-
Alum Distribution Tank	05 AT 01	1	0	Stailess Steel	0.4mW x 1.2mL x 0.4mH	-
06-Flocculation/Sedimentation Basins						
Sludge Collector	06 SC 11/12/21/22	4	0	Reciprocating Flight	5.35mW x 40.1m Span	0.75
De-sludge Valve	06 MV 11 to 24	8	0	Elecrtically Operated	Eccentric 150 mm	0.2
Sampling Pump	06 SP 01	1	0	Self-priming Centrifugal	0.06 m3/min x 12.0m	0.4
07-Filtration Units						
Inflow Gate	07 MG 11 to 41	4	0	Motorized Sluice	0.4mW x 0.4mH, L= 2.09m	0.4
Backwash Drainage Gate	07 MG 12 to 42	4	0	Motorized Sluice	0.5mW x 0.5mH, L= 3.55m	0.4
Effluent Valve	07 MV 11 to 41	4	0	Motorized Butterfly	350mmdia.	0.2
Backwash Valve	07 MV 12 to 42	4	0	Motorized Butterfly	350mmdia.	0.2
Air Scour Valve	07 MV 13 to 43	4	0	Motorized Butterfly	250mmdia.	0.2
Drain Valve	07 HV 11 to 41	4	0	Manual Sluice	150mmdia.	-
Backwash Pump	07 BP 51 to 71	2	1	Horizontal Centrifugal	7.72 m3/min x 8 m	18.5
Air Blower	07 AB 11 to 21	1	1	Roots Blower	62 Nm3/min x 3500mmAq	55
Sump Drainage Pump	07 DP 01/02	1	1	Submersible	0.1 m3/min x 15.0m	1.5
Lime Mixing Tank	07 LT 11	1	0	Cylindrical	1.5 m3 (1.2mdia. x 1.6mH)	-
Lime Mixer	07 MM 11	1	0	Vertical	(1.2mdia. x 1.6mH)	0.4
Lime Feed Pump	07 LP 11/21	1	1	Progressing Cavity Pump	7.6 l/min x 5 m	0.4
09-Clear Water Pump Station						
Transmission Pump (A-1)	09 CP 11/12	1	1	Horizontal Centrifugal	11.83 m3/min x 137m	450
Transmission Pump (A-2)	09 CP 21/22	1	1	Horizontal Multi-Stage	4.08 m3/min x 104m	90
Transmission Pump (A-3)	09 CP 31/32	1	1	Horizontal Centrifugal	10.24 m3/min x 102m	250
Discharge Valve (A-1)	09 MV 11/12	1	1	Motorized Butterfly	300mmdia. x 17 kgf/cm2	0.2
Discharge Valve (A-2)	09 MV 21/22	1	1	Motorized Butterfly	150mmdia. x 15 kgf/cm2	0.2
Discharge Valve (A-3)	09 MV 31/32	1	1	Motorized Butterfly	300mmdia. x 15 kgf/cm2	0.2
Sump Drainage Pump	09 DP 01/02	1	1	Submersible	0.1 m3/min x 12.0m	1.5
Plant Water Supply Unit	09 PU 01	1	0	Water Supply Unit	1.6 m3/min x 30 m	7.5 x 2
Chlorination Booster Pump	09 PP 11/21	1	1	Horizontal Centrifugal	0.26 m3/min x 45.0 m	5.5
Overhead Crane	09 HC 01	1	0	Manual Operated	7.5 t x 9.0mW	-
10-Chemical Building						
Alum Dosing System						
Alum Mixer	10 MM 11/12	2	0	Vertical	(2.0m x 2.0m x 2.5mH)	1.5
Alum Level Tank	10 AT 01	1	0	Cylindrical	500 mm dia.	-
Alum Pump	10 AP 11/21	1	1	Progressing Cavity Pump	12 l/min x 10 m	0.4
