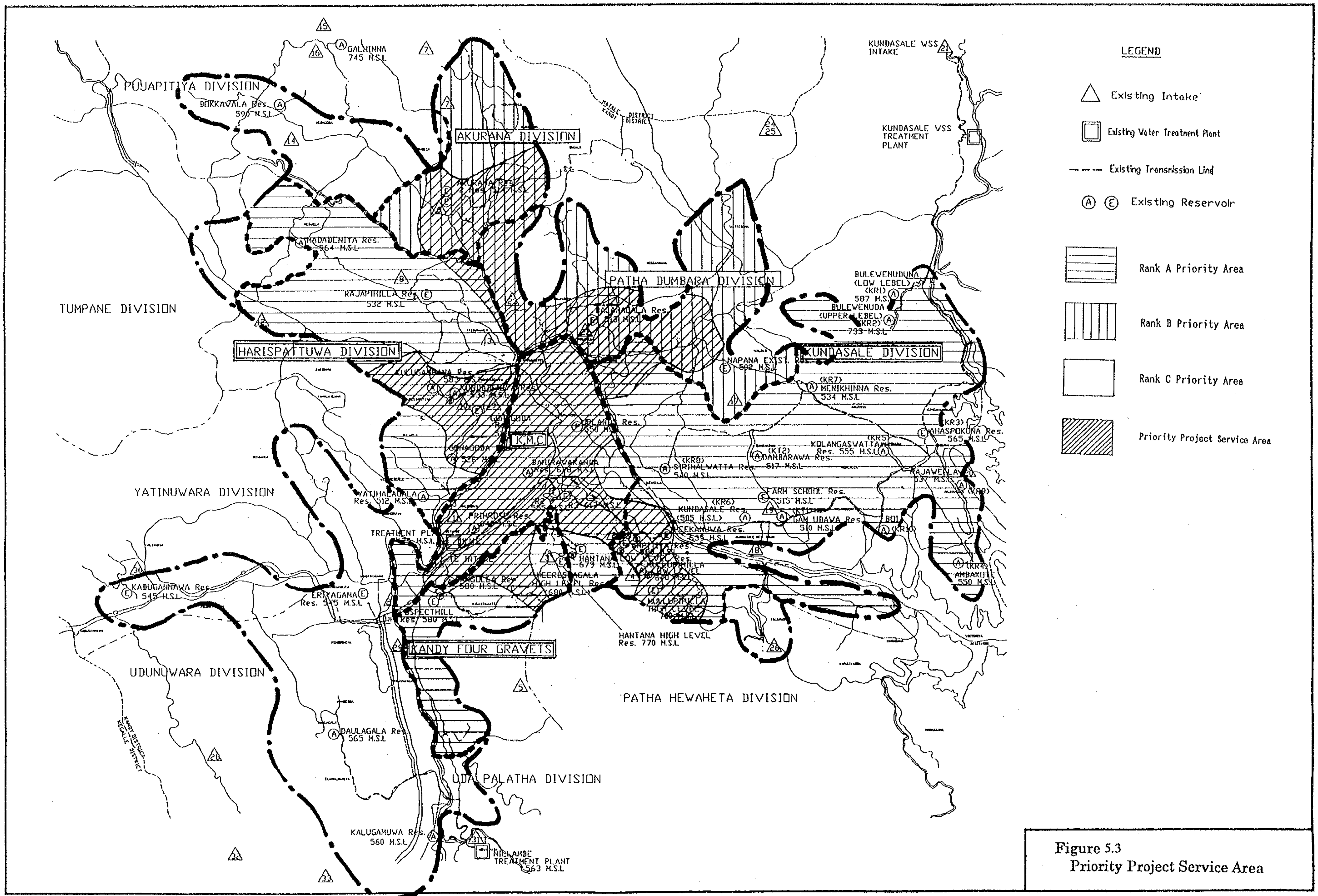

Figure 5.3
Priority Project Service Area

On the other hand, the southern part of the Mahaweli River, Ampitiya and Muluphilla, which the KMC water supply system formerly covered but which presently is presently out of operation due to lack of water, remains as a high priority area.

Akurana is ranked at B. However, the main water supply systems of Kahawatta and Kurugoda, which withdraw groundwater, have suffered a decrease of pumpage due to increasing drawdown. Thus, Akurana should also be highly prioritized.

Although Patha Dumbara is ranked at B, the groundwater level may not be stable. Katugastota is developing as commercial area and Kahalla, Balanagala, Bangalawatta, and Pihilladeniya are to be developed as residential areas. Among them, Kahalla and Balanagala have suffered water shortages. Therefore, Patha Dumbara is prioritized.

An increase in water demand to 36,400 m^3/d in 2005 will be supplied from the proposed Katugastota water treatment plant. The necessary transmission pumps, transmission pipelines and distribution reservoirs shall also be provided by the year 2005 as the Phase 1 project (refer to Figures 5.4 and 5.5).

5.6 Preliminary Design of Facilities

Facilities to be developed in the project consist of following:

(1) Intake and Conveyance
- Intake Mouth
- Grit Chamber
- Conveyance pumps

(2) Treatment Plants
- Coagulation and Sedimentation Basins
- Rapid Sand Filters
- Purified Water Reservoir
- Chemical Dosing Facility
- Chlorination Facility
- Administration Building

(3) Transmission/Distribution Facility
- Transmission Pumps

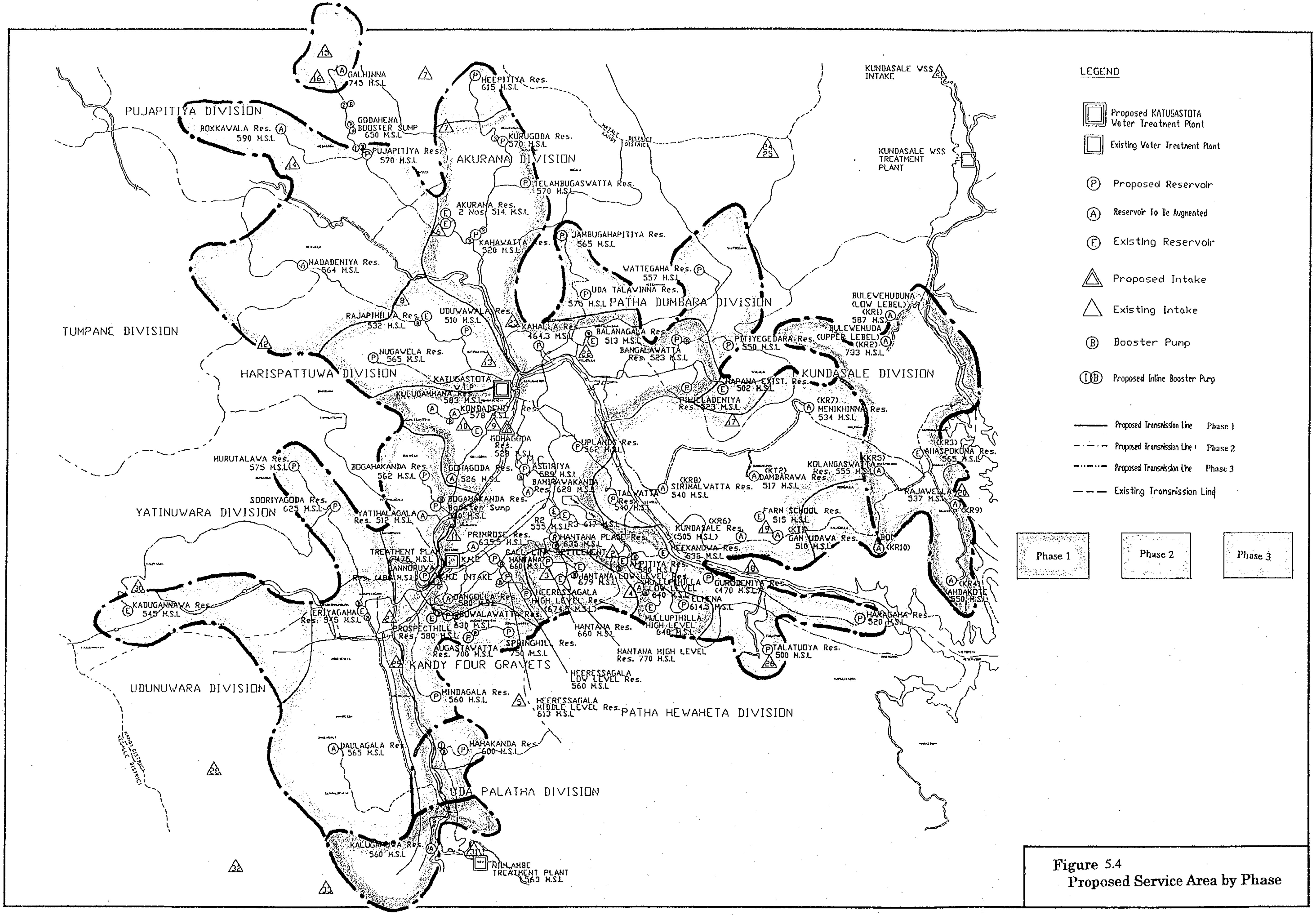

Figure 5.4
Proposed Service Area by Phase

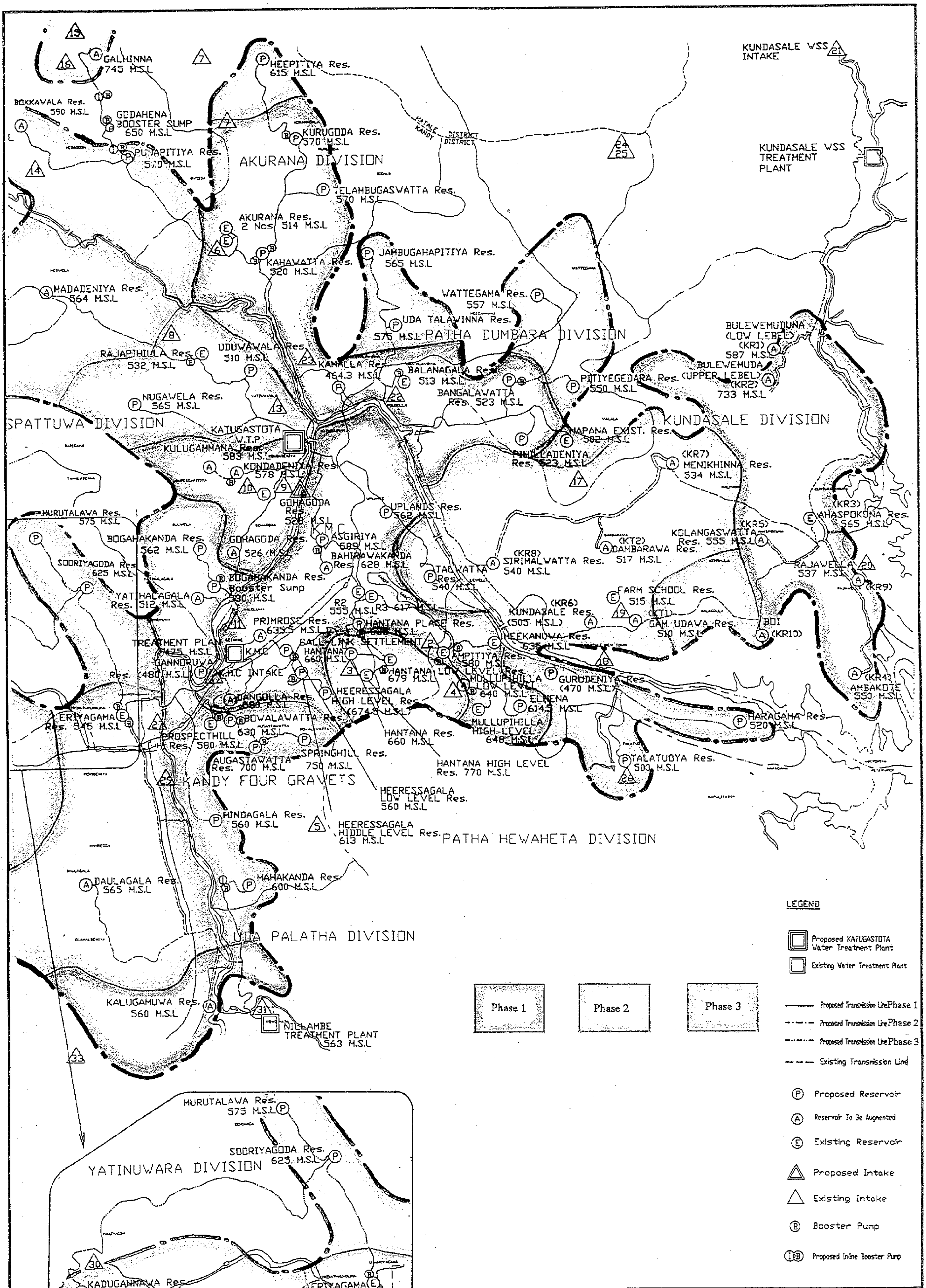

Figure 5.5
Proposed Service Area by Phase (Detail)

Table 5.8 Construction Plan of Facilities

Facility	Unit	Ph-1	Ph-2	Ph-3	Remarks
Intake Facilities	Intake Mouth	3/3	-	-	
	Sluice Way	3/3	-	-	
	Grit Chamber	3/3	-	-	
	Conveyance Pump	1/3	1/3	1/3	
	Electrical Facilities	1/3	1/3	1/3	
	Power Supply Facilities	1/3	1/3	1/3	
Conveyance Facilities	Conveyance Pipe	3/3	-	-	Partially phased
Water Treatment Plant	Receiving Well	3/3	-	-	
	Sedimentation Basin	1/3	1/3	1/3	
	Rapid Sand Filter	1/3	1/3	1/3	
	Clear Water Reservoir	1/3	1/3	1/3	
	Back Wash Return Tank	3/3	-	-	
	Back Wash Return Pump	1/3	1/3	1/3	
	Sludge Lagoon	1/3	1/3	1/3	
	Office	3/3	-	-	
	Pump House	3/3	-	-	
	Chemical House	3/3	-	-	
	Chlorination House	3/3	-	-	
	Store House	3/3	-	-	
	Mech. And Elec. Facilities	1/3	1/3	1/3	
	Power Supply Facilities	1/3	1/3	1/3	
Chlorination Facilities of Distribution Reservoir	Chlorination Facilities	1/3	1/3	1/3	
Transmission Facilities	Transmission Pipe Line	vary	vary	vary	Depends on economy
	Transmission Pump	1/3	1/3	1/3	
	Pump House	3/3	-	-	
	Electrical Facilities	vary	vary	vary	Depends on capacity
	Power Supply Facilities	vary	vary	vary	Depends on capacity
Distribution Facilities	Distribution Reservoir	3/3	-	-	

Table 5.9 Summary of Project

Facilities	Unit	Quantity				Remark
		Phase 1	Phase 2	Phase 3	Total	
1 Intake Facility						
Intake/Grit Chamber/Pump House	L.S.	1	-	-	1	
Pump	Units	2	1	1	4	
Electrical Equipment/Power Supply	L.S.	1	1	1	1	
Conveyance Pipe (φ 800, 900 mm) / Balancing Tank	L.S.	1	1	1	1	
2 Treatment Plant	m3/d	(36,670)	(73,330)	(110,000)	(110,000)	capacity
Earth Work/Piping/Teatment Facilities/Micsellaneous	L.S.	1	1	1	1	
3 Chlorination Facilities for Distribution Reservoir						
Equipment	Units	20	12	46	78	
Chlorination House	Units	20	12	46	78	
4 Transmission Pipeline						
Pipeline						
PVC (75 - 225 mm)	m	23,745	26,610	52,050	102,405	
DCIP (250 - 900 mm)	m	18,400	27,879	37,795	84,074	
Aqueduct						
φ 350-120m	L.S.	-	1	-	1	
(φ 600, φ 600)-120m	L.S.	1(φ 600*1)	-	1(φ 600*1)	1(φ 600*2)	
(φ 700, φ 600)-120m	L.S.	1(φ 700*1)	-	1(φ 600*1)	1(φ 700, φ 600)	
φ 110- φ 600,20m	L.S.	5	2	2	9	
4 Pumping Station						
Pump/Pump House/Electrical Equipment/Power Supply	Stn.	8	5	13	26	*
5 Distribution Reservoirs						
Concrete/Form Work/Reinforced Bar/Miscellaneous	Units	20	12	27	59	

*: Numbers of pumping stations excluding those at water treatment plants.
Augmentation of existing stations is excluded.

