CHAPTER 12

STUDY ON COUNTERMEASURES FOR WATER POLLUTION CONTROL IN THE STUDY AREA

CHAPTER 12 STUDY ON COUNTERMEASURES FOR WATER POLLUTION CONTROL IN THE STUDY AREA

12.1 General

Lake Manyame and Chivero belong to the Upper Manyame River Basin and are the most important water sources for drinking water in the Harare Metropolitan area. Fisheries and recreational activities are also abundant on these lakes.

Water pollution is becoming increasingly serious in these public water bodies due to the following circumstances:

1) Various pollutants are discharged into these lakes from Harare and the surrounding area.
2) They are closed water bodies.
3) Most of the lakes' water is retained and not circulated due to insufficient rain run-off.

The countermeasures for water pollution will be examined and formulated focusing on the major pollution sources, namely the public sewerage system, wastewater from factories/ slaughter houses, leachate from dumping sites and agricultural/stockbreeding effluent, based on the pollution analysis and pollution load reduction plan described in the previous section. Furthermore, the relevant laws and regulations to be enforced will be studied, including the requirements to accept industrial wastewater into the public sewerage systems, as well as the monitoring systems.

12.2 Public Sewerage Systems

12.2.1 General

Public sewerage systems consist of 1) sewage collection systems and 2) treatment facilities. Such systems provide great benefit to the conservation of public water bodies and aid in the creation of a comfortable living environment by preventing offensive odors, diseases, etc.

The public sewerage systems in the study area are highly developed, excepting Epworth, in comparison with other African countries and many of the area s inhabitants benefit from these systems. In addition to this contribution to water pollution control, treated effluent is a precious water resource in the study area due to the area s limited rainfall. Sludge is also used as fertiliser on many farms.

The plans of the sewage collection and treatment facilities in the study area are presented for the respective urban areas based on the water pollution study as well as on the reuse of effluent and sludge.

12.2.2 Service Coverage by Administrative Area

At present, the service coverage of the public sewerage systems of the four urban authorities (Harare, Chitungwiza, Norton and Ruwa) is at a high level, excepting a part of the low density area of Harare, Norton and Ruwa, where they use septic tanks. The areas in Harare may continue to use septic tanks in the future for economic reasons and the sufficient natural assimilation capacity in the area, whereas the areas of the other authorities may be merged with the existing public sewerage systems. The sewerage system of Epworth will also be developed upon securing the necessary financial arrangements.

The service area of a public sewerage system is established in consideration of the need for effective water pollution control. Other factors considered are the effective utilisation of the existing sewerage facilities, the expansion of administrative area in accordance with the future land use plan as well as any economic/construction advantages. The study area defined the entire administrative area in the intermediate (2005) and final target (2015) year as shown in Table 12.2.1 and Figure 12.2.1 to Figure 12.2.4.

Table 12.2.1 Service Coverage by Urban Authority

Authority	Treatment Area	2005 (km^2)	2015 (km^2)
Harare City	Crowborough T. A.	174.00	174.00
	Firle T. A.	194.35	194.35
	Marlborough T. A.	3.78	11.07
	Donnybrook T. A.	16.90	16.90
Harare Expansion	Harare South T. A.	137.81	137.81
	Harare East T. A. *1	25.86	25.86
Norton Town	Norton T. A.	26.90	59.60
Ruwa Local Board	Ruwa T. A.	38.40	38.40

*1 : Including the Epworth Local Board (11.1 km^2)