Lime Dosing System						
Lime Mixer	10 MM 21/22	2	0	Vertical	(2.0m x 2.0m x 2.5mH)	2.2
Lime Level Tank	10 LT 01	1	0	Cylindrical	500 mm dia.	-
Lime Pump	10 LP 11/21	1	1	Rubber Lined Centrifugal	0.2m3/min x 10 m	5.5
Lime Feed Pump	10 LP 31/41	1	1	Progressing Cavity Pump	12 l/min x 10 m	0.4
Lime Dust Extraction Fan	10 EF 11	1	0	Multiblade Fan	10m3/min x 50 mmAq	0.75
Lime Dust Extraction Tank	10 GW 11	1	0	Water Spray	0.4mW x 1.8mL x 0.4mH	-
Chemical Crane	10 MC 01	1	0	Motorized with Trolley	2.0 t	1.1 + 0.4
Chlorination System						
Chlorine Container	10 CC 01 to 14	2	12	Steel Container	1.0 t Cylinder	-
Weighing Scale	10 WD 01	2	0	Losd Cell	4.0 t	-
Chlorinator - Pre	10 CL 11/12	1	1	Self-Stand Vacuum	12 kg/hr	0.025
Chlorinator - Post	10 CL 21/22	1	1	Self-Stand Vacuum	5 kg/hr	0.025
Injector	10 IJ 11/21	2	0			-
Chlorine Crane	10 MC 02	1	0	Motorized with Trolley	2.0 t	1.1 + 0.4
11-Backwash Recovery Facility						
Recycle Inlet Valve	11 HV 11/21	2	0	Manual Sluice	700mmdia.	-
Backwash Recovery Pump	11 WP 11/21	1	1	Horizontal Slurry	4.45 m3/min x 15 m	30
Sump Drainage Pump	11 DP 01/02	1	1	Submersible	0.1 m3/min x 15.0m	1.5
12-Sludge Lagoons						
Sludge Lagoon Inlet Valve	12 HG 11 to 21	2	0	Manual Sluice	450mmdia. , L= 1.6m	-
304-Kahawatta (E)						
Booster Pump	304 BP 11/21	1	1	Horizontal Centrifugal	2.94 m3/min x 64m	55
Chlorination Unit						
Mixer	304 MM 11/12	1	0	Vertical	(0.9m x 0.9m x 0.9mH)	0.4
Hypo-chlorite Tank	304 AT 01	1	0	Vertical Rectangular	500 l	-
Hypo-chlorite Pump	304 AP 11/21	1	0	Diaphragm Pump	350ml/min x 30 m	0.4
310-Kondadeniya (H)						
Booster Pump	310 BP 11/21	1	1	Horizontal Centrifugal	1.11 m3/min x 64m	30
315-Asgiriya (G)						
Booster Pump	315 BP 11/21	1	1	Horizontal Centrifugal	1.58 m3/min x 68m	30
318-R2 (F)						
Booster Pump	318 BP 11/21	1	1	Horizontal Centrifugal	1.36 m3/min x 102m	55
320-Heerasagala Low (B)						
Booster Pump	320 BP 11/21	1	1	Horizontal Centrifugal	1.90 m3/min x 68m	37
321-Heerasagala Middle (C)						
Booster Pump	321 BP 11/21	1	1	Horizontal Centrifugal	0.49 m3/min x 77m	18.5
324-Ampitiya (D)						
Booster Pump (D-1)	324 BP 11/21	1	1	Horizontal Centrifugal	0.83 m3/min x 45m	11
Booster Pump (D-2)	324 BP 11/21	1	1	Horizontal Centrifugal	0.68 m3/min x 146m	37
Booster Pump (D-3)	324 BP 11/21	1	1	Horizontal Centrifugal	1.49 m3/min x 73m	37