5.7 Project Cost

5.7.1 Composition of Project Cost

The composition of project cost is shown below:

<u>Project Cost</u>

- Construction Costs — Direct Cost
  - Civil Work
  - Mech./Elec. Work
  - (Site Expenses)
  - (Packing/Transportation Cost)
  - (Import Tax)
  - (Administration Cost, partial)
- Equipment Procurement — Equipment
  - (Packing/Transportation Cost)
  - (Import Tax)
  - (Administration Cost, partial)
- Engineering Services
  - Detailed Design
  - Construction Supervision
- Common Costs
  - General/Administration Expenses
  - Land Acquisition
- Contingencies
- GST (12.5 %)

5.7.2 Conditions for Cost Estimate

(1) Conditions

1) Basic conditions

The project cost is estimated on the basis of the preliminary design. Unit prices and lump sum prices are established taking into considering local conditions, sub-contractors, hiring equipment, available construction equipment and materials as well as the suitability of the construction method.

Assumptions and conditions applied for the cost estimate are as follows:

Price level	:	as of November 1998
Foreign exchange rate	:	Sri Lankan Rs. 1.00 = Japanese Yen 1.8

2) Direct cost

a. Unit prices obtained from the NWSDB and actual international contract prices from the Towns South Project etc. are compared and established as unit costs as of November 1998.

b. Administration cost mainly covers mobilization/demobilization for the construction works. The magnitude of the project is too large for local contractors.

3) Common expenses

Land acquisition cost for the new reservoirs is estimated based upon the 6.6 ha required for Phase 1, 2 and 3. The required land should be secured prior to the commencement of construction.

Land acquisition costs for the intake facilities, water treatment plant and service reservoir sites are estimated as follows:

Grater Kandy (6.6 ha)=Rs.86 million

4) Contingency

A total of 15 percent for the contingency fund is included in the project cost for both physical contingency and price escalation.

(2) Scope of work to be implemented under foreign finance

The following works are recommended for implementation under foreign financial assistance.

1) Procurement of engineering services for detailed engineering design and construction supervision.

2) Construction work including procurement of equipment and materials as identified in the preliminary design and project cost estimate.

(3) Scope of work to be implemented by the counterpart fund

The following indigenous works are to be implemented by the counterpart fund of the Sri Lankan Government:

1) Land acquisition and relocation of local residents from the proposed construction sites and along the proposed pipeline routes.

2) Construction of perimeter fence at the proposed water treatment plants sites.

3) Provision of water quality examination equipment and apparatus.

4) Cost of electricity, fuel and chemicals required for the testing activities at the water treatment plant prior to actual operation, except for individual tests on the electrical

equipment.

5.7.3 Project Cost

The total cost of the proposed project is estimated at approximately Sri Lankan Rs 11,264 million as shown in Table 5.10 (refer to Appendix 5.7 for details).

5.7.4 Construction Equipment and Materials

Most of the construction materials are imported from adjacent countries, except sand, gravel, concrete pipe etc. The imported materials, however, are available in the local market in Sri Lanka. Mechanical and electrical equipment must however, be imported from foreign countries.

Local products and imported materials and equipment are listed below. However, the imported materials for civil work are considered to be procured through sales agents and suppliers in Sri Lanka.

(1) Local material

Cement, stone, aggregate, sand, timber, plywood, steel reinforcement bars, structural steel, small PVC Pipe, concrete pipe, steel pipe, road curb, concrete block, brick, AC roof and tiles, pre-cast built wall, fence, road/pedestrian gates, wire nails, gabion mesh, gasoline, diesel, lubricants, admixtures, waterstop, scaffolding, metal forms, guardrail, asphalt, emulsion and other small items.

(2) Imported material

Construction equipment, valves, fittings, ductile iron pipe, truck cranes, vehicles, motorcycles, computers, pumps, motors, transformers, switchgears, disinfection facilities, laboratory equipment, flow meters, and other mechanical and electrical equipment.

Table 5.10 Estimated Total Project Cost

Unit : Thousand Sri Lankan Rs.

Facilities	Phase 1		Phase 2		Phase 3		Total		Remarks
	Breakdown	Total	Breakdown	Total	Breakdown	Total	Breakdown	Total	
(1) Construction Cost									
1) Intake Facilities		416,929		126,535		96,160		639,624	
Intake, Grit Chamber, Pump, Conveyance Pipe	416,929		126,535		96,160		639,624		
2) Water Treatment Plant		777,043		719,569		719,574		2,216,186	
Civil Work	242,243		189,669		189,674		621,586		
Mechanical/Electrical Work	534,800		529,900		529,900		1,594,600		
3) Chlorination Facilities of Distribution Reservoir		21,000		12,600		48,300		81,900	
4) Transmission Facilities		1,062,291		742,440		880,062		2,684,793	
Pipelines	805,103		613,012		760,052		2,178,167		
Pumping Facilities	257,188		129,428		120,010		506,626		
5) Distribution Reservoir		457,966		157,066		380,176		995,208	
6) Distribution Pipeline Rehabilitation		335,000		113,000		337,000		785,000	
7) NRW Reduction Program (Leak Detection & Repair)		103,000		0		0		103,000	
8) Administration Cost		158,771		93,790		122,728		375,289	about 5% of others
Sub Total		**3,332,000**		**1,965,000**		**2,584,000**		**7,881,000**	
(2) Procurement of maintenance equipment		**37,000**		**0**		**0**		**37,000**	
(3) Engineering Cost									
1) Detailed Design	138,000		81,000		107,000		326,000		(55%)
2) Construction Supervision	112,000		66,000		87,000		265,000		(45%)
Sub Total		**250,000**		**147,000**		**194,000**		**591,000**	about 7.5% of (1)
(4) Common Expenses									
1) General and Administrative Expenses	20,000		20,000		20,000		60,000		
2) Land Acquisition	86,000		16,000		35,000		137,000		
Sub Total		**106,000**		**36,000**		**55,000**		**197,000**	
(5) Continge(15%)		**559,000**		**322,000**		**425,000**		**1,306,000**	
(6) GST (12.5%)		**536,000**		**309,000**		**407,000**		**1,252,000**	
Total		**4,820,000**		**2,779,000**		**3,665,000**		**11,264,000**	

Note : Exchange rate : SL Rs. 1.00 = Japanese Yen 1.80 (as of Nov.,1998)

5.8 Implementation Program

5.8.1 Implementation Schedule

In connection with the target years for this Study (2005 and 2015), Phase 1 is an urgent and priority project and is expected to be completed by the end of 2004, while Phases 2 and 3 to complete the overall project are considered to be achieved by the end of 2008 and 2013 respectively.

Phase 1 (1999 to 2004) - Priority Project

1999-2000	Preparation of project
2001-02	Detailed design, bidding
2002	Commencement of construction & procurement of equipment
2002-04	Construction
2005	Commencement of operation

Phase 2 (2003 to 2008)

2003-04	Preparation of project
2005-06	Detailed design, bidding
2006	Commencement of construction & procurement of equipment
2006-08	Construction
2009	Commencement of operation

Phase 3 (2008 to 2013)

2008-09	Preparation of project
2010-11	Detailed design, bidding
2011	Commencement of construction & procurement of equipment
2011-13	Construction
2014	Commencement of operation

The project implementation and disbursement schedule with estimated annual disbursement of project cost is presented in Table 5.11.

5.8.2 Activities in Project Implementation

Construction periods for the major works are estimated in months, as follows:

1) Intake Facilities	Phase 1	Phase 2	Phase 3
- Mobilization	1.0	1.0	1.0
- Grit Chamber	24.0		
- Mechanical / Electrical Work	(8.0)	(6.0)	(6.0)
- Conveyance Pipelines	6.0	4.0	4.0

		Phase 1	Phase 2	Phase 3
2)	Water Treatment Plant	Phase 1	Phase 2	Phase 3
	- Mobilization	1.0	1.0	1.0
	- Civil Work	30.0	21.0	21.0
	- Mechanical / Electrical Work	(12.0)	(6.0)	(6.0)
	- Test Operation	1.0	1.0	1.0
	- Training	2.0	1.0	1.0
	Total	33.0	24.0	24.0
3)	Transmission Facilities	Phase 1	Phase 2	Phase 3
	- Mobilization	1.0	1.0	1.0
	- Civil Work	30.0	21.0	21.0
	- Mechanical / Electrical Work	(24.0)	(15.0)	(15.0)
	- Test Operation	1.0	1.0	1.0
	- Training	1.0	1.0	1.0
4)	Distribution Facilities	Phase 1	Phase 2	Phase 3
	- Mobilization	1.0	1.0	1.0
	- Civil Work	32.0	23.0	23.0

Table 5.11 Implementation and Disbursement Schedule of Greater Kandy Water Supply Project

Item (Phase / Year)		Phase 1						Phase 2				Phase 3				
		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Implementation Schedule																
1. Preparation of Project																
2. Pre-Construction Stage																
2.1 Detailed Design																
2.2 Bidding																
3. Construction																
3.1 Intake Facilities																
3.2 Water Treatment Plant																
- Civil Work																
- Mechanical/Electrical Work																
3.3 Transmission Facilities																
3.4 Distribution Facilities																
4. Procurement of Equipment																
5. NRW Reduction Program																
Disbursement Schedule	**Total Cost (Million SL Rs)**					Phase 1	4,820			Phase 2	2,779				Phase 3	3,665
1. Land Acquisition	137.0			86				16					35			
2. Administration	60.0			2	6	6	6	2	6	6	6		2	6	6	6
3. Construction Work	7,778.0				807	1,076	1,346		491	655	819			646	861	1,077
4. Procurement of Equipment	37.0					37										
5. NRW Reduction Program	103.0			16	29	29	29									
6. Engineering Service	591.0			138	28	42	42	81	16	25	25		107	21	33	33
7. Contingency	1,306.0			36	131	179	213	15	77	103	128		22	101	135	166
8. GST(12.5%)	1,252.0			35	125	171	205	14	74	99	121		21	97	129	161
Total of Annual Disbursement	11,264.0			313	1,126	1,540	1,841	128	664	888	1,099		187	871	1,164	1,443

CHAPTER 6 PRIORITY PROJECT OF WATER SUPPLY SYSTEM PLAN

CHAPTER 6 PRIORITY PROJECT OF WATER SUPPLY SYSTEM PLAN

6.1 Identification of the Priority Project

As discussed in Chapter 5, prioritization of service areas was conducted to identify the priority project. Based on this review, priority areas were selected for first phase project to cope with the augmentation of the treatment capacity. Because of the urgency of the project, the first phase project should be the subject of a feasibility study.

Augmentation of the water production capacity by construction of the new Katugastota Treatment Plant will be carried out. Construction work in the long-term plan will be conducted in three phases because of financial constraints. The new Katugastota plant will also be constructed in phases. In the first phase, one train of the treatment facilities of the plant will be constructed out of the total of three trains. Augmenting the existing reservoirs will also be conducted together with the provision of new reservoirs in areas of high water demand, where necessary. In addition, part of transmission pipelines will also be constructed to transport the water in the first phase. The diameters of pipes and sizes of reservoirs will be determined based on the projected flow for 2015, in principle. However, an economic analysis was performed to assist in the determination of pipe diameter to increase the cost effectiveness of the investment.

Planning fundamentals for the priority project are as shown in Table 6.1.

Table 6.1 Major Planning Fundamentals for Priority Project

Fundamental Conditions	Overall System (Existing & New)	Priority Project (New)
Target Year	2005	2005
Population	717,600	256,400
Served Population	615,800	220,000
Total Water Demand in the Study Area (daily average, m^3/day)	122,900	-
Total Water Supply Capacity in the Study Area (m^3/day)	102,630	36,670
Peak Factor (maximum daily demand / average daily demand)	1.2	1.2
Peak Factor (hourly peak flow / average daily demand)	2.0	2.0
Capacity of New Katugastota Treatment Plant (m^3/day)	-	36,670

6.2 Preliminary Design of Water Supply System

6.2.1 Design Conditions

(1) Topographic condition

A new intake facility will be constructed at Gohagoda along the Mahaweli River. The proposed site is grassland at elevations ranging from 440.5 m to 442.5 m and gradually becomes a gentle climbing slope from the riverside. At higher elevations, the area turns to rice field. The proposed site of the water intake is currently unoccupied open land approximately 40 m wide facing precipices at both sides. The proposed sites for water intake, grit chamber and pump house have enough space to accommodate the necessary facilities.

The proposed site for the water treatment facility is located 2.2 km downstream from the intake facility and on unused rice fields with small hillocks ranging in elevation from 442 m to 448 m. The treatment facilities are designed to be located at an elevated position, while the sludge treatment facility is located at a lower elevation area near the flood retention pond to the east.

The proposed locations of distribution reservoirs will have sufficient space to accommodate the required facilities and enough elevation to allow water distribution by gravity flow.

(2) Geological condition

Boring test data obtained from two boring holes at the proposed intake facility location indicated that surface soil to 1 m deep consists of coarse sand, weathered rocks from 1 m to 4.5 m deep, and bed rock appears at 5.6 to 6.2 m deep. Rock will therefore be encountered where excavation depth exceeds 5 m in the construction of the intake facility.

A total of 5 test borings at the proposed water treatment plant site revealed that the surface soil is very thin, with clay and sand seen up to a depth of 1 m, and weathered rock was found from 3.8 to 5.45 m, after which bed rock appears. However, N values at 3 m depth in test holes Nos.TP-02, TP-04 and TP-05 were smaller than those at 1.5 m depth, namely 5, 15 and 16. Taking into account the depth of foundations soil replacement or concrete piles are deemed necessary for a depth of several meters.

Borings were also carried out at the proposed sites of the new reservoirs and at the existing reservoir sites to be expanded. The test results revealed that soil replacement is required to a depth of about 1.5 m at the Kurugoda reservoir and about 1.0 m depth at Kahala reservoir and Kahawatta reservoir, while Heerassagala Upper reservoir requires 4 to 5 m depth of concrete pile foundation. The other reservoir sites will not require such foundation preparation.

Major transmission line routes, i.e. from the new Katugastota Water Treatment Plant to the Asgiriya reservoir in the KMC Water Treatment Plant and to the Upland reservoir, cross the Mahaweli River by means of an aqueduct. Piers of this aqueduct will also require concrete pile foundation.

(3) Reliability of power supply

The Ceylon Electricity Board (CEB) operates and maintains electricity supply in Sri Lanka. The available electricity supply in Greater Kandy is 400V, 11 kV and 33 kV. In Kandy MC area, 400V by general distribution and 400V by bulk supply are available. The bulk supply is usually used where demand is more than 42 kVA and is supplied by "Link Supply" which is more reliable than general distribution. There is also an 11kV supply for large demand. All power supply connections in Kandy MC area are by underground cables. A 33kV power supply is available only for connections beyond the Kandy MC limits such as those supplied by overhead cables. The present electricity supply is not reliable and CEB's records show frequent power failures.

Table 6.2 Record of Power Supply Failure

Supply Mode / Period	Low-Tension		High-Tension	
	Frequency (time/month)	Total Duration (hour/month)	Frequency (time/month)	Total Duration (hour/month)
March 1998	158	186	26	62
July 1998	180	170	16	21

The low-tension supply shows frequent and prolonged power failures when compared to the high-tension supply.

The CEB is implementing a project to improve the electricity supply in the Kandy MC and suburban areas, outlined as follows:

Kandy Electricity Distribution Development Project

Financing Agency: World Bank loan and local funds

Project cost: Rs. 700 million

Project Area: Kandy MC and suburbs

Completion of the project

Kandy MC: April 2000

Suburb: End of 2000

Components

Replacement of entire underground cables in the KMC

Rehabilitation of overhead cables in the KMC

Strengthening of 33 kVA supply

Electrical Engineers of the CEB are confident that the electricity supply in the Kandy MC will be significantly improved after completion of this project.

A new water intake at Gohagoda and the new water treatment plant in Katugastota which, will require a electricity supply of 900 kVA and 1800 kVA respectively, will be constructed as part of the first stage under the Greater Kandy Water Supply Project.

Under the electricity development project, a new gantry connected to two national grid stations will be constructed at Katugastota and an exclusive line can be provided for the new intake and plant.