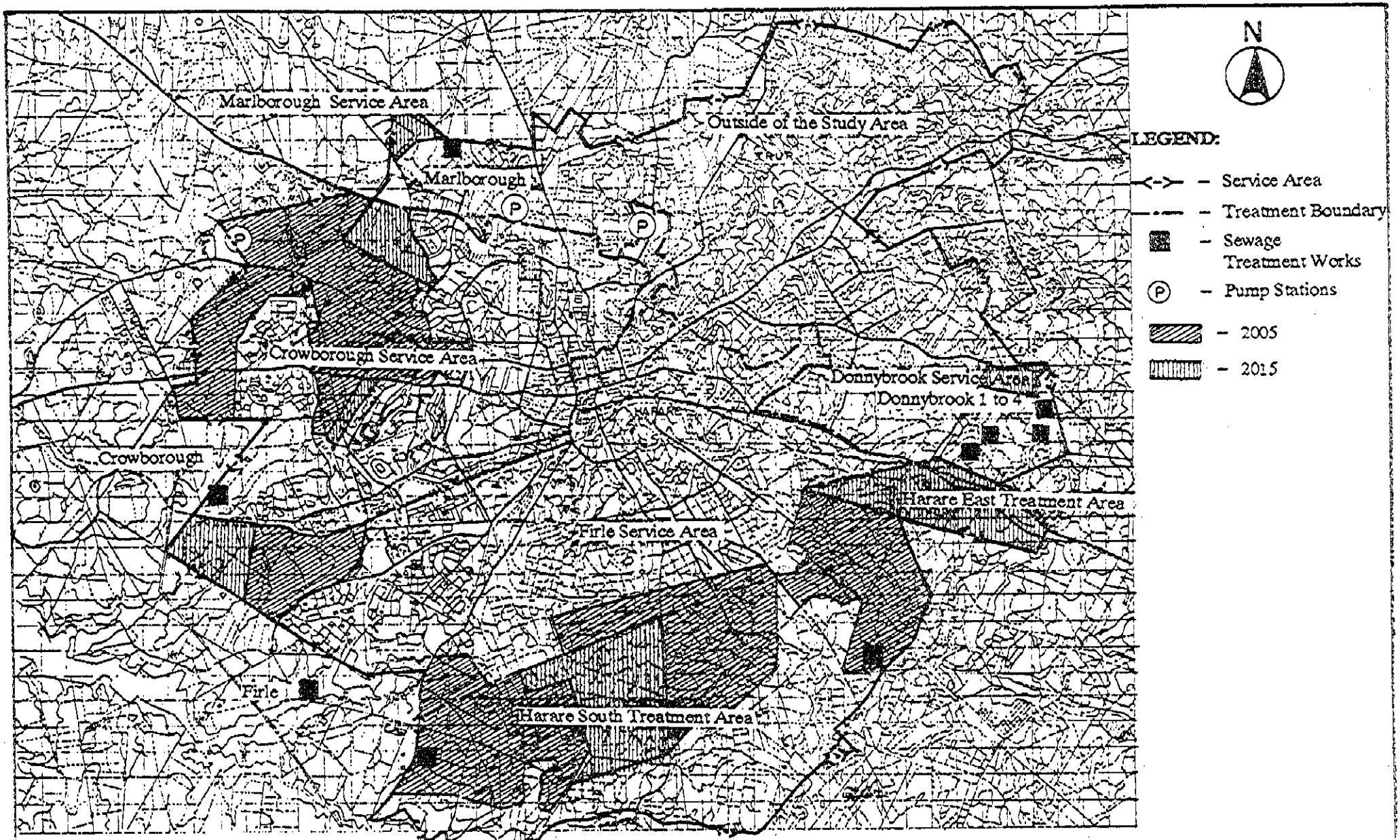


Figure 12.2.1 SEWERAGE SERVICE AREA IN HARARE S=1/200,000

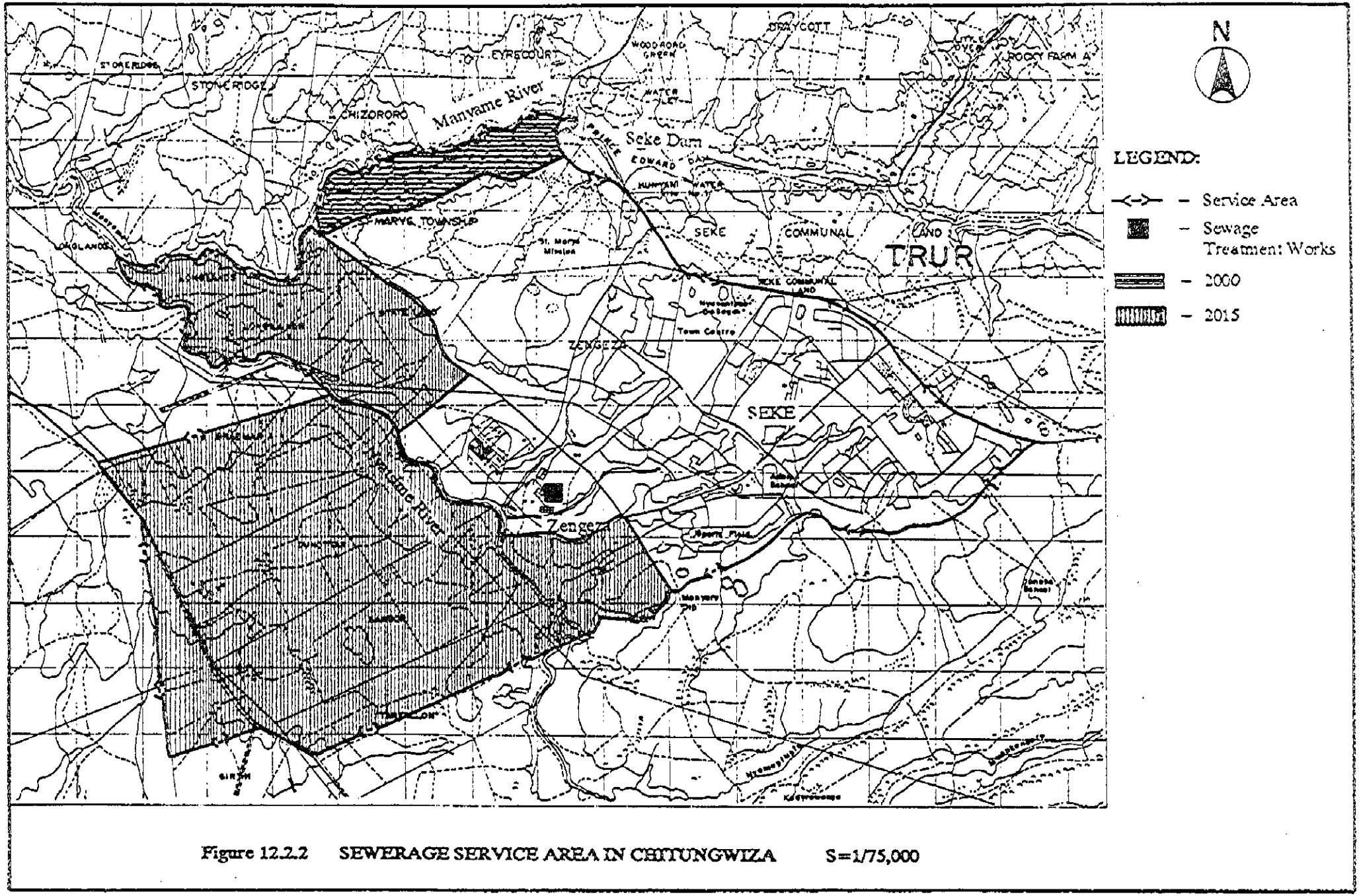


Figure 12.2.2 SEWERAGE SERVICE AREA IN CHITUNGWIZA S=1/75,000

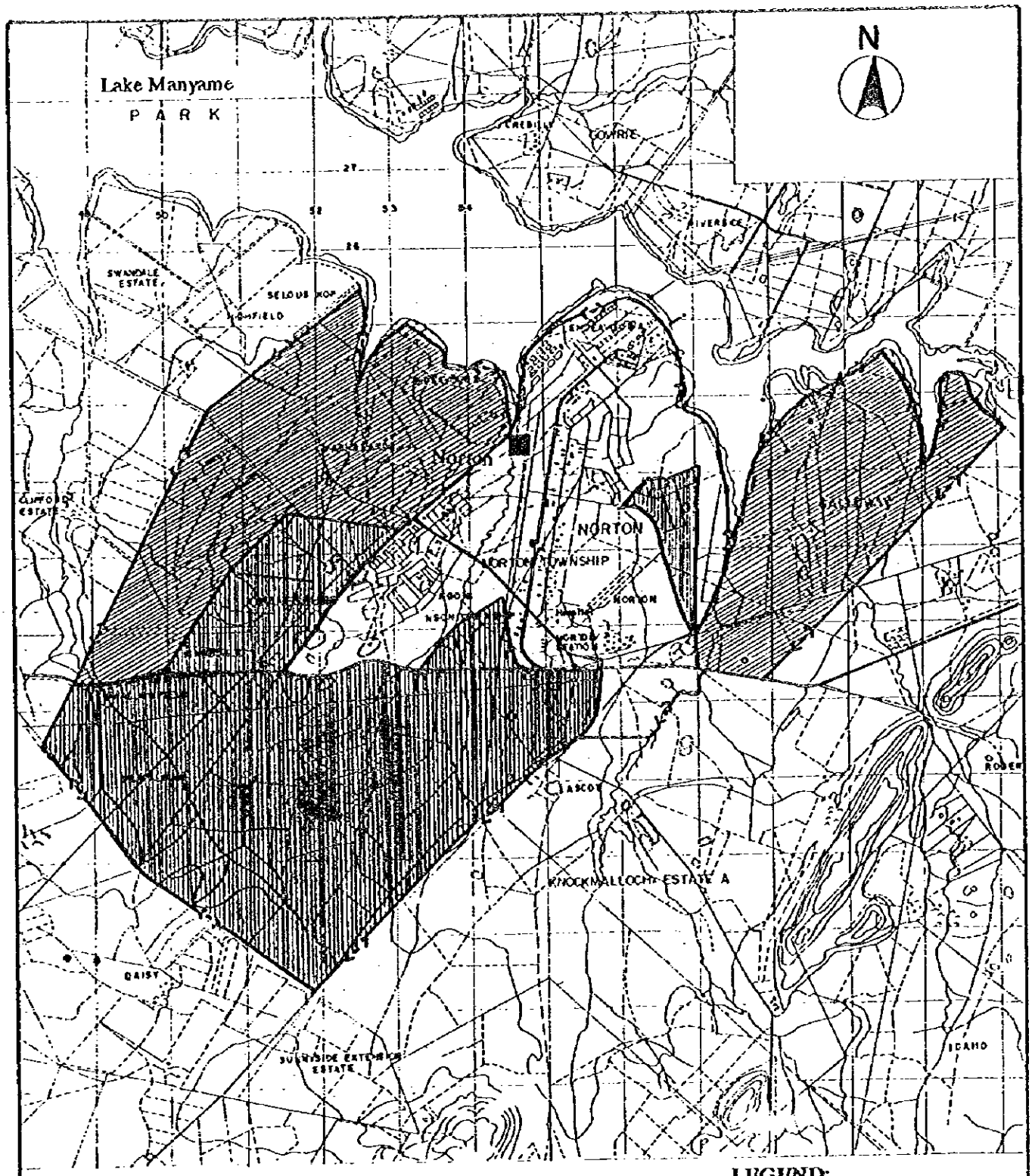


Figure 12.2.3 SEWERAGE SERVICE AREA IN NORTON S=1/75,000

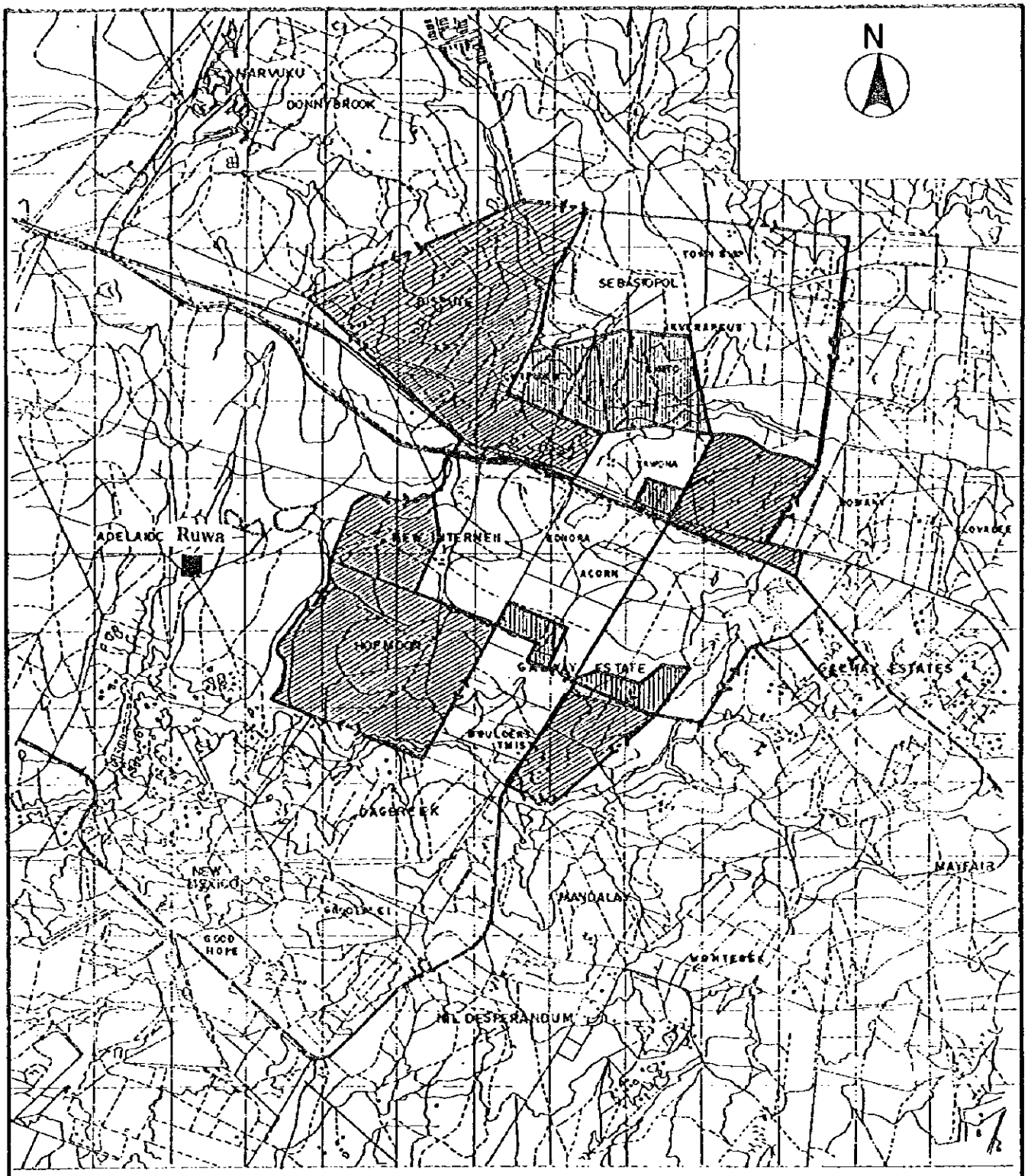


Figure 12.2.4 SEWERAGE SERVICE AREA IN RUWA S=1/75,000

Authority	Treatment Area	2000 (km^2)	2005 (km^2)	2015 (km^2)
Chitungwiza	Zengeza T. A.	42.00	42.00	54.50

Note : T. A. ; Treatment Area

12.2.3 Fundamentals for Design of Sewerage Facilities

(1) Design Base Year and Target Years

The design base year and target years for the planning purpose were determined as follows.

Base year	: 1995
Urgent year (2 to 5 years after the base year)	: 1997 - 2000
Intermediate year	: 2005
Final target year	: 2015

(2) Design Served Population

The design served population was estimated by Scenario-1 and Scenario-2, respectively. The estimates for Chitungwiza, Norton and Ruwa were employed based on the values discussed in section 6.2. In case of the present administrative area of Harare, the design served population was estimated in consideration of the areas with on-site septic tanks.

Table 12.2.2 shows the design served population by Scenario. (refer to Table 12.2.3.6 and Table 12.2.3.7, Section 12.2, Chapter 2, Supporting Report)

(3) Design Sewage Quantity and Quality

1) Unit quantity of domestic sewage

The unit domestic sewage quantity on the Average Dry Weather Flow (ADWF) was studied in the section 8.2.1. Table 12.2.3 shows the unit figures to be used for projection of sewage quantity through the future.