APPENDIX 4

TENTATIVE CONSTRUCTION SCHEDULE

A Tentative Construction Schedule

1. WATER TREATMENT PLANT

The contractor after award of the Contract will have to carry out a thorough study of the Engineer's drawings relating to the Intake facility, Conveyance Facility, and Water Treatment Plant and first of all will have to prepare his shop drawings and obtain the Engineer's approval for them. This will nearly take about 7 months, during which period no site activities can take place. In the meantime he will have to draw up his work programmes to select the most suitable one identifying the critical and non critical items, which would give him the earliest and latest completion dates. Once the critical path has been decided the contractor will have to allocate adequate resources to ensure completion of these activities as scheduled.

On receipt of approval for the shop drawings in the 8th month the contractor will be free to commence work simultaneously at the above three sites.

At the Intake site, the disposal of a huge garbage dump to a land arranged by NWSDB will be the first activity and will take about 1 ½ months, and afterwards the access road will commence, and the completion of which will require 2 months. The next will be the earthwork including rock excavations requiring another 2 months. The Civil and Building works on Grit Chamber will commence afterwards and the completion will take 8 months. At the beginning of 21st month the mechanical installation of the Grit Chamber is due to start and will be completed in the 25th month. The Building Works on the Electrical Building will commence in the 20th month and complete by 24th month. The Yard Piping, Electrical Work on Grit Chamber and Electrical Building will commence simultaneously in 25th month and complete by 28th month. The Guard House to be commenced in 26th month and complete by 28th month. Accordingly, all works at Intake site is programmed to be complete in the 28th months.

The conveyance facility includes laying of raw water conveyance pipe and construction of the balancing tank. The earthwork on the balancing tank to be commenced in the 8th month, which will require ½ month. The Civil works would start afterwards and will complete in the middle of 13th month. The yard piping will start afterwards and will be complete by the 14th month. The miscellaneous works will take the next 1 ½ months. The work on open channel also will be commenced after the site work is complete in mid 11th month and will be complete by mid 16th month.

The pumping part of conveyance main will be commenced immediately afterwards and will be complete within 1 ½ months. The gravity main,which is much longer, will take the next 4 ½ months.

The Water Treatment Plant consists of several structures. The access road and the temporary east site footpath which are priority needs will be commenced first after the 7th month and will be complete in 2 ½ months and ½ month respectively. The next work is the conveyance road and the earthwork, which will be commenced simultaneously in mid 10th month and completed by the 12th month. On the 13th month work on east side road, flocculation and sedimentation basin, filtration unit, clear water pumping station, backwash water recovery facility, maintenance building will be started simultaneously. These works will be completed in 2 ½, 9, 10, 5,5, and 4 months respectively. The work on electrical substation and generator building will commence in the 16th month and complete by 22nd month. Chemical building will commence in 18th month and complete by 23rd month. Administration building will commence in 17th month and complete by 23rd month. The next works to commence are the distribution chamber, sludge lagoons and yard piping simultaneously in 21st month and complete by 26th month. In 23rd month clear water reservoir, mechanical and electrical works will commence and will complete by 26th and 28th months respectively. The surrounding roads will commence in mid 23rd moth and complete by mid 25th month. The guardhouse will commence in 25th month and complete by 26th month. Miscellaneous works to commence in mid 25th month and complete by 28th month. The second part of east side road will commence in 26th month and complete by 28th month. Hence, the entire treatment plant work will be completed in 28 months.

2. TRANSMISSION, SERVICE RESERVOIRS, AND DISTRIBUTION SYSTEM

The target for completion of transmission and distribution works has been fixed for a total of 30 months as shown in the attached Construction Schedule, and therefore maximum possible activities should be started at the outset and be executed throughout the construction period without any hindrance. To facilitate this 3 main site offices have been proposed to be established in Northern, Central and Southern Zones of Greater Kandy for better organizing and closer supervision to increase productivity.

Before commencement of the construction works it is important to implement a public awareness programme by the NWSDB to educate the public especially the residents of the benefits of the Project for themselves, and the need to cooperate to the maximum and bear with the temporary inconveniences, which may affect them during the construction period by way of traffic congestions, access problems, vibrations, noise, night time work, water supply and other service interruptions etc.

Initially there will be a lead time for the necessary further desk and field studies, investigations and preparation of Shop Drawings and to receive Engineer’s approval. For Transmission mains this will be the longest with 7 months, and 4 months for SRs and Distribution lines which are relatively much less complicated.