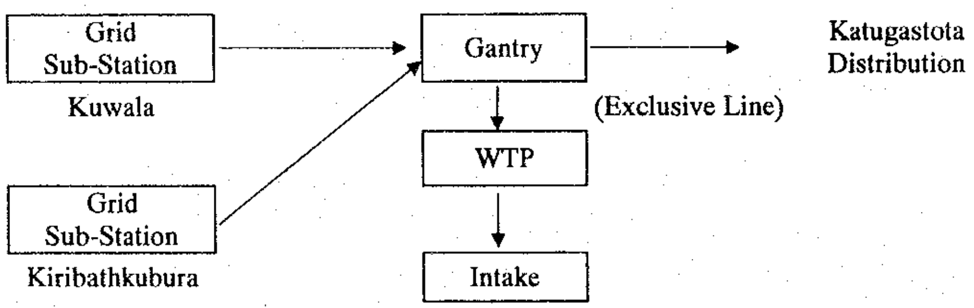

Figure 6.1 National Grid System at Katugastota

No generator is therefore planned at the intake pumping station and the water treatment plant. Nevertheless, a few trailer-mounted generators will be provided to supply electricity for pumping stations in the Kandy MC and the Greater Kandy area. Trailer-mounted generators will be transported to the power failure areas as back up.

6.2.2 Intake Facility

(1) Water Intake Method (refer to Appendix 5.6)

The open inlet method will be adopted for the water intake facility. Raw water will be taken from water intake to grit chamber via conduit.

The water level in the Polgolla Dam varies between 440 m and 446.4 m depending on the river flow rate. The present elevation of the riverbed at the proposed intake point is 438 m with a water depth of about 2 m. Since the thickness of accumulated sand/mud deposits in the river are estimated to be about 2 m, there exists a possibility to lower the water level by flushing the accumulated deposits during the maintenance period of the dam. In this respect, the bottom plate of intake facility will be designed at 2 m below the present level of the riverbed.

The said maintenance of the Polgolla Dam is usually carried out for about a one month period during the dry season. The water level in this period will be near to the riverbed. Owing to the nearly flat conditions of the riverbed, the route of the river may change from time to time. Thus, dredging of riverbed by means of a bulldozer will be required to lead the river-flow toward the intake facility. For protection of this temporary water path, sandbags will be used.

The water intake and conduit will be designed to have a minimum width of 4 m to allow for operation of a bulldozer for dredging work.

(2) Grit chamber

The bottom slab of the grit chamber will be designed to secure an effective water depth of 2 m, even during the maintenance period of the Polgolla Dam.

The cost effectiveness of capital investment for the intake facility, square-shape conduit and raw water transmission pump was studied, and concluded that the construction of such facilities required for the target year 2015 will be undertaken by 2005.

The design criteria for the grit chamber are shown in Table 6.3.

Table 6.3 Design Condition of Grit Chamber

Name of Facility	Dimension
Grit Chamber	6.0 m W x 33.5 m L x 2.0 m Effective Depth x 2 units

(3) Intake pump

A vertical axial flow type pump is used for raw water transmission. The design criteria for the pump are shown in Table 6.4.

Table 6.4 Design Condition of Raw Water Transmission Pump

Name of Facility	Dimension
Raw Water Transmission Pump	38,500 m^3/day x 50 m Pumping Head x 2 units

(4) Raw water conveyance pipe

The raw water conveyance pipeline route has a total length of 2.2 km that consisting of 1.6 km of pressure pipe and 0.6 km of gravity flow with a control tank that is provided at the junction point of these two pipelines.

The cost effectiveness of capital investment was reviewed and it was concluded that the pressure pipe should be a dual pipeline, while gravity flow should be single pipeline configuration as shown below.

Table 6.5 Design Condition of Conveyance Pipe

Name of Facility	Dimension
Conveyance Pipe (Pressured Pipe)	800 mm dia. x 0.6 km x 1 line
Conveyance Pipe (Gravity Flow Pipe)	800 mm dia. x 1.6 km x 1 line

(5) Control Tank

Since the longitudinal cross-section of the conveyance pipeline route has an elevated area midway, a control tank is provided at the high point as shown below.

Table 6.6 Design Condition of Control Tank

Name of Facility	Dimension
Control Tank	7.5 m dia. x 3.0 m Effective Depth x 1 unit; Capacity - 132 m^3

6.2.3 Water Treatment Plant

The overall capacity of new water treatment plant is considered to have the daily maximum supply amount with a 5 % additional treatment capacity to cope with in-plant water consumption. The treatment plant is planned to be expanded in three stages. The first stage implementation is for 1/3 of the total capacity, though some of the common facilities are to be constructed in the first stage implementation.

The total required capacity, based on the daily maximum supply amount, is 110,000 m^3/day and the priority project is designed to cater for 36,670 m^3/day as 1/3 of the total capacity. In view of the above, the total capacity will be 115,500 m^3/day, while the priority project will have 38,500 m^3/day.

The treatment process is designed to be a chemical coagulation-rapid filtration process. The design criteria for water treatment facilities are shown in Table 6.7 (refer to Appendix 6.3). It should be noted that the layout of the treatment facilities are prepared to meet with the full design capacity as shown in Figure 6.2.

Table 6.7 Design Condition of Water Treatment Plant

Name of Facility	Dimension	Implementation Scale
Receiving Well	3.9 m W x 3.9 m L x 4.0 m E.D. x 2 units	3/3
Mixing Chamber	6.0 m W x 33.5 m L x 2.0 m E.D. x 2 units	1/3
Flocculation Basin	Step 1: 1.2 m W x 11.0 m L x 3.5 m E.D. x 2 units Step 2: 1.6 m W x 11.0 m L x 3.5 m E.D. x 2 units Step 3: 2.4 m W x 11.0 m L x 3.5 m E.D. x 2 units	1/3
Sedimentation Basin	11.0 m W x 50.0 m L x 4.0 m E.D. x 2 units	1/3
Rapid Sand Filter	5.5 m W x 5.8 m L x 10 units	1/3
Clear Water Reservoir	10.5 m W x 22.5 m L x 3.5 m E.D. x 2 units	1/3
Back Wash Return Tank	8.0 m W x 11.0 m L x 3.0 m E.D. x 2 units	3/3
Back Wash Return Pump	3.5 m^3/min x 20 m x 2 units (including 1 standby)	1/3
Sludge Lagoon	32.0 m W x 39.0 m L x 2.0 m E.D. x 2 units	1/3
Office	10.0 m W x 30.0 m L	3/3
Pump House	11.4 m W x 23.5 m L	3/3
Chemical House	10.0 m W x 30.0 m L	3/3
Chlorination House	8.0 m W x 15.0 m L	3/3
Store House	10.0 m W x 30.0 m L	3/3
Mechanical & Electrical Facilities	Corresponding to staged expansion	1/3
Power Supply Facility	Corresponding to staged expansion	1/3

Legend: E.D. – effective depth

6.2.4 Transmission Facility

(1) Transmission pump

The transmission pump will be installed at water treatment plant and reservoirs. When installed in the treatment plant, the electrical and mechanical facilities and the pump house are commonly used with other facilities, while reservoirs, the pump house and electrical facilities will be independently constructed. The transmission pump house will be designed as a part of the clear water reservoir and distribution reservoir.

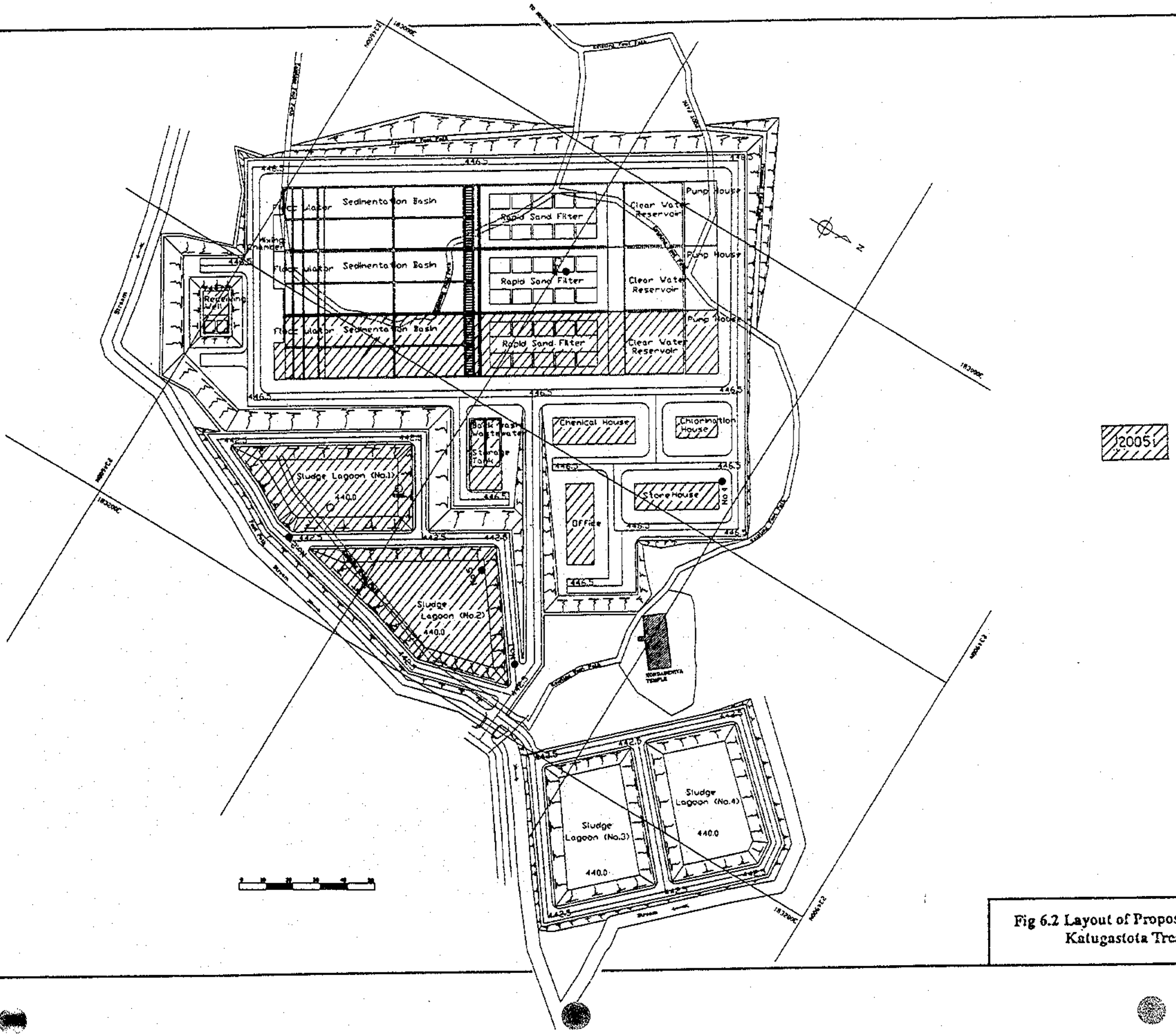

Fig 6.2 Layout of Proposed
Katugastota Treatment Plant

The optimum type and capacity of transmission pump will be selected taking into account pumping head and volume of water to be transported. These pumps will consist of 13 units for the Katugastota Water Treatment Plant, 3 units for the existing KMC Water Treatment Plant, 6 units for the Ampitiya Water Treatment Plant and 2 to 3 units (including 1 standby) for each distribution reservoir.

Table 6.8 Design Condition of Transmission Pump

Location	Pump Capacity (m^3/day)	Pumping Head (m)	Power Requirement (kW)	Number of Units (Including standby)
Katugastota W.T.P.	48,700	150	1,416	5
	41,100	111	886	3
	5,100	120	118	3
	3,900	5	4	2
KMC W.T.P	2,000	172	66	3
Heerasagala Low Reservoir	2,000	115	44	3
Heerasagala Middle Reservoir	1,000	57	11	2
Ampitiya Reservoir	1,000	40	8	2
	700	70	10	2
	800	66	10	2
Kahawatta Reservoir	5,600	80	88	3
Kondadeniya Reservoir	3,900	153	116	2
Asgiriya Reservoir	6,700	64	84	2

(2) Transmission Line

Pipe material will be PVC (Poly-vinyl-chloride) and DCIP (Ductile Cast-Iron Pipe) with the minimum diameter of 75 mm as follows:

PVC: 75 to 225 mm dia.

DIP: 250 mm or larger

For preparing the staged implementation plan for the transmission lines, the cost effectiveness of the capital investment must be evaluated. Several restrictive conditions as discussed in Appendix 6.1. Transmission lines to be implemented under the priority project consist of four (4) major routes from the new Katugastota Water Treatment Plant and a branch route of the main transmission line from the existing KMC Water Treatment Plant. The evaluation results revealed that 23 sections out of the total 30 sections in the said four (4) major transmission lines will be single, while the remaining 7 sections will be double.

6.2.5 Distribution Facility

Since the NWSDB undertakes the bulk water supply, the priority project is focused on major water supply facilities starting from water intake up to distribution reservoirs. A total of 20 reservoirs will be constructed or augmented in the priority project (refer to Appendix 6.2).

With regard to the distribution network, connection pipes between the new distribution reservoirs and the existing distribution lines and augmentation of the existing distribution lines are considered as a part of the priority project. Though the distribution network analysis is necessary to identify the required costs for the work, it could not be conducted because of lack of data and information. Consequently, it was considered that this work will constitute two times of the costs required for identified interconnection distribution pipelines.

6.3 NRW Reduction Program

In the priority project, the costs for a leakage detection survey of 70 percent of the total length of the distribution network and for leakage repair will constitute 5 percent of the current total construction cost of the existing distribution network. In addition to the above, improvement or augmentation work of the distribution network is considered to contribute to leakage reduction.

As a result of these project inputs, the current 42 percent of NRW are expected to be reduced to 34 percent by the target year of 2005 and to 25 % by the master plan target year of 2015.

6.4 Project Cost

Total cost of the proposed project is estimated at approximately Sri Lankan Rs 4,820 million as shown in Table 6.9. (refer to Appendix 6.2 for details).

Table 6.9 Estimated Project Cost

Unit: Thousand Sri Lankan Rs.

(1) Construction Cost		
1) Intake Facility		416,929
Intake Mouse/Grit Chamber		
Conveyance Pump/Conveyance Pipeline		
2) Water Treatment Plant		777,043
Civil Work	242,243	
Mechanical/Electrical Work	534,800	
3) Chlorination Facility of Distribution Reservoir		21,000

4) Transmission Facility		1,062,291
Pipe Facility	805,103	
Pump Facility	257,188	
5) Distribution Reservoir		457,966
6) Distribution Pipeline Rehabilitation		335,000
7) NRW Reduction Program (Leakage Detection)		103,000
8) Administration Cost		158,771
Sub-Total		**3,332,000**
(2) Procurement of Maintenance Equipment		37,000
(3) Engineering Cost		
1) Detailed Design	138,000	
2) Construction Supervision	112,000	
Sub-Total		**250,000**
(4) Common Expenses		
1) General and Administration Expenses	20,000	
2) Land Acquisition	86,000	
Sub-Total		**106,000**
(5) Contingency (15%)		**559,000**
(6) GST (12.5%)		**536,000**
Total		**4,820,000**

Note: Exchange rate: SL Rs. 1.00 = Japanese Yen 1.80 (as of November, 1998)

6.5 Implementation Program

6.5.1 Implementation Schedule

With regard to the target year for this Study (2005), the phase 1 or priority project is expected to be completed by the end of 2004.

Phase 1 (1999 to 2004)	Priority Project
1999-2000	Preparation of project
2001-02	Detailed design, bidding
2002	Commencement of construction & procurement of equipment
2002-04	Construction
2005	Commencement of operation

The project implementation and disbursement schedule with estimated annual disbursements of project cost is presented in Table 5.11 in Chapter 5. The required project activities are described below:

6.5.2 Activities in Project Implementation

The required project activities are described below:

(1) Preparation of Project

Preparatory work for the project implementation includes:

- Budgetary arrangements within the Sri Lankan Government for land acquisition and institutional development,
- Negotiation of grant/loan with foreign lending institution/s, and
- Selection of consultants in accordance with the agreement executed between the foreign lending institution and the executing agency of the Sri Lankan Government

This preparatory work shall be commenced by the middle of 1999 and completed by the end of the same year.

It should be noted that the institutional development of the executing agency and staffing as required for project implementation are a prerequisite not only to insure the successful achievement of the project objectives, but also to secure the firm commitment of financial assistance from the foreign lending institution/s. Appraisal missions by the institution will focus on the preparedness and maturity of the proposed project as well as the implementing capability of the executing agency, both financially and institutionally.