Table 12.2.3 Unit Sewage Quantity

Category	Present (l/capita/day)	2005 (l/capita/day)	2015 (l/capita/day)
High Density	60	65	70
Medium Density	210	210	210
Low Density	315	315	315
Rural Area	Same to high density area		

2) Unit quality of domestic sewage

The unit domestic sewage quality was studied in section 8.2.2. Table 12.2.4 shows the unit sewage quality to be used for calculation of pollution load in the future.

Table 12.2.4 Unit Sewage Quality

Item	High Density (g/capita/day)	Medium Density (g/capita/day)	Low Density (g/capita/day)
Per capita BOD Quality	44	47	50
Per capita T-N Quality	11	12	13
Per capita T-P Quality	1.2	1.3	1.4

3) Industrial wastewater quantity

The flow of industrial wastewater was studied in section 10.2. Table 12.2.5 shows the industrial wastewater quantity by target year for the respective sub-basins.

Table 12.2.5 Industrial Wastewater Quantity

Authority	Sub-Basin	Industrial Wastewater Quantity (m^3/day)		
		2000	2005	2015
Harare	Marimba River (Crowborough)	11,392	11,392	11,392
	Mukuvisi River (Firle)	37,932	37,932	41,762
	Ruwa River (Harare East)	0	0	25,642
	Manyame River (Harare South) *1	1,533	39,533	39,533
Chitungwiza	Nyatsime & Manyame River *1	1,206	1,401	12,764
Norton	Lake Manyame	1,154	3,386	18,042
Ruwa	Ruwa River	2,660	3,545	4,632

Note : *1 ; Manyame River Sub-Basin (Mukuvisi River to Seke Dam)

Table 12.2.2 Design Served Population by Sewage Works

(Unit : person)

Authority	Sewage Works	Population in Scenario-1		
		2000	2005	2015
Harare	Crowborough	512,200	1,016,300	1,151,200
	Firle	724,500	929,700	1,018,900
	Marlborough	4,500	4,500	13,300
	Donnybrook	105,800	105,800	153,000
	Sub-Total	1,347,000	2,056,300	2,336,400
Harare Expansion	Harare South	94,000	181,600	524,200
	Harare East	76,000	84,000	101,100
	Sub-Total	170,000	265,600	625,300
Chitungwiza	Zengeza	439,500	439,500	573,100
Norton	Norton	50,800	62,400	118,300
Ruwa	Ruwa	49,500	70,600	90,800
Total		2,056,800	2,894,400	3,743,900

Authority	Sewage Works	Population in Scenario-2		
		2000	2005	2015
Harare	Crowborough	513,800	591,300	765,500
	Firle	781,100	898,900	1,163,600
	Marlborough	4,800	5,500	7,200
	Donnybrook	98,000	112,700	145,900
	Sub-Total	1,397,700	1,608,400	2,082,200
Harare Expansion	Harare South	14,600	16,800	21,800
	Harare East	76,000	84,000	101,100
	Sub-Total	90,600	100,800	122,900
Chitungwiza	Zengeza	537,800	668,300	962,500
Norton	Norton	24,800	27,400	32,900
Ruwa	Ruwa	1,800	1,900	2,300
Total		2,052,700	2,406,800	3,202,800

4) Industrial wastewater pollution load

The pollution load of industrial wastewater was studied in section 9.3. Table 12.2.3.20, Section 12.2, Chapter 2, Supporting Report shows the industrial wastewater quality by sub-basin.

5) Commercial wastewater quantity

The unit commercial wastewater quantity was studied in section 8.2.1. According to this section, the total water consumption for commercial, industrial and institutional uses at present may be assumed at 75 % of domestic water consumption. Therefore, the commercial and institutional wastewater quantity is calculated by deducting the industrial wastewater from the corresponding consumption.

6) Commercial/Institutional wastewater pollution load

The unit commercial wastewater quantity was studied in section 8.2.1. However, no data was available for commercial and institutional wastewater quality. It was assumed to be the same as that of domestic sewage.

7) Peak factor for design of the sewerage facilities

In the design on the sewerage facilities, the local authorities have adopted the following peak factors in the "Sanitation Manual Design Procedures". Table 12.2.6 shows the Peak Wet Weather Flow (PWWF) to ADWF. The peak factor is employed for sewerage designing.