Transmission pipelines consist of laying 23 mains 38,700m of 150 to 800 mm dia DI pipes, and 2,900 m of 90 to 225 mm dia uPVC pipelines, and the distribution pipelines consist of 41 mains 21,700m of 225mm dia and smaller uPVC pipes, and 6,000m of DI pipes 250mm dia and larger. In addition, there are 19 service reservoirs (15 ground type and 4 elevated types) 7 pump houses with 5 in combination with SRs, and 2 independent ones, and 2 main pipe bridges across Mahaweli River and Pinga Oya to be constructed.

The Works should be so programmed that no time is lost or wasted unnecessarily. Work norms have been evaluated from the data obtained from certain other similar projects carried by the NWSDB in Colombo (e.g. Non Revenue Water Project**).** It is also suggested that a minimum of 3 pipe laying crews should be engaged at all times complete with the necessary equipment in each zone as shown in the attached table. If there are mains to be laid along access roads leading to SRs being constructed, such mains should be laid after completing the structures to protect the pipeline from heavy traffic. The pipelines should be laid on road shoulders wherever possible to reduce damage to the road surface. On Matale (A9) Road only of 30 percent of the road this is possible, but on Gohagoda road it is 70 percent. In selecting the pipe laying sites concern has to be given not to open up close by sites in a manner that the traffic congestion would be further enhanced. The crucial issue in pipe laying is that it should not create traffic congestions and ways and means have to be developed to eliminate or minimize this effect. Permanent Road reinstatement has been excluded from the schedule (except for Matale A9 road) as it will be carried out by the relevant road authority at the cost of the Project.

The major transmission pipeline to be laid is on the Matale A9 road in northern zone, Mahayiyawa Road in the central zone and at Ampitiya in the southern zone. The earlier two roads are two lane ones and therefore working during day time will be possible leaving one lane open for the traffic. However, RDA has ruled that on A.9 road pipe laying during day time could not be permitted due to heavy traffic plying on this road, and hence night time work is planned. In general, it may become necessary for the contractor to remove the excavated materials away from the road to a nearby suitable location for stockpiling for later use to avoid piling up of excavated earth on the road and worsen traffic congestions. The Ampitiya Road is a narrow road with one lane and virtually no road shoulders over 90 percent of the road, and hence night time work will have to be necessarily planned, except for the section deviated from the main road. There are also other routes such as the transmission mains up to Heerassagala Upper SR, which is a single lane road and night work will have to be planned. Furthermore, there are also several other mains mainly distribution mains to be laid on roads, which can be done during day time by detouring the traffic.

Our experience on night time work in Colombo where the traffic is heavy and the roads are heavily congested with underground services was that the progress was much slower than the day time work. However, in Greater Kandy the traffic and the congestion of underground services are much less and hence the progress of work may be expected to be better than day time work. Therefore, planning night time work wherever possible may be more productive than day time work. This is a decision to be taken by the contractor in consultation with the