(2) Pre-construction stage

It should be noted that the institutional development of the executing agency and staffing as required for project implementation are prerequisite not only to insure the successful achievement of the project objectives, but also to secure the firm commitment of financial assistance from the foreign lending institution/s. Appraisal missions by the institution will focus on the preparedness and maturity of the proposed project as well as the implementing capability of the executing agency, both financially and institutionally.

After preparation of the tender documents, bidding for the procurement of maintenance equipment and for the construction of the proposed project will be executed by the end of 2000.

In parallel with the above project activities, the executing agency will, in accordance with the detailed design, negotiate with respective landowners and acquire the required land for construction. Other important subjects, such as a tariff system for water supply service for cost recovery, shall also be carried out by the executing agency.

(3) Construction

Construction periods for the major works are estimated in months, as follows:

1) Intake Facilities

- Mobilization	1.0
- Grit Chamber	24.0
- Mechanical / Electrical Work	(8.0)
- Conveyance Pipelines	6.0

2) Water Treatment Plant

- Mobilization	1.0
- Civil Work	30.0
- Mechanical / Electrical Work	(12.0)
- Test Operation	1.0
- Training	2.0
Total	33.0

3) Transmission Facilities

- Mobilization	1.0
- Civil Work	30.0
- Mechanical / Electrical Work	(24.0)
- Test Operation	1.0
- Training	1.0

4) Distribution Facilities

- Mobilization	1.0
- Civil Work	32.0

(4) Procurement of maintenance equipment

Preparation of bid documents and specifications for the maintenance equipment, such as water quality analysis equipment, leakage detection equipment, trucks with loading cranes, etc. will be prepared by the consultant during the detailed design of the water facilities and procured within 2002 by international bidding.

6.5.3 Construction Equipment and Materials

Most of the construction materials are imported from adjacent countries, except sand, gravel, concrete pipe etc. The imported materials, however, are available in the local market in Sri Lanka. Mechanical and electrical equipment must however, be imported from foreign countries.

Local products and imported materials and equipment are listed below. However, the imported materials for civil work are considered to be procured through sales agents and suppliers in Sri Lanka.

(1) Local material

Cement, stone, aggregate, sand, timber, plywood, steel reinforcement bars, structural steel, small PVC Pipe, concrete pipe, steel pipe, road curb, concrete block, brick, AC roof and tiles, pre-cast built wall, fence, road/pedestrian gates, wire nails, gabion mesh, gasoline, diesel, lubricants, admixtures, waterstop, scaffolding, metal forms, guardrail, asphalt, emulsion and other small items.

(2) Imported material

Construction equipment, valves, fittings, ductile iron pipe, truck cranes, vehicles, motorcycles, computers, pumps, motors, transformers, switchgears, disinfection facilities, laboratory equipment, flow meters, and other mechanical and electrical equipment.

CHAPTER 7 OPERATION AND MAINTENANCE PROGRAM FOR WATER SUPPLY SYSTEM

CHAPTER 7 OPERATION AND MAINTENANCE PROGRAM FOR WATER SUPPLY SYSTEM

7.1 General

The water supply facilities must be maintained to ensure that the required supply of sufficient quantities of safe and potable water at the required pressure is available at all times.

Any omission or neglect of proper operation and maintenance functions may result in unexpected failures to the water supply facility and which will require additional cost and time for repair.

Regular activities to maintain facilities and equipment mainly comprise patrol/inspection and maintenance works. Patrol/inspection is commonly carried out to check operating status of respective facilities/equipment, while maintenance is to be performed to insure normal operating conditions are maintained.

7.2 Work Program for Operation and Maintenance

7.2.1 Intake Facility and Water Treatment Plant

The Operation and Maintenance (O&M) activities for the intake facility and water treatment plant are normally classified into two categories, - daily and periodical functions. The work categories by O&M type are shown in Table 7.1.

Table 7.1 Work Categories for Intake and Treatment Facilities by O&M Types

O&M Category	Working Category
Daily Inspection	-Flow rate of water intake and distribution, -Water level at reservoirs, -Operating conditions of rapid sand filters and back washing, -Operating conditions of wastewater return pumps, -Operating conditions of chemical dosing/injection facility -Removal and transfer of sludge to the sludge lagoon -Operating conditions of mechanical/electrical facilities -Water quality examination
Periodical Work	-Removal of grit at grit chamber (monthly/seasonal) -Removal of dried sludge from sludge lagoon (monthly) -Inspection/repair of mechanical/electrical facilities (annually) -Overhaul of mechanical/electrical facilities (at 5 to 10 year interval)

The O&M activities for the intake facility and water treatment plant should be carried out in accordance with the program below:

(1) Daily work program

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 insure that the required quality of water is produced and efficient operation of the treatment facilities, inspection of: operation conditions at rapid sand filters and back; removal and transfer of sludge to the sludge lagoon; 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 also important to determine any defects and to take immediate countermeasures to rectify such.

(2) Periodical work program

Periodical 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.

(3) Laboratory

Continual water quality examinations will be required to insure treated water quality is maintained within permissible levels of drinking water quality standards during the water treatment process. The water quality examination laboratory is planned, therefore, to be located at the treatment plant. The necessary staff will be assigned for within the waterworks or hired from local contractors/laboratories. The water quality indices and examination frequency are shown in Table 7.2. Examinations for heavy metals and pesticide shall be contracted out to local contractors/laboratories to obviate the purchase of expensive equipment for infrequent use.

Table 7.2 Laboratory Tests and Frequency

Characteristics	Receiving Well	Sedimentation Basin	Filter	Clear Water Reservoir	Tap Water
Water Temp.	*	4 times/d	Once a month	once a month	
Turbidity	*	*	Once a month	once a day	once a month
Color	once a month	once a month	Once a month	once a month	once a month
pH Value	*	*	Once a month	once a month	once a month
Odor	once a month	once a month	Once a month	once a month	once a month
Taste				once a month	once a month
Ammonia	once a month	once a month	Once a month	once a month	
Nitrite	once a month	once a month	Once a month	once a month	once a month
Nitrate	once a month	once a month	Once a month	once a month	once a month
$KMnO_4$	once a month	once a month	Once a month	once a month	once a month
Chloride	once a month	once a month	Once a month	once a month	
T-Alkalinity	*				
T-Hardness	once a month	once a month	Once a month	once a month	
Total solids	twice a year	twice a year	Twice a year	twice a year	
E.C.	once a month	once a month	Once a month	once a month	
Sulfate				once a year	
T-Iron	once a month	once a month	Once a month	once a month	
T-Manganese	once a month	once a month	Once a month	once a month	
Zinc	once a month	once a month	Once a month	once a month	
Copper	once a month	once a month	Once a month	once a month	
Lead	once a month	once a month	Once a month	once a month	
H-Chromium	twice a year	twice a year	Twice a year	twice a year	
Cadmium	twice a year	twice a year	Twice a year	twice a year	
T-Mercury	twice a year	twice a year	Twice a year	twice a year	
Arsenic	twice a year	twice a year	Twice a year	twice a year	
Fluoride	twice a year	twice a year	Twice a year	twice a year	
Selenium	twice a year	twice a year	Twice a year	twice a year	
A-Surfactant	once a month	once a month	Once a month	once a month	
Cyanide	twice a year	twice a year	Twice a year	twice a year	
Organic-Phosphate	twice a year	twice a year	Twice a year	twice a year	
Phenol	twice a year	twice a year	Twice a year	twice a year	
Bacteria	once a month	once a month	Once a month	once a month	
E. Coli	once a month	once a month	Once a month	once a month	once a month
Res. Chlorine				*	once a day
Tri-methane				twice a year	twice a year
Pesticide	twice a year				

T: total H: hexa Res.: residual Tri: trihalo
* Examination Frequency ∗ : Continuously

7.2.2 Transmission and Distribution Facilities

O&M activities include daily inspection, site investigation, rehabilitation of damaged pipes, etc. as shown in Table 7.3.

Table 7.3 Work Categories for Distribution Facilities by O&M Type

O&M Type	Working Items
Daily Inspection	-Operation of pumping facilities -Operation of electrical facilities
Site Investigation	-Confirmation of transmission/distribution facilities and their surrounding environment.
Rehabilitation	-Replacement/repair of damaged pipes
Water Quality Examination	-Periodical water quality examination of respective reservoirs and distribution lines.

The O&M for the transmission and distribution facilities should be conducted in accordance with program below:

(1) Daily inspection

Pumping facilities are designed to operate automatically based on change of water level in the reservoirs. Daily inspection of pump stations is required to monitor the operating conditions of pumps and associated electrical system.

(2) Site investigation

The transmission and distribution lines, reservoirs and surrounding environment should be surveyed regularly for damage caused by land-subsidence, erosion of slopes by rainfall, etc.

(3) Rehabilitation

Leakage repair of transmission/distribution lines and replacement of wearing parts for pumping equipment are the usual rehabilitation works.

Replacement of damaged pipes is usually sub-let to local contractors based on the annual rehabilitation plan or based on regular inspection reports. Water Board officials in charge of such repair work should prepare reports on situation and cause of damages, and countermeasures taken up for rehabilitation, as future reference for preventive O&M work.

(4) Water quality examination

Periodical sampling and water quality examination should be carried out at reservoirs, distribution lines and taps (end points of distribution lines) to confirm conformity to drinking water quality standards.

7.3 Organization for Operation and Maintenance

Proposed number of staffs for operation and maintenance is assumed at 23 persons for Phase 1, 28 persons for Phase 2, and 33 persons for Phase 3, as shown below.

Table 7.4 Required Number of Staff for O & M of Water Supply System

(Unit: persons)

Field & Position		Phase 1	Phase 2	Phase 3	Assignment
Manager		1	1	1	Responsible for overall management/ supervision of waterworks
Transmission/Distribution Facility					
Operation & Maintenance	Engineer	1	1	1	Responsible for work control/ supervision
	Forman	2	4	6	Responsible for site works
	Worker	6	8	10	Workers/team
	Driver	1	1	1	Workers/team
Vehicle Maintenance*	Mechanic	-	-	-	Maintenance of vehicles/equipment
Water Treatment Plant					
Operation	Engineer	1	1	1	Responsible for work control/ supervision
	Forman	2	2	2	Responsible for site works
	Operator	2	2	2	Responsible for plant operation
Maintenance	Technician	2	2	2	Responsible for site works
	Worker	4	5	6	Responsible for site works
Water Quality Examination	Chemist	1	1	1	Water quality examination and control
Total		**23**	**28**	**33**	

* Vehicle maintenance shall be done by the municipal workshop.

7.4 Operation and Maintenance Cost

The operation and maintenance program, as stipulated in the preceding sections, requires the following items and annual costs for transmission/distribution facilities and water treatment plant. Detailed cost is shown in Appendix 7.1.

Table 7.5 Operation and Maintenance Cost

(Unit: Thousand Rs./year)

Item	Phase 1	Phase 2	Phase 3
Personal Expenses	6,120	7,320	8,520
Electricity Cost	68,803	132,129	195,388
Chemical Cost	6,068	12,137	18,205
Repair Cost	6,896	13,211	20,197
Removal of Sediments *	1,200	1,200	1,200
Total	89,087	165,997	243,510

*: Removal of sediments from Polgolla impoundment in front of intake facility at the time of dam maintenance. It will be conducted about once in every five years. Costs are divided to each year.

CHAPTER 8 GROUNDWATER RESOUCES

CHAPTER 8 GROUNDWATER RESOURCES

8.1 Physiography

8.1.1 Geographic Setting

The GKSA (Greater Kandy Study Area) is characterized by rolling hills and ridges on the middle peneplain with elevations from 450m to 700m. The entire GKSA (460 km^2) is within the large Mahaweli Ganga drainage basin, which is an important source for hydroelectric power and irrigation water. The Mahaweli Ganga (River) and its tributaries are responsible for dissecting the middle peneplain, resulting in the rolling hills and ridges in the central and greater Kandy area.

Precipitation in the GKSA occurs during both monsoon seasons with up to 2000mm annually falling in the GKSA. The temperature fluctuates very little, staying between 25°C and 30°C most of the year. The upland areas are generally planted with tea while rubber and other crops are grown in the lower areas. Paddy cultivation (rice) is limited to the flat valleys.

8.1.2 Geology

Underlying the GKSA are the HC (Highland Complex) and the KC (Kadugannuwa Complex), consisting of high-grade multi-phase metamorphic Precambrian rocks. Meter scale layering and an internal fabric characteristic of ductile deformation, with extreme flattening and stretching dominate the HC and KC structures. Probably up to 6 phases, including minor phases, of deformation have contributed to the complex internal structure and layering. The repeated and intense metamorphism of these Precambrian rocks has resulted in strong folding (antiforms, synforms, and overturns), shearing along the fold axes, and lithological changes due to melting. Subsequent episodes of uplift and submergence have caused extensive regional faults and fault zones. Shallow fractures due to the effects of weathering and erosion can also be found throughout the HC and probably the KC.

Predominant lithologies in the GKSA are biotite-hornblende gneiss and garnet-sillimanite-biotite gneiss, with less dominant quartzites, marble, calc-gneiss, and charnockitic gneiss. These lithologies are an important source of road metal, sand, and gemstones in Sri Lanka.

8.1.3 Geophysical Surveys

A total of 30 single dimension electrical resistivity soundings were conducted in the GKSA to identify the contact of the fresh rock and search for deep fractures. The locations are given in Table 8.1 and shown in Figure 8.1. Sounding locations were decided based on proximity to Kandy MC, current water availability, and demonstrated need as discussed with NWS&DB personnel. This information was combined with geologic and topographic information to determine the best locations to carry out the soundings. Soundings penetrated to depths of up to 200m. The survey equipment consisted of a "Sting R1" (AGI Inc.) instrument with accessories. Analysis was conducted with the assistance of commercial software and interpreted by a hydrogeologist.

Table 8.1 Electrical Resistivity Soundings

Sounding No.	Date	Site Name	Location X	Location Y
1	2 Jul 98	Rambukewela	177.08	244.37
2	2 Jul 98	Godahena	177.03	245.54
3	2 Jul 98	Watagalatenna	177.64	245.24
4	3 Jul 98	Nova Zembla	176.92	246.92
5	3 Jul 98	Enasalmada	178.43	249.09
6	3 Jul 98	Ellekade	180.36	244.85
7	4 Jul 98	Konkalagala	183.27	243.10
8	4 Jul 98	Arambepola	181.89	244.26
9	4 Jul 98	Kalalpitiya	182.72	247.70
10	6 Jul 98	Kalalpitiya2	182.93	246.44
11	6 Jul 98	Mawatapola	183.00	244.88
12	6 Jul 98	Mawatapola2	182.21	245.12
13	7 Jul 98	Talatuoya	191.06	228.34
14	7 Jul 98	Talwatta	189.42	230.15
15	7 Jul 98	Gurudeniya	191.39	229.18
16	7 Jul 98	Haragama	194.29	227.23
17	8 Jul 98	Nugaliyadda	190.80	226.27
18	8 Jul 98	Pananwala	189.58	226.85
19	8 Jul 98	Alekade	190.12	226.07
20	8 Jul 98	Hippola	189.25	228.25
21	9 Jul 98	Arambekade	175.13	238.10
22	9 Jul 98	Warakagoda	174.27	241.31
23	9 Jul 98	Molagoda	174.56	243.24
24	9 Jul 98	Wewala	176.10	243.38
25	10 Jul 98	Hapugoda	181.23	238.32
26	10 Jul 98	Kahawatta	182.22	239.04
27	10 Jul 98	Kendaliyadda	183.26	239.13
28	10 Jul 98	Waragashinna	183.11	240.63
29	11 Jul 98	Udalhagama	176.59	240.65
30	11 Jul 98	Madadeniya	177.85	240.90