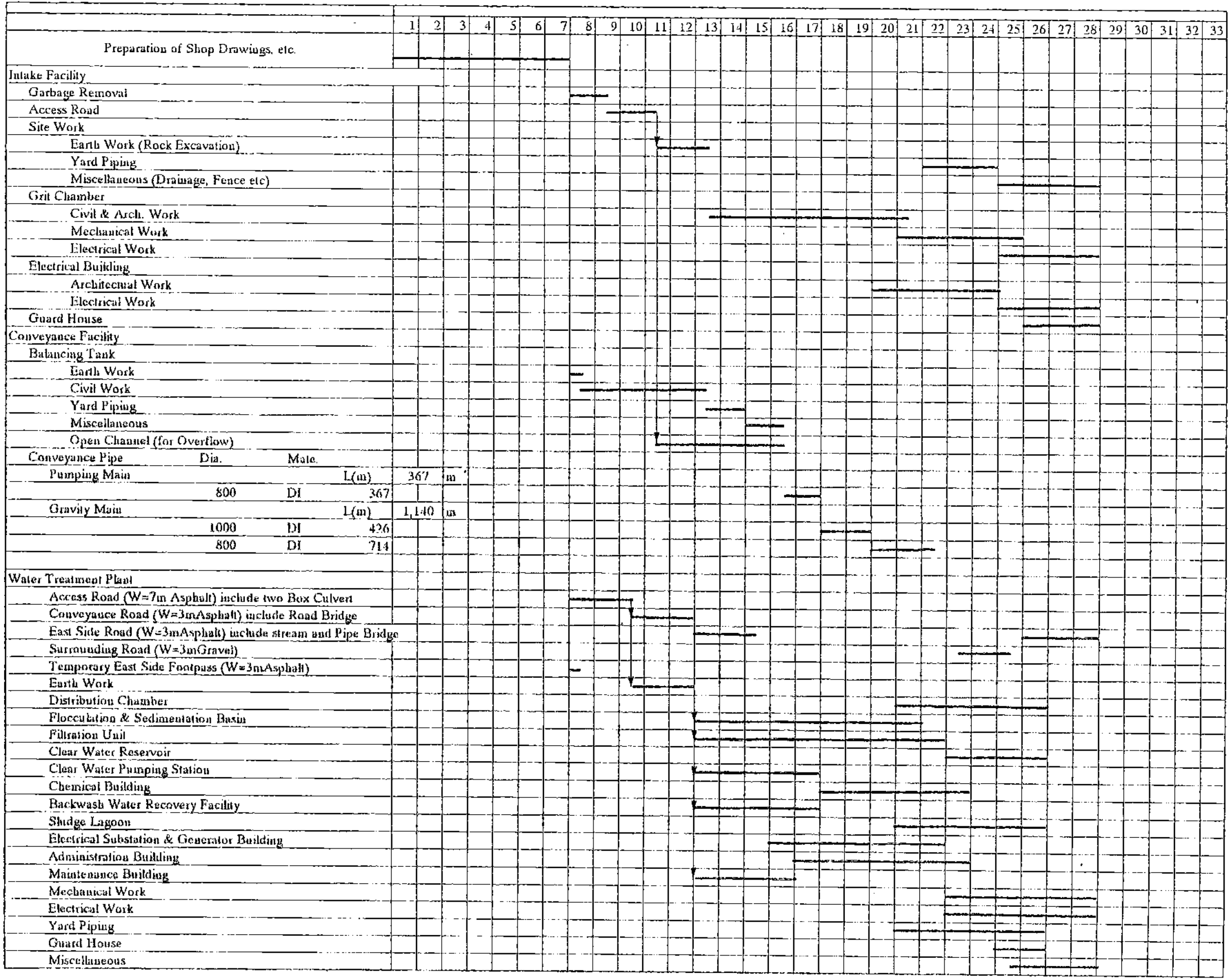
Engineer during construction Phase.

Similar norms for the construction of SRs/ pump houses have also been evaluated and that up to 3 reservoir will be approved to be in hand at any time in each zone. In the programme for SRs, 7 days should be allowed for curing of concrete before the next lift is cast. For superior quality and speedy work use of ready mixed concrete is stipulated. The 5 SRs in northern zone will take 23 months, 7 in central zone will take 21 months and 7 in southern zone will take 20 months for completion.

The bridge crossings should be started during the driest period when the river flow is minimum in cooperation to the Mahaweli Authority concerned as the foundations for the bridge crossings are to be laid in the river bed. The bridge crossing on Pianga Oya should not be started until Wattegama main is completed due to traffic considerations, as shown in the Construction Schedule.