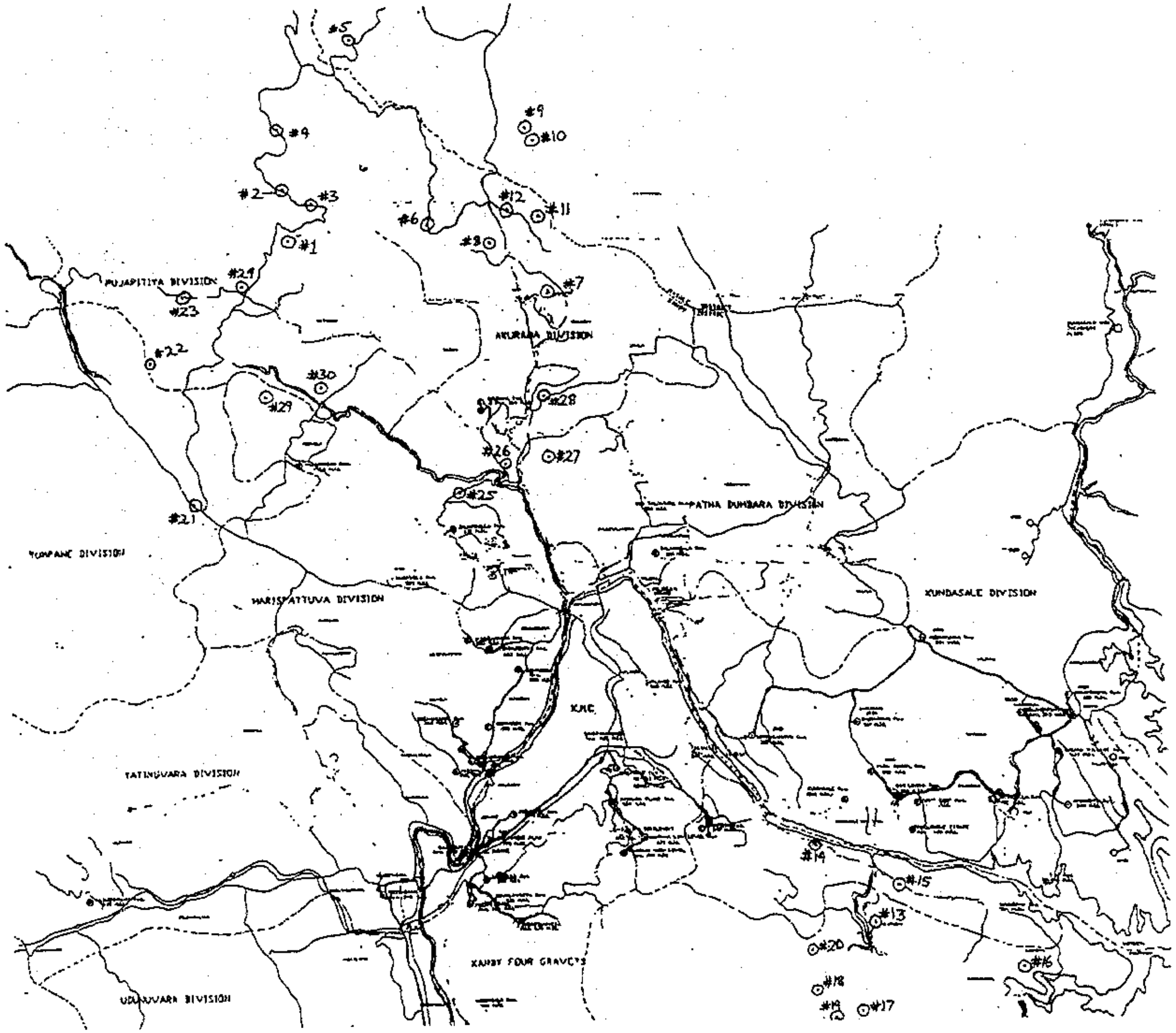

Figure 8.1

Electrical Sounding Locations in Greater Kandy

Sounding data and resistivity models are included in the appendix. Initial low-resistivity zones generally indicate alluvial deposits and weathered rock, usually ranging from a depth of 5 to 60m. Below this is a higher-resistivity zone, indicating a layer of clay or hard rock. Deeper, very thin, very low-resistivity zones usually indicate fractures in the hard rock or a saturated contact between formations. Deeper and thicker low-resistivity zones generally indicate a saturated permeable formation such as quartzite or limestone.

8.2 Hydrogeology

While this area is not a typical sedimentary system, the hydrogeology of the area and resistivity soundings indicate that there are some options to explore further. Typically, a groundwater system of two to four zones (aquifers, aquitards) is defined by the hydrogeology within the first 200m. These zones, which may or may not occur at various locations, are described below.

Overburden consists primarily of weathered gneisses, and commonly has a thickness of two to 35m. However, this weathered zone extends down as far as 70m or more below the surface in some valley locations. The overburden is stratified with lenses of clay and quartz, and is usually permeable. Most of the GKSA consists of relatively small hills and valleys, and consequently, overburden deposits are discontinuous and limited in extent. Groundwater in the overburden is classified as a local flow regime with recharge and discharge generally taking place within the same valley. In areas where quartzite or limestone formations occur at or near the surface, the overburden remains saturated during most of the year and receives recharge from the formation, which extends beyond the valley.

In areas of deep overburden a two to three meter zone of clay and freshly weathered rock can be found just above the contact with hard rock. In this zone, the clay is an aquitard, or confining layer, thus preventing any significant water seepage from reaching the layers below. In addition, the clay particles tend to adsorb petroleum chemicals and contaminants, effectively creating an environmental filter and barrier.

The hard rock typically has a shallow zone of fractures associated with weathering processes and is usually saturated. This zone is probably connected hydraulically with the overlying freshly weathered rock and can be considered a thin (two to ten meter) confined aquifer.

The remaining hydrogeologic zone is structurally controlled. A series of faults and shears result in regional-scale deep fracture zones. The shear zones are oriented primarily in a NW-

SE direction and typically extend from ten to over 100km, generally following the axial orientation of the major structural folds. The fault zones are oriented primarily in a NE-SW direction, which is generally perpendicular to the shear zones, and typically extend from ten to over 100km. Headwaters of many perennial streams and rivers originate in fault zones, indicating a discharge zone of these areas, and that the fault zones are saturated.

Figure 8.2 shows the locations of the major fracture zones in the GKSA. These zones generally correspond to areas where more groundwater is available, with the fault zones having the most potential as a resource. The figure shows that several relatively small faults occur around the GKSA, but not through central Kandy. On the other hand, several extensive shear zones penetrate the entire GKSA. These shear zones also have a strong potential as a groundwater resource but generally do not penetrate as deep; therefore we do not expect to find as much water as in the fault zones. Based on the feasibility study conducted in Nuwara Eliya, the shear zones might produce up to 500 m^3/day and the fault zones might produce up to 1200 m^3/day.

Quartzites and marble generally have fissures and joints that transmit water and springs are commonly found in low-lying zones of quartzite and marble. Wells completed in these zones usually have a good yield and are suitable for households and small farms, although water from the marble is usually hard due to higher concentrations of dissolved calcium and magnesium.

8.3 Conclusions and Recommendations

Analyses of existing and surveyed field data indicate that locally, potential groundwater resources exist in the Greater Kandy area. Several wells have been established as community and private water supplies and demonstrate that good groundwater resources occur in this area. However, in many areas problems were observed:

- Excessive drawdown due to overpumping
- Seasonal wells due to shallow depth
- Seasonal wells due to geologic properties
- Contaminated water due to shallow depth
- Contaminated or dirty water due to poor construction
- Lack of developed water supply

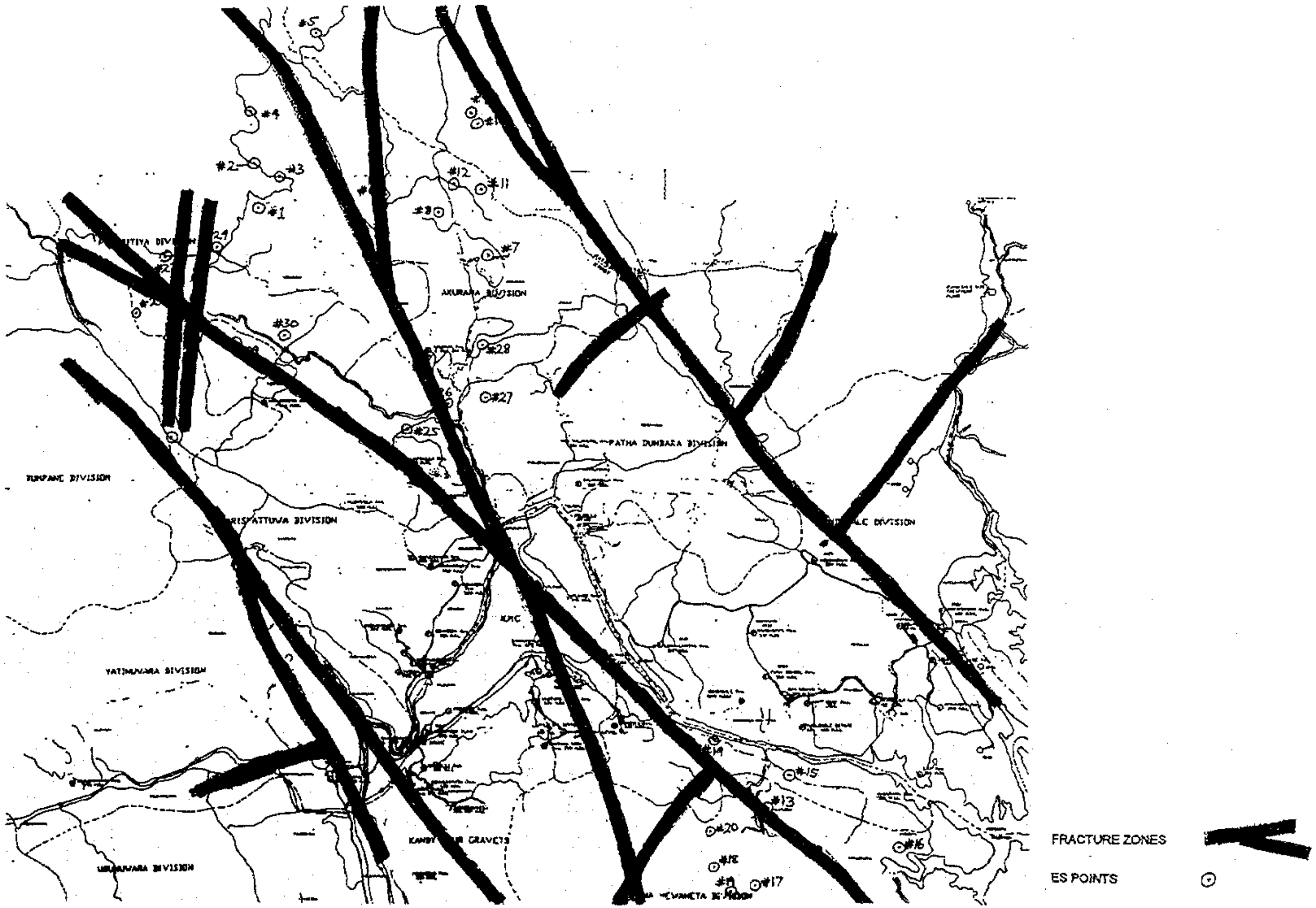

Figure 8.2

Locations of Major Fracture Zones

In some cases the well can be rehabilitated or re-evaluated, and in other cases it is best to locate and drill a new well to tap a more reliable source.

In the case of excessive drawdown, it is necessary to re-evaluate the previous pump tests to determine the correct pumping rate. It may be necessary to conduct a series of pump tests (step, long duration) to establish the correct pumping rate. If pump tests were previously conducted, it will be necessary to modify the parameters to give a better evaluation.

In some cases, the well might have problems related to construction materials or methods. This type of problem will have to be evaluated on a case by case basis to determine the nature of the problem and feasibility of corrective action. Typical problems might include leaky seal, cracked/collapsed casing, debris in the well, pump failure, and plumbing problems. The best solution should include a comparison against the cost and time to locate and drill a new well.

Well problems related to geologic conditions include unscreened loose/fine formations and hydraulic connections to the surface and would cause dirty and/or insufficient water. Generally this type of problem is not easily corrected and it might be more efficient to locate and drill a new well.

Shallow wells are the most susceptible to surface conditions such as dry climate and infiltration of contaminants. During the dry season, these wells dry up or the water level is too shallow to withdraw water. Seepage and infiltration of contaminants lead to unhealthy and dangerous water that is not safe to drink. These wells are usually 'dug' wells and have a large diameter, making it nearly impossible to use modern drilling machines to deepen the well. In these cases, the best alternative is to locate and drill a new well to provide a suitable source of drinking water.

In areas which lack an adequate water supply and groundwater is the preferred choice, a careful evaluation will have to be made of the hydrogeology to establish a suitable site to successfully drill a well.

In the course of this study, several areas were identified as having deficient water supplies or schemes, Bokkawala, Galhinna, Alawatugoda, and Talatu Oya. These are the areas where the field surveys were concentrated. Analyses of the data indicate that groundwater resources are probably available in these areas but may be somewhat limited, depending on the hydrogeologic conditions and logistics. Generally, low lying areas intersecting with a fracture zone will have the highest potential for groundwater exploration and development.

Based on available data and areas of focus, the following areas have been identified for groundwater feasibility studies and potential development.

Figure 8.3 shows several areas identified for future groundwater exploration and development which correspond to the villages mentioned above. In the Bokkawala area, a fault zone to the west will be the best place to explore. It should be possible to develop a good water supply from this zone. However, the fault zone is generally narrow and difficult to locate, therefore it will probably be necessary to perform geophysical surveys to correctly locate and identify it. If correctly located and developed it could possibly produce more than enough water for the area, up to 1000m^3/day per well. Additionally, a quartzite formation passes through the southern portion of the area. The quartzite will have the best results if it is more than 2 meter thick and found at depth.

In the Galhinna area, a shear zone to the northeast represents a potential source of groundwater and should be explored. If it can be located and developed, wells could produce up to 500m^3/day which would certainly help alleviate the water supply problems in the area. A quartzite formation in the southwest corner is part of a synform and it might be a good, but limited source of water if it can be located at depth, to the north of the outcrop.

Further to the east, between Galhinna and Alawatugoda, is a significant shear zone where some wells have already been drilled. These wells showed early promise as a good water supply, but due to a combination of factors, production has been limited. The factors contributing to the problem are 1) poor design (wells too close to each other), and 2) incorrect pumping rates for the existing well construction and hydrogeologic conditions. However, the structure and hydrogeology of this area clearly indicate a groundwater potential which should be explored and correctly evaluated. These wells could be re-evaluated with pump tests and used for production. This shear zone is rather extensive and would probably be a good source for additional wells, with potential yields of up to 400-500m^3/day.

The Alawatugoda area is situated in a valley that follows the axis of a syncline. Although current maps do not show a shear zone along the axis, it simply means that one has not been identified and mapped yet and in all likelihood there is one associated with the synform. There is a quartzite formation in the north of the Alawatugoda area that could also contribute significantly and should be explored. The combination of these potential sources should be capable of producing a sufficient amount of water for the immediate area. Geophysical surveys will help identify areas for drilling. Wells drilled in this area should be capable of producing 300 to 500m^3/day.