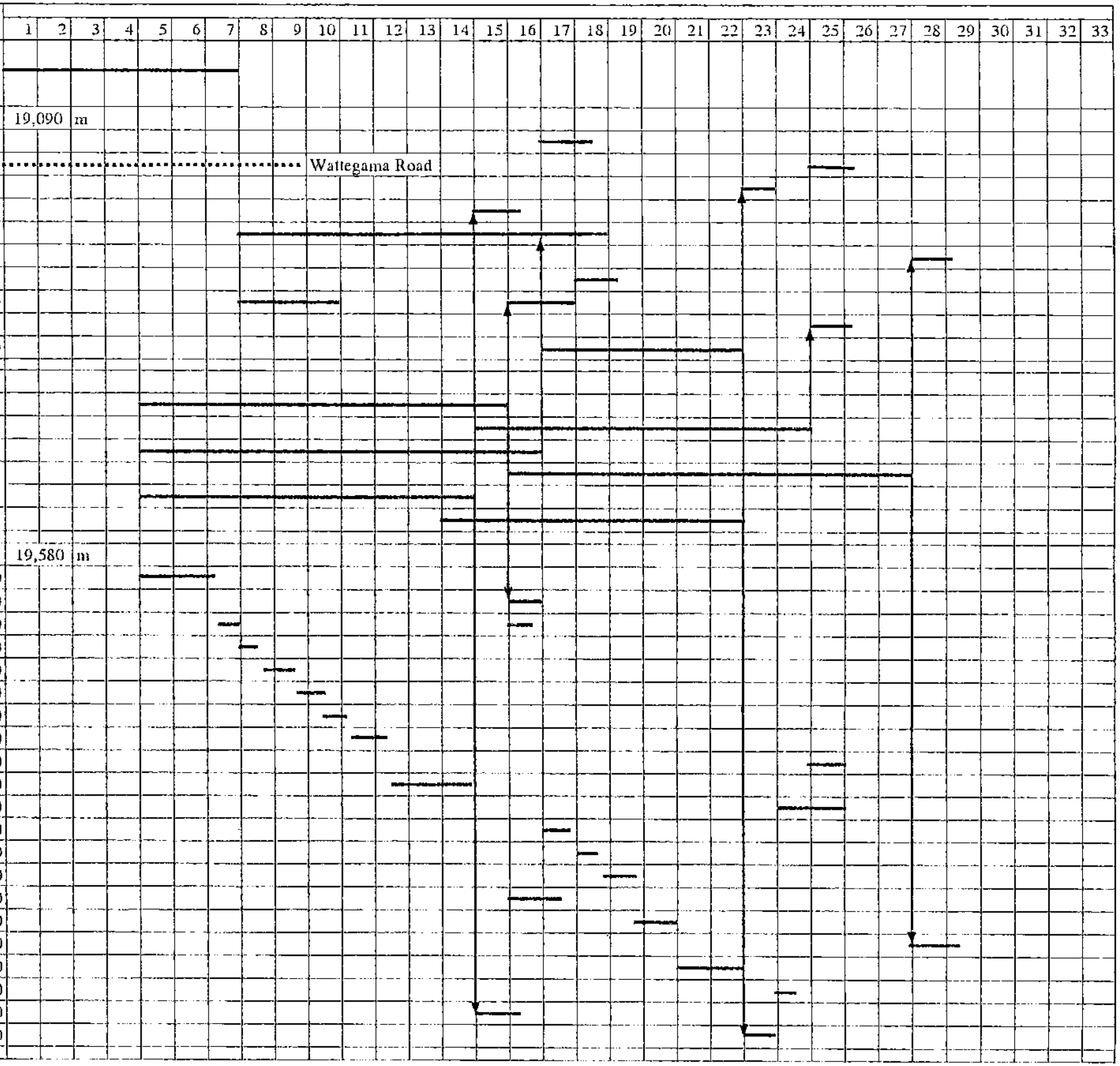
The attached proposed schedule for northern zone targets the completion of transmission mains in 29 months, SRs in 27 months and distribution mains in 29 months. The schedule for central zone targets completion of transmission mains in 26 months, SRs in 25 months and distribution system 23 months. Finally the schedule for southern zone targets completion of transmission mains in 24 months, SRs in 24 months and distribution mains in 23 months. However, provision has to be made for any unforeseen circumstances, which may arise and cause delay for the work. From these schedules it is obvious that the critical zone is the northern zone. In the central and southern zones the works could be completed ahead of the target date, and hence in the event of any shortfall of progress in northern zone, more resources could be diverted to this zone and catch up any lost time by opening up more sites.

Tentative Construction Schedule for Intake and WTP

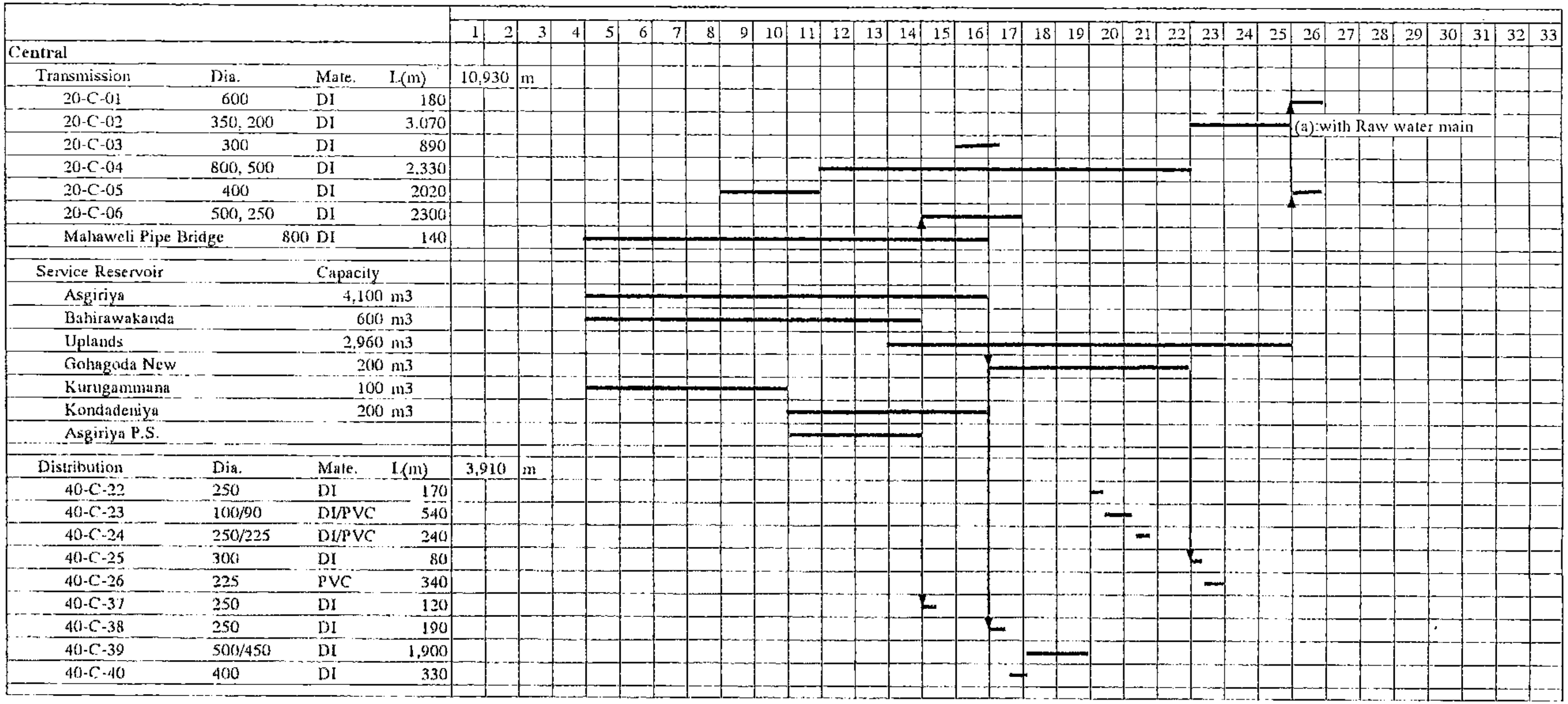


Tentative Construction Schedule for Transmission, Service Reservoirs, and Distribution Systems