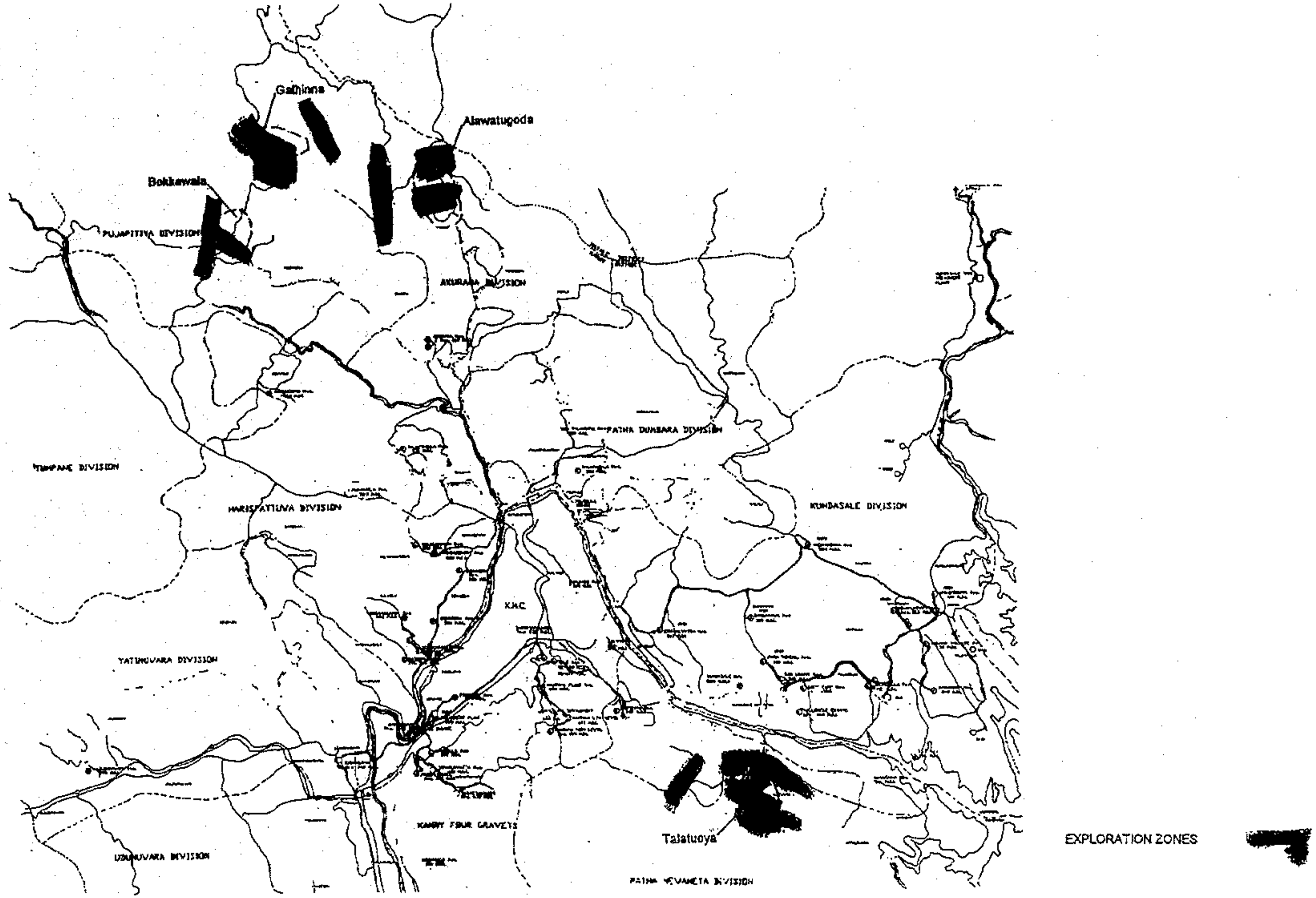

Figure 8.3

Areas for Future Exploration in Greater Kandy

Several features conducive to groundwater development characterize the Talatuoya area. A shear zone that passes through the area has no associated structural fold as shown on the geologic map and is probably the result of forces between two adjacent antiforms. A nappe also enters and terminates in this area, intersecting the shear zone. These two structural features, and especially the intersection, represent an area of high probability for groundwater development. Additionally, there are several strata of limestone/marble formations that are usually good water-bearing zones. However, water from limestone is generally 'hard' due to high concentrations of dissolved calcium and magnesium in the water. Fortunately this is not normally a health problem but is sometimes considered undesirable for other household uses. These formations represent an additional potential source which, when combined with the other structural features, should provide a very good source of water to supply the community. It is almost certain that abundant groundwater resources are available in this area and wells should be capable of producing 500m^3/day or more.

It is important to note that drilling boreholes in fractured rocks can present problems with well construction and development such as collapsing formations, fracture debris, and hydraulic connections to the surface. Drilling operations should be prepared to handle a variety of drilling conditions. Generally, the most desirable fracture zone will have a substantial layer of solid rock above it; therefore, it may be necessary to continue drilling beyond the point where the first water and fractures were found. The nature of fracture zones usually make it necessary to put a screen and gravel pack in the water bearing zone to prevent fracture debris from entering and clogging the plumbing. Additionally, it will be necessary to develop the wells sufficiently to ensure maximum yield and clear, clean water. To correctly evaluate the well and aquifer, it is necessary to conduct a pumping test using one or more properly constructed and spaced observation wells.

However, more fundamental problems still exist which will certainly prevent the successful development of groundwater resources in the GKSA. The correct construction materials are either in short supply or not available, such as blank steel casing (10", 12", 14", 16", 18", at least 80m per well), high quality PVC casing (straight, type 1000 or thicker), commercially made screens (ie. Johnson Screens). There is a lack of certain equipment and existing equipment is in need of repair. For example, drill bits are worn, size and type selections are inadequate, and there are not any portable mud pits. Before undertaking any additional exploratory or production drilling, a complete inventory should be taken to facilitate repairs to existing equipment and acquire materials and supplies. It is clear that fracture zone hydrology in Sri Lanka is poorly understood and that the NWSDB would benefit from assistance and training from experienced and qualified hydrogeologists and groundwater engineers.

It can be seen that there is a very high potential to locate and develop urgently needed groundwater resources in the GKSA. However, this will be difficult, if not impossible, without international assistance. It is strongly recommended that the Sri Lankan Government seeks and utilizes international assistance to resolve water supply problems in the GKSA, as well as improve their ability and equipment resources for future groundwater projects.

CHAPTER 9 NON-REVENUE WATER REDUCTION PROGRAM

CHAPTER 9 NON-REVENUE WATER REDUCTION PROGRAM

9.1 General

For the purposes of this investigation, NRW is defined as the difference between the quantity of water produced and the quantity for which the water utility receives revenue. NRW is not the same as unaccounted for water (UFW), as illustrated in Figure 9.1. The difference between UFW and NRW consists of water use by legal connections that are provided with water at no charge. The subject of billed water versus revenues actually received is discussed in Chapter 4.

It is strongly recommended that any proposed plans to augment water supplies be accompanied by a vigorous non-revenue water (NRW) reduction program. NRW can be due to a number of causes:

- Transmission main and distribution system leakage
- Reservoir leakage/overflow
- Unbilled legal connections
- Illegal connections
- Service connection meters
- Distribution system pressure
- Production metering
- Administrative errors

Figure 9.1

Non-Revenue and Unaccounted for Water[1]

Water Produced	Water Accounted for	Residential		Revenue Water
		Commercial		
		Industrial		
		Institutional		
		Special Consumption & Operational Consumption		Non-Revenue Water
	Water Not Accounted for	Illegal Consumption		
		Loss of Water	Overflow	
			Leakage	
			Waste	
		Metering Errors	Bulk Metering Errors	
			Service Connection Metering Errors	
			Estimation Errors	

Some of these components, unbilled legal connections such as public standposts, for example, are known but not billed for social or economic reasons and constitute no problem other than financial for the water utility. Other components, such as leakage, can only be estimated and reduced by relatively expensive methods. The cost of efforts to reduce NRW should not be greater than the value of the water saved by those efforts. It is therefore important to make as accurate as possible an estimate of the various components of NRW in order to provide a basis for designing a cost effective NRW reduction program. Estimates of the magnitude of the

[1] Adapted from: Operation and Maintenance of Water supply and Sanitation Systems, A Guide for Managers, World Health Organization, 1994.

various NRW components and a recommended NRW reduction program are presented in the following sections.

For convenience, water systems in the Greater Kandy area have been divided into three categories.

- Areas managed by NWSDB
- Areas managed by the Kandy Municipal Council
- Areas in Greater Kandy managed by other agencies

As shown in Table 9.1, these agencies presently supply 64,460 m^3/d of water to various communities in the Greater Kandy area. Other Greater Kandy agencies include those provided with bulk supplies by NWSDB and those who manage their own supply and distribution facilities.

Table 9.1 Water System Management Responsibilities

Management Agency	Present Supply (m^3/d)
NWSDB	23,340
Other Greater Kandy Agencies	7,720
Kandy Municipal Council	33,400
Total	64,460

The KMC system has 17,500 service connections and 470 standposts. There are 11 agencies in the Greater Kandy area that either manage their water systems exclusively or in conjunction with NWSDB. A summary of the available data pertinent to the subject of NRW is presented in Table 9.2. These agencies have a total of 5,206 service connections and 156 standposts (See Table 9.2).

NWSDB provides all management functions from supply to distribution system maintenance to billing for 23 separate water supply systems outside of the KMC with a total of 19,000 service connections and 500 standposts (See Table 9.3).

9.2 Present NRW

As indicated in Table 9.4, the average NRW for individual water systems managed by NWSDB presently ranges from 18.2 percent to 70.6 percent. Present NRW for Greater Kandy is 42 percent.

Table 9.2 Selected Data on Other Greater Kandy Water System Management Agencies

Management Agency	Connections		Production Capacity (m^3/d)	Pipeline Length (km)
	Direct Connections	Standposts		
Ampitiya P.S.	1,255	52	1,300	N.A.
NWSDB bulk supply/ Kundasale P.S.-Menikhinne	821	6	-	N.A.
Kundasale P.S.-Kundasale New Town	1,200	5	-	N.A.
Kundasale P.S.-Open Prison Camp	125	5	720	N.A.
Kundasale P.S.- Balagolla Settlement/BOI/Digana Village	506	44	-	N.A.
Farm School	N.A.	N.A.	1,900	N.A.
Wategama U.C	1,059	42	1,400	11.5
Patha Hewaheta P.S.	240	2	2,200	N.A.
NWSDB bulk supply management/Peradeniya University	N.A.	N.A.	N.A.	N.A.
Peradeniya T.T.C.	N.A.	N.A.	N.A.	N.A.
Gampola U.C.	N.A.	N.A.	N.A.	N.A.
Totals	5,206	156	7,520	

Table 9.3 Selected Data on NWSDB Managed Water Systems

Water System	Connections		Production Capacity (m^3/d)	Pipeline Length (km)
	Direct Connections	Standposts		
Hantana	455	-	300	8
Mullepihilla	63	9	-	3
Mahakanda	13	-	-	3
Upper Hantana	20	-	2,000	2
Akurana	1,060	53	1,000	22
Alawathugoda	1,002	33	300	20
Rajapihilla	764	41	650	25
Gohagoda and Yatihalagala	1,870	32	1,920	40
Kondadeniya	914	18	-	20
Hediniya	1,178	56	840	23
Kulugammana	1,553	17	900	38
Bokkawela	745	21	950	18
Ankumbura	247	8	-	8
Galhinna	370	17	80	8
Polgolla	236	-	-	2
Balangala	1,200	38	-	12
Polgolla (Napana)	574	36	-	18
Talatu Oya	295	0	0	4
Udu/Yatinuwara	5,794	121	4,600	120
Welamboda				
Kadugannawa	352	0	800	9
Kalugamuwa	N.A.	N.A.	9,000	N.A.
Mariyawatta	295	0	0	6
Totals	19,000	500	23,340	409

9.3 Transmission Main and Distribution System Leakage

9.3.1 NWSDB

The NWSDB has only recently (1 August 1998) initiated a program to keep track of leak repair activities in systems under their jurisdiction and no data is currently available.

Table 9.4 Present NRW in Greater Kandy

Area	Avg. NRW (%)	Production (m^3/d)
Low NRW Areas		
Talatuoya	18.2	139
Hanthana	28.6	427
Hedeniya	29	758
Udu/ Yati nuwara	31	5,263
Kadugannawa	33.1	772
Average NRW	28.0	
High NRW Areas		
Mullepihilla	37.2	120
Bokkawala	38.2	609
Balanagala	40.4	1,462
Akurana	42.0	1,329
Kandy MC	42.1	31,641
Ampitiya	43.4	1,145
Rajapihilla	54.3	1,236
Polgolla	55.3	1,132
Gohagoda, Kondadeniya, Yatihalagala, Kulugammana	70.6	7,378
Average NRW	47.1	

Most of the commercially available leak detection equipment relies primarily on the detection of noise resulting from pipes leaking under high pressure. Large sections of the study area distribution systems do not operate at sufficient pressure to produce detectable leakage sounds, thus limiting the effectiveness of conventional leak detection equipment. There is no practical method for directly measuring the present level of leakage in these systems. It is, however, possible to make some estimate of the other components of NRW. By subtracting the estimated values for these other components from the total NRW, we can arrive at an approximation of current leakage levels. The magnitude of the leakage component relative to other NRW components will provide an indication of how much of the NRW reduction program effort should be expended on leak detection and repair. The range of pressures in any given distribution system will dictate what types of leak detection equipment and methods would be appropriate.

As indicated in Table 4.3, NWSDB records indicate that there are some 409 kilometers of transmission mains and distribution pipes in the water systems under their jurisdiction. There are no rigid joint (cast iron with lead joints) pipes in the system, but there are about 42 kilometers of asbestos cement pipe which is difficult to repair and believed by maintenance staff to be a source of many leakage problems.

The actual length of distribution piping is substantially greater than this figure. A significant proportion of the existing service meter installations have very long, small diameter service connection lines extending from the nearest available distribution main to the service meter inside the consumer property line. Distribution system pipelines are primarily confined to major roads and have not been extended to many secondary streets and lanes due to insufficient funds. Applicants for service connections are required to pay for the connecting lines, and the NWSDB has been honoring requests for service connections by installing individual connecting lines for new customers. This has resulted in "bundles" of small diameter service (mostly 12 to 25 mm) connection lines in many secondary streets. These "bundles" often consist of up to a dozen pipes in a single street with little or no cover. The NWSDB maintenance staff have initiated a street by street survey to determine how many of these streets with "bundled" service connection lines exist and have thus far covered about five percent of the NWSDB service area. Fifteen kilometers of streets with "bundled" pipes have been identified thus far. A brief visual survey of secondary streets in the service area indicates that such streets have an average of about five service connection pipes. If the portions of the service area that have not yet been surveyed have a similar concentration of such pipes, the total length of service connection pipes could be as much as 750 kilometers, or almost twice as much pipe length as all of the existing pipeline.

A characteristic of water distribution systems is that the amount of leakage per kilometer is essentially independent of pipeline diameter. The expansion of the effective length of pipelines in the distribution system that has been caused by past service connection practices has undoubtedly contributed significantly to the amount of leakage. Most of the service connection pipes are not buried deep enough to offer protection against pedestrian or vehicular traffic. This suggests that leakage rates per kilometer from service connection pipes could well be even higher than from the larger transmission and distribution pipes, which for the most part are buried at much greater depths under paved streets. Because there is inadequate data to support this supposition, estimated leakage has been allocated between major pipelines and service connection lines solely on the basis of pipeline length.

9.3.2 KMC

The existing KMC transmission and distribution system has approximately 235 kilometers of pipe, 140 kilometers of which are old cast iron with poured lead joints. There are numerous secondary roads with long "bundles" of small diameter service connection pipes between the nearest distribution line and customer premises. Some of the older service connection lines (about 1,000 connections) have galvanized iron pipes, but all of the more recent ones are of PVC. KMC is in the process of replacing the galvanized iron service connection pipes due primarily to their age. KMC estimates that there are approximately 50 kilometers of streets with "bundled" service connection lines in their service area. This amounts to an additional service connection line length equal to about 50 percent of the total existing distribution system pipeline length.

KMC maintenance staff recently initiated a valve rehabilitation program, and estimate that about 90 percent of the larger diameter valves are fully functional. Many of the smaller valves are in need of repair or replacement. KMC is currently preparing a comprehensive valve rehabilitation program. Some 700 leaks per month are repaired by KMC maintenance staff, only about five of which are on transmission or distribution lines, with the balance being some form of service connection leak.

9.4 Reservoir Leakage/ Overflow

9.4.1 NWSDB

NWSDB maintenance staff report that two of their reservoirs are experiencing overflow problems on a regular basis due to inadequate shutoff valves. They estimate that about 300 m^3/d is lost because of this problem. This amount represents 1.3 percent of the production of water systems under NWSDB management.

9.4.2 KMC

Interviews with maintenance staff uncovered no indication of leakage or overflow problems with KMC reservoirs. Although the major KMC reservoirs are relatively old (30-40 years) and there is probably some undetected subsurface leakage, it has been assumed for the purposes of this report that the amount is negligible.

9.5 Unbilled Legal Connections

It is common practice in many water utilities not to bill certain categories of legally connected water users. Such categories can include municipal parks and buildings, religious institutions, government institutions, schools or low-income groups. Although it is certainly within the purview of water utility management to make essentially social decisions of this type, such selective favoring of one group of customers over another will affect the financial viability of the utility. The quantities of water resulting from such decisions and the cost to the utility should be clearly identified.

9.5.1 NWSDB

The NWSDB has no consumer categories for which they provide any kind of a rate subsidy. All standposts either have meters or their use is estimated based on the consumption records of metered standposts. Bills for standpost use are presented to the Municipal Council for payment. All religious institutions, schools and Government agencies are metered and billed in accordance with current water rates. Payments for water used by government agencies such as housing projects, military bases or police establishments, are made by the appropriate Government Ministry.

9.5.2 KMC

The following consumer categories are legally connected to the KMC system but are not billed by the water utility and their consumption is not included in the billed quantity records.