Preparation of Shop Drawings, etc.			
North			
Transmission	Dia.	Mate.	L(m)
20-C-07	600	DI	430
20-C-08	600, 300	DI	5,510
20-C-09	200, 225	DI/PVC	600
20-C-10	250	DI	1,120
20-C-11	600, 500	DI	4,590
20-C-12	200	DI	840
20-C-13	200	DI	1,230
20-C-14	350	DI	3,820
20-C-15	250	DI	910
Ping Oya Pipe Bridge	600	DI	40
Service Reservoir		Capacity	
Kurugoda		600 m3	
Thelambugahawatta		500 m3	
Kahawatta		600 m3	
Kahalla		600 m3	
Bangalawatta		300 m3	
Pihilladeniya		200 m3	
Distribution	Dia.	Mate.	L(m)
40-C-01	250/225/150	DI/PVC	2,050
40-C-02	225/110	PVC	880
40-C-03	90	PVC	1,040
40-C-04	225	PVC	240
40-C-05	160	PVC	560
40-C-06	160	PVC	420
40-C-07	90	PVC	440
40-C-08	225/160	PVC	1,080
40-C-09	110	PVC	890
40-C-10	160/90	PVC	2,160
40-C-11	160	PVC	290
40-C-12	100/110	DI/PVC	590
40-C-13	110	PVC	350
40-C-14	225	PVC	800
40-C-15	300/225	DI/PVC	900
40-C-16	300/160	DI/PVC	1,230
40-C-17	250/225/160	DI/PVC	1,320
40-C-18	160 to 90	DI/PVC	1,670
40-C-19	90	PVC	300
40-C-20	250/225	DI/PVC	1,280
40-C-21	225	PVC	1,090



Tentative Construction Schedule for Transmission, Service Reservoirs, and Distribution Systems



Central				
Transmission	Dia.	Mate.	L(m)	10,930 m
20-C-01	600	DI	180	
20-C-02	350, 200	DI	3.070	
20-C-03	300	DI	890	
20-C-04	800, 500	DI	2.330	
20-C-05	400	DI	2020	
20-C-06	500, 250	DI	2300	
Mahaweli Pipe Bridge	800	DI	140	
Service Reservoir		Capacity		
Asgiriya		4,100 m3		
Bahirawakanda		600 m3		
Uplands		2,960 m3		
Gohagoda New		200 m3		
Kurugammana		100 m3		
Kondadeniya		200 m3		
Asgiriya P.S.				
Distribution	Dia.	Mate.	L(m)	3,910 m
40-C-22	250	DI	170	
40-C-23	100/90	DI/PVC	540	
40-C-24	250/225	DI/PVC	240	
40-C-25	300	DI	80	
40-C-26	225	PVC	340	
40-C-37	250	DI	120	
40-C-38	250	DI	190	
40-C-39	500/450	DI	1,900	
40-C-40	400	DI	330	

Tentative Construction Schedule for Transmission, Service Reservoirs, and Distribution Systems

				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
South																																				
Transmission	Dia.	Mate.	L(m)	11,720	m																															
20-C-16	300	DI	1,790														▬	▬	▬																	
20-C-17	200, 225	DI/PVC	3,920									▬	▬							▬	▬															
20-C-18	150	DI	1,900											▬	▬							▬														
20-C-19	160, 90	PVC	240											▬																						
20-C-20	350	DI	1,010																				▬	▬												
20-C-21	200, 225	DI/PVC	1,270																			▬	▬													
20-C-22	160, 150	DI/PVC	770											▬																						
20-C-23	200	DI	820																							▬	▬									
Service Reservoir		Capacity																																		
Mullepihilla Low New		100 m3						▬	▬	▬	▬	▬	▬																							
Elhena		300 m3												▬	▬	▬	▬	▬	▬																	
Hantana Place		200 m3																		▬	▬	▬	▬	▬	▬											
Heerassugala Low		200 m3						▬	▬	▬	▬	▬	▬																							
Heerassugala Middle		250 m3												▬	▬	▬	▬	▬	▬	▬	▬															
Heerassugala Upper		200 m3						▬	▬	▬	▬	▬	▬																							
R2 P.S.													▬	▬	▬	▬	▬																			
Ampitiya P.S.																		▬	▬	▬	▬	▬														
Distribution	Dia.	Mate.	L(m)	4,310	m																															
40-C-27	250/225	DI/PVC	810																	▬																
40-C-28	160	PVC	430																		▬															
40-C-29	160	PVC	540																		▬	▬														
40-C-30	Not applicable																																			
40-C-31	225	PVC	380																							▬										
40-C-32	160	PVC	340																				▬													
40-C-33	225/160	PVC	510																				▬	▬												
40-C-34	110	PVC	600																					▬	▬											
40-C-35	250/200	DI	260																			▬														
40-C-36	110	PVC	160																						▬											
40-C-41	250	DI	280																				▬													