Category	Quantity (m^3/d)
Standposts	1,410
Bathing places	340
Temples	10
Parks	60
Cemeteries	16
Community centers	68
Schools	530
Playgrounds	5
Total	2,439

The total legally connected but unbilled consumption is 7.5 percent of the billed quantity and 4.4 percent of total production.

9.6 Illegal Connections

9.6.1 NWSDB

Illegal connections that have been discovered in the NWSDB system include unrecorded taps on distribution pipes and the service connection lines of legally connected customers as well as meter bypasses. A variety of mechanisms for masking illegal water use have been encountered, including changing meter dials to read in liters instead of gallons, reversing the direction of the meter and stopping or retarding movement of the meter register mechanism. All of these methods are difficult to detect and have in some cases been made with the assistance of water utility staff. Some or all of these types of illegal water use have been noted in all of the study area water systems.

Although the NWSDB has made repeated efforts to identify such connections over the years, maintenance staffs are convinced that there are still a substantial number remaining in the system. They estimate that about five percent of the total connections have an illegal bypass and another five percent are illegally connected in some fashion to distribution or service connection pipes, which would account for six percent of total production.

9.6.2 KMC

KMC management and maintenance staff estimate that between two and five percent of all water use is illegal. A figure of three percent of production has been adopted for the purposes of this investigation.

9.7 Service Meters

9.7.1 NWSDB

As of mid 1998, the status of NWSDB service connections (including areas outside of the study area) was as follows:

- Total connections 37,080
- Estimated 1,535
- Defective 996
- Un-metered 71

Estimated connections are those that are inaccessible or unreadable for some reason. The billed quantity for these connections, as well as the defective meters, are estimated by comparison with previous billing records when the meters were readable and operational or with metered use for similar customers. This is an acceptably accurate method and no contribution to NRW has been assumed from this source. The number of un-metered connections is so small (less than 0.2 percent) as to be negligible and inaccuracies due to this component has been assumed to be zero.

NWSDB service connection policy requires connections be made to roof tanks so that there will be an air gap to provide positive protection against reverse flow into the distribution system. Although the NWSDB has made every effort to follow this policy, it has been extremely difficult for them to do so because of the limited supplies and low system pressures that have characterized their systems in recent years.

It was noted during field inspections of service connections in the NWSDB service area that some meters are subject to reversal of the meter registration if the distribution system pressure becomes negative. If household water is drawn into the distribution system, there is a considerable risk of contamination of the public supply. If, as has been observed to occur in some service connections, there is an open tap or leak in the household plumbing, a very rapid meter reversal can occur when air is forced through the meter into the distribution system. In either case, reversal of meter registration can result in significant under billing for individual service connections.

Most of the service area is subject to alternating periods of adequate and inadequate pressures. NWSDB distribution system maintenance personnel indicate that negative pressures occur in the distribution system on a regular basis affecting about ten percent of the service connections. It is known that meters can also be subject to high rates of over registration during periods when pressures are changing from negative to positive, and that some or all of the under registration could be cancelled out by this effect. There are, however, no available data to indicate how large the net result of inadequate system pressure induced fluctuations in registration are, or whether the resultant is positive or negative. The possibility therefore remains that a significant portion of the estimated NRW is due to such fluctuations.

Some NWSDB service meters have special valves built into them that are designed to prevent reverse flow from service connections. Unfortunately, it has been noted by maintenance staff that these valves are prone to clogging by grit and sand particles, thus limiting their effectiveness. It is estimated that about twenty percent of the service meters with reverse flow prevention valves in the NWSDB system experience this type of problem. Another type of service meter used in the NWSDB system is not equipped with a reverse flow prevention valve and can allow free exchange of water and air flow between service connection plumbing and the distribution system. Approximately 30 percent of the existing NWSDB service meters are of this type. Another problem with this type of meter is that it allows the customer to reverse the meter and cancel out all or part of the actual water use.

The NWSDB meter workshop repairs about 200 meters per month, or over 12 percent of the total number of installed meters per year. Workshop staff indicate that most of the meters are so clogged with debris and rust that very little water will pass through them. Thirty two meters that had been brought in for repair were tested by NWSDB maintenance staff prior to being repaired. As indicated in Table 9.5, the average meter tested read 77.4 percent below the actual quantity passing through it. Although it can reasonably be assumed that the meters entering the meter workshop are in worse condition than the average meter in the system, nonetheless it appears that under registration is a major contributor to NRW.

Table 9.5 NWSDB Meter Accuracy before Repair

Meter Number	Percent Error	Meter Number	Percent Error	Meter Number	Percent Error
1	-100.0	12	-100.0	23	-0.8
2	-100.0	13	-100.0	24	-99.6
3	-100.0	14	-100.0	25	4.2
4	-100.0	15	-100.0	26	-98.2
5	-100.0	16	-100.0	27	4.0
6	-100.0	17	-100.0	28	6.0
7	-100.0	18	-100.0	29	-98.7
8	-100.0	19	-100.0	30	1.2
9	-100.0	20	-100.0	31	2.4
10	-100.0	21	-100.0	32	2.4
11	-100.0	22	-100.0	Average	-77.4%

Based on the above, a figure of ten percent of total production has been assumed for this NRW component.

9.7.2 KMC

KMC service connection policy is to charge the customer for service connection pipe and fittings from the nearest distribution line to a meter located on the customer's property. KMC staff are responsible for installation of the first 30 meters of service pipe. All taps on distribution lines are done by KMC staff or by plumbers registered with KMC. No specific installation charge is made for the meter at installation, but the cost is recovered via a monthly charge. As is the case for most of the water utilities in the study area, this practice, coupled with limited availability of funds to construct distribution line extensions, has resulted in numerous streets with "bundles" of service connection lines. The presence of these "bundles" substantially increases the length of pipeline subject to leakage and illegal connections for which the utility is responsible.

Ninety percent of the KMC service meters are less than ten years old. Approximately sixty percent of the KMC service connection meters are of the type that have non return valves built into them, the remainder, mostly older meters, do not. Although some meter reversal due to negative system pressures has been observed in the KMC system, it is believed that this condition does not occur as often as it does in the surrounding NWSDB systems. Clogging of the non return valves that would allow reverse registration of the meter only occurs with any frequency in areas served by several small, untreated water supply systems. Areas served with treated water from the KMC treatment plant have not been observed to have this problem.

The KMC meter workshop repairs and calibrates 150 meters per month, but currently has a backlog of about 3,000 meters that cannot be serviced with the existing facilities. The service meters that are repaired are primarily in response to customer complaints, which are usually based on the perception that the meter is reading too high. Most of the 3,000 meter backlog are meters that have been identified by meter readers that do not register flow. The unrepaired meter backlog equals 17 percent of the total number of KMC service connections.

Based on the above, the magnitude of the NRW component attributable to various service meter problems has been assumed to be ten percent of total production.

9.8 Distribution System Pressure

9.8.1 NWSDB

NWSDB maintenance staff report that distribution system pressures are generally low, vary throughout the day and in some cases are negative during peak demand periods or when service to one area is curtailed in order to make it possible to deliver water to another area. Pressures vary widely throughout the service area, with about 30 percent of the area ranging between 10 and 20 meters, 50 percent reaching pressures up to 50 meters and 10 percent with very high pressures up to 80 meters. About 10 percent of the service area experience negative pressures sometime during the day.

All of the conditions described above contribute in some way to the NRW problem. Wide variations in system pressure can cause surges that damage pipes and appurtenances in a variety of ways that will increase the rate of leakage. Leaks from pipes with low pressures are very difficult to detect because the characteristic noise made by water escaping under pressure is too low to be heard with most leak detection equipment. Leaks subject to high pressures leak at much higher rates than those subject to normal system pressures. Negative pressures often cause reversal of service meter registration, resulting in under billing of the consumer and a higher NRW figure.

In some cases, examination of the manner in which the distribution system pressure zones are delineated can identify areas where modification of pressure zone boundaries will reduce leakage by reducing system pressures. This method can of course only be used in areas where pressures are excessive, which usually applies to relatively small areas in supply deficient systems of the type that are the subject of this investigation.

9.8.2 KMC

In spite of a limited water supply, KMC has maintained a policy of providing service connections for all applicants, with the result that system pressures have declined in recent years. Although no specific data was available on KMC system pressures, discussions with KMC maintenance staff indicate that conditions are similar to those obtaining in the NWSDB distribution systems.

9.9 Production Metering

9.9.1 NWSDB

Production meters for NWSDB schemes are generally in poor condition and have not been calibrated for some time. NWSDB has facilities to calibrate bulk meters at their Udu Yatinuwara water treatment facility, but meters requiring repair are sent to NWSDB Colombo. Based on maintenance staff comments regarding the general condition and accuracy of NWSDB bulk meters, a provisional allowance of two percent of production has been adopted for this component of NRW.

9.9.2 KMC

Water production at the major KMC treatment facility is measured by an electromagnetic type of bulk meter that was installed in 1989. Although this meter has not been calibrated since it's installation, such equipment is normally quite robust and the operations staff indicate that its accuracy is within normal operating parameters.

9.10 Administrative Errors

For the purposes of this investigation, administrative errors have been taken to include the following:

- Estimated Meter Reading (for defective meters)
- Errors in estimating unmetered Consumption

NWSDB, KMC and most of the other Greater Kandy water utility management agencies all read meters on a monthly basis and estimate billing quantities for service connections with defective meters by comparison with the last three months metered consumption. Where no metered record is available, consumption is estimated by comparison with metered consumption for similar dwellings. Only six percent of the NWSDB service connections are estimated, but for KMC this figure is 25 percent. To allow for the higher risk of administrative error in the KMC system relative to the NWSDB systems, one percent has been allowed for this component for KMC and zero for NWSDB.

9.11 Other Greater Kandy Water System Management Agencies

Data for other Greater Kandy water system management agencies is limited, and, as of the date of completion of this report, only information on the Wattegama water system was available. A summary of that information is presented below to provide an indication of conditions in water systems currently managed by agencies in Greater Kandy other than NWSDB and KMC. Limited field observations of several of the systems being managed by other agencies suggests that conditions are similar to those found in the Wattegama system.

The Wattegama U.C. water system presently has no means to measure water production, and all customers are charged a flat rate. It is therefore not possible to draw any specific conclusions about the magnitude of the various components of NRW for this system, or for that matter, even to estimate the total NRW. Inspection of the water supply facilities indicates, however, that the problems that cause such high NRW rates in other study area water utilities are also present in the Wattegama system. Most of the service meters are about twenty years old and a substantial amount of the transmission system is asbestos cement pipe. Water utility staff report that they have to deal with over 100 leaks per month. An inspection of the distribution system found a substantial number of leaking pipe joints and service connections. Service connection pipes were in general not buried and exposed to possible damage by pedestrian and vehicular traffic. The water utility has no meter readers. The service connection applicant is required to pay for the cost of all service pipe from the distribution main to the property line where a meter is installed inside the property line. Very limited funds are available for distribution line extensions, so a considerable number of long, small diameter service connection lines have resulted.

9.12 Summary of Estimated NRW Components

A summary of the estimated NRW components discussed above is presented in Table 9.6. As can be seen from inspection of Table 9.6, the major contributors to NRW in the NWSDB and KMC water systems are service connection line leakage and meter under registration. The primary focus of NRW reduction efforts by NWSDB and KMC should therefore be focused on these two components.

Table 9.6 Estimated NRW Components

Item	NRW (% of Production)	
	NWSDB	KMC
Transmission Main and Distribution System Leakage	8	15
Service Connection Line Leakage	14	9
Reservoir Leakage/Overflow	1	0
Unbilled Legal Connections	0	6
Illegal connections	6	3
Low Service Connection Meter Registration	10	10
Production Metering	2	0
Administrative Errors	0	0
Total	41	42

As noted in previous sections, estimates of most of the other NRW components are in themselves only very general approximations. The resultant estimate of the leakage component can thus only provide an approximate range within which the true leakage amount will fall.

9.13 The Cost of Non Revenue Water

Water saved due to implementation of a NRW reduction program is immediately reflected either in a reduction of projected demand or an increase in water utility revenues. The reduction of some NRW components, such as leakage, where the loss is not being put to a useful purpose, will result in a reduction in projected demand. Elimination of other components, such as illegal connections, where the water is being put to some beneficial use, will result in greater water utility income.

The increase in utility income may not, however, be equal to the value of the entire quantity used by illegal connections because this water is no longer being provided to the customer free of charge. The net effect of a successful NRW reduction program will be to increase water utility revenue and thus the ability to pay for water supply augmentation projects, and savings in construction and operation and maintenance costs for projects that can be delayed or reduced in size.

Because the existing supply in Greater Kandy is woefully inadequate to meet present demands, the question of project postponement does not arise. The cost of NRW can therefore be taken as equal to the present day costs to augment existing supplies to a given service area. For convenience in comparing water supply augmentation costs to NRW reduction program costs, both have been presented in terms of Rs/m^3.

For the purposes of this investigation, water supply augmentation costs for KMC and those areas in Greater Kandy outside of KMC have been taken as equal to the average cost to treat and deliver Mahaweli River water to the respective service areas.

As shown in Table 9.7, the value of water saved due to NRW reduction efforts in Greater Kandy would be Rs 29.02/m^3.

Table 9.7 Unit NRW Costs

Item	
Greater Kandy	
Capacity (m^3/d)	100,000
Capital cost (1,000 Rs.)	6,160,760
Annual O&M cost (1,000 Rs./year)	244,375
Amortized capital cost (1,000 Rs./year)	814,986
Average annual cost (1,000 Rs./year)	1,059,361
Unit NRW cost (Rs./m^3)	29.02
Nuwara Eliya	
Capacity (m^3/d)	5,070
Annual O&M cost (1,000 Rs./year)	6,689
Capital cost (1,000 Rs.)	156,818
Amortized capital cost (1,000 Rs./year)	10,970
Average annual cost (1,000 Rs./year)	17,659
Unit NRW cost (Rs./m^3)	9.54

9.14 Recommended NRW Reduction Program

The recommendations given in the following sections to reduce NRW have been based on the limited data available at the time of preparation of this report. As implementation of the NRW reduction program proceeds, better information will become available and more accurate estimates of the relative importance of the various NRW components can be made. The form and emphasis of the NRW reduction program presented below should therefore be periodically reviewed and updated to ensure that program efforts are cost effective.

9.14.1 Waste Management Districts

The location of areas where there are high concentrations of leaking pipes or illegal connection activity is best accomplished by dividing the distribution system into waste management districts. Waste management districts are areas that can be isolated from the rest of the distribution system by means of appropriately placed valves. Water supply to the district can then be measured by one or two specialized waste meters and the results compared to billing record data. Measurements are usually carried out during minimum water use periods during the early morning hours.

Experience on NRW reduction programs in Colombo indicates that waste meters cannot be effectively employed where the following conditions exist:

- Low distribution system pressures
- Consumers have tanks that are filled at night when pressures are highest
- High system connectivity

- Valves in poor condition, insufficient in number or not properly located to facilitate waste district isolation

Because all of these conditions exist to a significant degree in the study area water supply systems, the classical approach to estimation of leakage quantities by comparing minimum night flows to service meter records cannot be employed until these conditions have been removed. Visual inspection and sounding methods are the only practical means of leak detection that can be utilized until conditions have been improved.

9.14.2 Leak Detection and Repair

NWSDB has an ongoing NRW reduction program with ADB assistance that has been primarily concentrated on the Colombo area for several years. The NWSDB is now considering shifting some of the focus of this program to the Kandy area and has recently provided a substantial quantity of leak detection equipment to the Kandy staff. A list of this equipment is presented in Table 9.8. The suppliers of this equipment have provided a limited amount of training in the use of this equipment to NWSDB staff, but additional training will be required for maintenance staff to gain adequate proficiency in leak detection techniques.

The existing NWSDB leak detection equipment should be adequate for training in the use of leak detection equipment and initiation of NRW reduction program activities. As implementation of the NRW reduction program proceeds, additional equipment needs may be identified.

Table 9.8 Existing NWSDB Leak Detection Equipment

Description	Quantity			
	RSC G/C	RSC Central		Total
		Badulla	Kandy	
Electro Magnetic flow meter		1	1	2
Gauging rod		1	1	2
Data logger	2	3	3	8
Pressure transducer	2	3	3	8
Depth transducer		1	1	2
Portable pressure recorder	2	5	5	12
Hand held pressure gauge		10	10	20
Valve locator	1	1	1	3
Metallic pipe locator	1	1	1	3
Pocket display unit	1	1	1	3
Leak locator	2	1	1	4
Pulse unit	2	3	3	8
Listening stick	16	8	8	32
Tap connector	12	10	10	32

It is understood that there are not enough valves in any of the study area distribution systems to facilitate isolation of reasonably short sections of pipe for repair work. Shutting down long segments of the distribution system piping for repairs causes excessive inconvenience to the public as well as loss in water sales. In such situations, maintenance staff are often forced to make repairs on pressurized mains, which can create future maintenance problems. Repairs carried out on pressurized pipes, particularly if inadequate dewatering equipment is available, often result in poor quality repair work that will add to the leakage problem in the future as well as high water losses during the repair process. A valve rehabilitation program should be implemented to provide a sufficient number of distribution system valves to facilitate repair work. It is understood that most of the existing valves lack adequate valve chambers, a situation that should be corrected as part of the valve improvement program. As the valve rehabilitation work proceeds, a parallel activity should be pursued to provide additional valves as required to facilitate the establishment of waste management districts which will in turn allow the isolation of suitably sized segments of the distribution system for water loss detection activities.

Increases in the number and severity of leaks that usually accompany the addition of new water supplies to an existing system can overwhelm the leak repair capacity of existing maintenance staff and increase NRW. Unless steps are taken to minimize the negative impact of higher system pressures, the planned benefits of the additional water supplies may not be fully realized. When the new water supplies that will be part of the proposed water system improvement project come on line, system pressures are expected to increase dramatically. Leakage rates and the number of pipe bursts can also be expected to increase substantially, which will create a major problem for the already overburdened maintenance staff. This increase in maintenance workload should be a relatively short-term phenomenon. Given sufficient resources to find and repair the new leaks, the number and severity of leaks in a distribution system will tend to reach a steady state at some point where additional expenditures for leakage reduction would no longer be cost effective.

Consideration should be given to the use of private contractors to augment the leak detection and repair capabilities of regular maintenance staff until such a steady state condition can be achieved. Increases in permanent water utility maintenance staff should be limited to that required to maintain a cost effective leakage level status quo.

Implementation of the NRW reduction program should be carefully coordinated with the schedule of improvements to the water systems to allow maintenance staff time to deal with the higher leakage repair work load and minimize increases in leakage and waste by customers.

This can best be accomplished by identifying areas in advance of connection of new supplies where distribution system piping can be isolated from surrounding areas. Leakage repair resources should be focused on each of these areas in turn as new supplies are connected.

9.14.3 Reservoir Leakage/ Overflow

As part of the proposed NRW reduction program, all existing reservoirs should be tested for leakage by isolating the reservoir and measuring change in reservoir depth with time, preferably over a 24-hour period. Defective or inadequate reservoir ball valves known to be causing significant water losses should be repaired or replaced.

9.14.4 Unbilled Legal Connections

Although most unbilled legal connections are for worthy social causes (public standposts, schools, religious institutions, the Town Hall, etc.) the cost of such connections should not necessarily be borne by the water utility and its customers. Most of these uses are of benefit to the population at large and their costs should more appropriately be shouldered by some more broadly based financing mechanism (e.g. property tax). In most cases in the study area this is already being done or policy decisions have been made which will eventually result in shifting the burden of these costs away from the water utility. NWSDB either meters or estimates all water users and bills the appropriate public agency or private institution.

9.14.5 Illegal Connections

Although it is widely believed that illegal connections exist, their detection is no easy matter. All of the water utilities already have some procedures in place to detect illegal water users, but there are many factors that limit the effectiveness of these procedures. NWSDB periodically prints out a list of low water use customers that are investigated by field staff to identify anomalies between housing type and consumption level. All study area water utilities rely on reports from the public, meter readers and maintenance staff for assistance in locating illegal connections.

The presence of numerous long service connection lines before the service meter provides ample opportunity for additional illegal connections to be made before the meter. The existence of service connections without meters, unreadable meters or meters that will register flow when installed in a reverse direction all contribute to the difficulty of identifying illegal connections. All of these conditions should be corrected to minimize the probability that illegal connections will remain undetected.

9.14.6 Service Connections

Based on the data available to date, it appears that the major causes of NRW in all of the study area water systems are related to the service connections. Although it is not clear whether the greatest impact is due to the extensive "bundles" of service connection pipes or under registration of the meters, it is apparent that their collective impact is large. Over 98 percent of the leaks repaired by the maintenance staff are associated with service connection leakage and service meters brought in for repairs have major under registration problems.

It is NWSDB policy to install service meters within the customer's property to ensure that the customer will take responsibility for the meter's physical security. In many cases, the customer's property line is located some distance from the nearest distribution line and long service connection lines result. In some areas, service connection lines have been observed extending over 300 meters from the distribution pipe. The development of service connections often proceeds in a stepwise fashion, with each new customer on a street resulting in another long service connection line parallel to the last one. Eventually individual streets may have as many as a dozen service connection lines extending up both sides of the street in shallow or unburied "bundles" of small diameter service connection pipes.

Although a single larger diameter extension line properly buried in the street would be preferable to the service connection "bundles" and possibly less expensive in the long run, the NWSDB finds it difficult to provide funding for all of the extensions required in a rapidly growing service area. The customer is required to pay for the service connection based on the length of line, thus solving the NWSDB's extension line funding problem. The unfortunate result of this solution is that the NWSDB inherits many more kilometers of pipelines that are prone to damage and a temptation for illegal tapping than would be the case if they could install proper extension lines as development proceeds.

There appears to be no reason why the customer could not pay for the extension line, because they have already proved willing to do so in the form of many meters of small diameter service connection lines. Some alternative financing method could be employed that would not encourage the development of multiple service connection lines along individual streets and the proliferation of maintenance problems that attend such development. A revolving fund with adequate capital to finance distribution extension lines as they became necessary that would be replenished by customer payments proportional to the cost of providing a connection to individual customers might be considered. Another possibility would be to set up "improvement district contracts" where benefiting property owners would be required to pay a pro rata amount towards the cost of the extension facility upon receiving a service connection.

Consideration should be given to using polyethylene pipe (PE) for small diameter distribution main extensions and service connection lines instead of the PVC currently used by most water utilities in the study area. PE pipe offers a number of advantages over PVC, including a reduced number of joints (and thus less potential for leakage) and greater flexibility and resistance to damage. This type of pipe comes in rolls in the smaller diameters and is relatively easy to transport and install. It is understood that PE pipe has been manufactured in Sri Lanka for some time and is competitive with PVC in price.

One of the problems facing study area water utilities in replacing the existing "bundles" of service connection pipes with proper distribution system extensions is the high cost of disturbing and reinstating pavement for extension mains and service connection lines. It has been suggested that the introduction of horizontal boring techniques that would allow placing pipelines under streets without disturbing the pavement should be considered. There may be situations, such as a requirement to cross a busy intersection with a water line, where such techniques may be appropriate. However, many of the study area streets are on hillsides or on rocky materials where such equipment would difficult to employ. It is therefore recommended that introduction of this type of equipment be approached on a pilot scale basis to evaluate it's suitability and cost effectiveness under study area conditions.

The high rate of clogging that has been observed in many service meters is undoubtedly due in large measure to the surging effect on pipe flow rates that is a natural result of being forced to operate with inadequate supplies and widely varying distribution system pressures. As supplies increase with implementation of the proposed water system improvements, meter clogging should eventually diminish, but in the mean time attention to keeping repaired or newly installed pipes free from debris and periodic flushing of mains should help to minimize the problem.

Correction of the service meter flow reversal problem will involve a number of actions.

- Provide enough additional water supply to ensure adequate 24 hour pressures in the distribution system. This is a major objective of the proposed water supply improvement project, but it is also a precondition for solving the meter registration reversal problem.

- Provide existing service meters that do not have reverse flow prevention capability with effective reverse flow prevention devices.
- Ensure that the reverse flow prevention devices on existing service meters are operational by periodic inspection or provision of suitable backup equipment.
- Install all new service connections in accordance with appropriate back flow prevention plumbing regulations.

NWSDB has adequate service meter repair and calibration equipment and workshop area to meet current service meter maintenance requirements. The present capacity of KMC meter repair and calibration facilities is estimated to be about 400 meters per month. KMC currently has a 3,000 meter backlog of meters requiring repairs.

None of the study area water utilities have a pro-active policy towards meter servicing, where all meters are periodically pulled for inspection and calibration. Most water utilities do not follow such a practice due to the high cost of such a policy relative to the increases in revenue, except in the case of large water users. Given the relatively high rates of under registration that the limited available data suggests exists in the study area, a pro-active meter repair policy may have merit. A more detailed analysis of the present extent of under registration should be carried out to determine if application of such a policy to study area service meters would be cost effective.

9.14.7 Distribution System Pressure

Although some areas do exist in the Greater Kandy water systems where excessive pressures aggravate the leakage problem, these areas are not extensive. The transmission mains that will augment existing supplies as part of the Greater Kandy system improvements all involve pumping water from the Mahaweli River to significantly higher elevations. Appropriate pressures in the distribution systems that will be served by these mains have been provided by placing service reservoirs and take off points at elevations that will provide a reasonable range of pressures. Although no requirement has been identified during the feasibility level analysis of the study area transmission systems, it is still possible that some requirement for pressure reducing valves may be identified during the detailed design phase.

9.14.8 Production Metering

Only NWSDB has any capability for bulk meter maintenance in the study area, and that capability is limited to meter calibration and does not include repairs. To meet bulk meter servicing needs for the NWSDB, the choices are to expand facilities at the Udu Yatinuwara water treatment plant to include bulk meter repairs, or to continue to provide repair services to the Kandy NWSDB from Colombo. It is felt that it would be preferable to expand the Udu Yatinuwara facilities to provide all bulk meter service requirements not only for the Kandy NWSDB systems, but also for other water systems in the study area, possibly including Nuwara Eliya. There are several reasons for this suggestion.

- Although there are a relatively small number of bulk meters in water systems presently managed by the NWSDB, this number is expected to increase substantially as implementation of the NRW reduction program proceeds.
- When the low pressure and inadequate valve problems of the present systems have been alleviated and it becomes practical to use waste metering equipment as part of the NRW reduction efforts, the number and sophistication of large meters operated by NWSDB will increase significantly.
- It will be difficult for the smaller water utilities in the study area to develop the capabilities required for proper maintenance of large meters. It would be more cost effective if these water utilities could provide such services from an expanded NWSDB bulk meter servicing facility.

Production metering equipment at some of the water systems managed by NWSDB are in need of repair or replacement. NWSDB is currently conducting a survey to identify their production meter upgrading requirements.

9.14.9 Customer Leakage and Waste

The service connection pipes between the meter and the building plumbing in the study area are, in many cases, of poor quality materials and workmanship and subject to high levels of leakage and waste. As the additional supplies that will be developed under the proposed water system improvement project come on line, leakage and wastage on the consumer side of the meter is expected to escalate in tandem with the increases that will undoubtedly occur in the distribution systems. Although leakage and waste on the customer side of the service meter are generally not considered to be the problem of the water utility, there is an indirect negative impact on the utility. Excessive water use by water utility customers, even though they pay for it, ultimately increases the quantity of new water supplies that must be financed and developed by the utility in order to satisfy demand. Given the relatively high cost of new water supplies in the study area, it is a benefit to the water utility to minimize future demand and postpone the development of new water sources for as long as possible.

There are a number of tools available that can be used to raise public awareness of this problem and enlist their support in the conservation of water. The NWSDB has had extensive experience with public education programs that included use of TV spots, newspaper articles, radio commercials, posters, leaflets, public meetings and school competitions. All of these methods have been used successfully in previous projects, and should be applied to a conservation oriented public awareness campaign.

A recommended adjunct to the public education methods noted above is to provide assistance to the customer in identifying sources of leakage and waste. Although a customer may be thoroughly convinced by the public education campaign that water conservation is a worthy goal, he does not necessarily have the expertise to do anything about it. One technique that has met with success elsewhere is to pinpoint customers that could potentially have a leakage and waste problem. Computer searches of the billing records can be used to identify customers where usage has increased dramatically from the same month the previous year, or even to a level more than some percentage above their average use for the last few months. Notification to customers with a potential problem can be included with their monthly bill, or, in cases where exceptionally large increases are noted, direct contact may be warranted. Assistance to the customer in identifying and repairing sources of leakage and waste can be provided by the water utility in the form of lists of plumbers certified to posses the skills and equipment required for the detection and rectification of leakage and waste problems. Local plumbers are often lacking in such skills, so it is advisable that one of the requirements for certification by the water utility be completion of a training course in detection and repair of leakage and waste sources in buildings.

9.14.10 Technical Assistance and Training

The establishment of an effective NRW reduction capability will require a substantial upgrading of study area water utility staff capabilities in a number of areas. Technical assistance will be required to train maintenance staff in the skills that will be needed to implement the proposed NRW reduction program and to assist them in establishing appropriate procedures to accomplish the various program objectives. Areas where it is believed that technical assistance and training are needed are as follows.

- Leak detection methods and equipment
- Bulk meter repair and calibration
- Service meter calibration
- Service connection installation and repair

- Leak repair methods and equipment
- Pipe installation methods

9.14.11 Data Collection

One important observation that can be made as a result of this analysis is that there are many areas where data that is essential to planning and implementation of an effective NRW reduction program is either not available or inadequate. A list of the types of information that should be collected and recorded in support of the NRW reduction program is given below.

- Distribution system pressures
- Leak repairs (leakage rate, type of pipe, reason for leak)
- Valves (type, last date inspected, repaired, operated, condition)
- Bulk meter flow measurements
- Service meter records (accuracy when pulled for repair, accuracy of meters in place, reasons for repair)
- Waste meter flow measurements

9.14.12 Estimated Costs

A number of defects in the existing study area water systems are either responsible for the excessive NRW rates or make it difficult to identify the causes of NRW, the most important of which have been discussed above. A listing of the actions needed to correct them is given below.

- Replace "bundles" of service connection lines with appropriately sized distribution main extension pipes
- Provide adequately calibrated bulk meters on all sources of supply
- Repair or replace gate valves to drop tight condition
- Repair or replace ball valves on reservoirs to prevent overflow losses
- Install air valves as required to minimize service meter reversal
- Replace old pipes with excessive leakage
- Relay pipes that have not been buried to an adequate depth
- Repair or replace leaking service connection valves
- Repair or replace under registering service meters
- Install meters on all service connections
- Provide additional leak detection equipment
- Provide adequate leak repair equipment and materials

- Provide additional meter repair and calibration equipment
- Provide waste metering equipment

It is arguable as to which of these items of system rehabilitation should be attributed to the cost of NRW reduction and which are simply standard maintenance responsibilities for a properly operated water system. No matter what the costs are charged against, all of these system improvements will be required to support an NRW reduction program. In any case, the cost of any NRW reduction activity should be compared to the value of the water expected to be saved (See above discussion on the cost of NRW).

Though the required cost for the NRW reduction program will be determined based on the intensive field investigation, it was estimated as follows for planning purposes in the study:

- Leakage detection by sounding (for 70 percent of all existing distribution pipeline by foreign specialists)
- Repair of leaks (estimated to be 5 percent of the potential construction cost of the existing distribution pipeline)
- Improvement and augmentation of the distribution pipeline network to cope with the rearranged distribution system in the study area will also contribute to a reduction in NRW

9.14.13 Implementation

The estimated magnitude of the various components of NRW presented in the preceding sections are necessarily very approximate due to the limited amount of data currently available. A more accurate estimate is beyond the scope of the present investigation, but is required to provide a more reliable basis for development of a detailed NRW reduction program. The recommended NRW reduction program that is based upon the current estimate should consequently be regarded as only a starting point for the development of a more detailed program.

Refinement of the present estimate of the magnitude of individual NRW components will require the collection of additional data (See previous discussion on data collection needs) that was not available during the course of the current investigation. Development of reasonably accurate estimates of the cost of system improvements required in support of the NRW reduction program will involve a detailed analysis of the existing water systems. NWSDB and KMC have initiated such an analysis, but it will be some time before sufficient information has been developed.

Implementation of the NRW reduction program should proceed in stages. An initial data gathering stage should be carried out to provide an adequate basis for a refined estimate of NRW components and the costs to upgrade existing facilities to the point where conventional leakage and loss detection methods can be applied. Once this information is available, development of a detailed short term and long term action plan can proceed, followed by full-scale implementation of the recommended NRW reduction program. It is suggested that technical assistance in planning, coordination and implementation of the NRW reduction program be provided to study area water utilities.