Table 12.2.6 Peak Factor for Design of Sewerage facilities

Average Dry Weather Flow		Required Perk Factor
Megaliters/day	Liters/second	
0 to 2	0 to 23	5.25
2 to 6	23 to 69	4.50
6 to 20	69 to 231	3.75
20 to 200	231 to 2,315	3.00
above 200	above 2,315	2.70

8) Groundwater infiltration into sewers

The rate and quantity of infiltration is related to the length of the sewers, the age and condition of the sewers, and the soil and topographic features of the service area.

Older sewers have a higher rate of infiltration than the more recent sewers which use rubber-ring joints and concrete manholes. The groundwater infiltration ratio used in Harare is 15% of the base flow (ADWF). Usually 10 to 20% of the base flow is adopted in the sewer design.

9) Design Sewage Quantity

The design sewage quantity was estimated by Scenario-1 and Scenario-2 comprising domestic, commercial and industrial, wastewater. Table 12.2.7 shows the design sewage quantity.(refer to Table 12.2.3.1 to Table 12.2.3.14, Section 12.2, Chapter 2, Supporting Report).

10) Design Sewage Quality

The design sewage quality was estimated by Scenario-1 and Scenario-2 covering domestic, industrial and commercial wastewater. Table 12.2.8 shows the summary of design sewage quality (refer to Table 12.2.3.15 to Table 12.2.3.22, Section 12.2, Chapter 2, Supporting Report).

The unit Suspended Solids (SS) was assumed in use of the relationship with BOD. Data of last one year (fiscal year 1995) on BOD and SS in Harare City were referred to as in below.

Unit: mg/l

STW	BOD	SS	SS/BOD (%)
Crowborough	619	650	105
Firle (No.1 & 2)	483	509	105
Firle (No.3)	461	583	126
Firle (No.4)	474	589	124
Hatcliff	705	791	112
Average	548	624	114

The average ratio between BOD and SS, 1.15 was employed.

Table 12.2.7 Design Sewage Quantity

(Unit : m^3/day)

Authority	Sewage Treatment Works	Scenario-1					
		Average Dry Weather Flow			Peak Wet Weather Flow		
		2000	2005	2015	2000	2005	2015
Harare	Crowborough	85,500	148,100	178,900	256,500	444,300	536,700
	Firle	180,200	248,100	309,700	540,600	669,870	836,190
	Marlborough	2,000	2,000	4,800	10,500	10,500	21,600
	Donnybrook	7,700	7,900	12,300	28,875	29,625	46,125
Harare Expansion	Harare South	13,200	63,600	92,100	49,500	190,800	276,300
	Harare East	5,500	6,300	37,600	24,750	23,625	112,800
Chitungwiza	Zengeza	37,500	38,700	70,200	112,500	116,100	210,600
Norton	Norton	6,400	12,400	41,300	24,000	46,500	123,900
Ruwa	Ruwa	8,400	13,200	18,400	31,500	49,500	69,000
Total		346,400	540,300	765,300	1,078,725	1,580,820	2,233,215

Authority	Sewage Treatment Works	Scenario-2					
		Average Dry Weather Flow			Peak Wet Weather Flow		
		2000	2005	2015	2000	2005	2015
Harare	Crowborough	84,800	92,700	124,200	254,400	278,100	372,600
	Firle	183,700	205,300	277,900	551,100	554,310	750,330
	Marlborough	2,000	2,000	2,600	10,500	9,000	11,700
	Donnybrook	7,100	8,400	11,700	26,625	31,500	43,875
Harare Expansion	Harare South	3,500	47,100	47,400	15,750	141,300	142,200
	Harare East	5,500	6,300	37,600	24,750	23,625	112,800
Chitungwiza	Zengeza	45,500	58,100	107,700	136,500	174,300	323,100
Norton	Norton	3,800	7,600	26,500	17,100	28,500	79,500
Ruwa	Ruwa	3,200	4,300	5,700	14,400	19,350	25,650
Total		339,100	431,800	641,300	1,051,125	1,259,985	1,861,755

Table 12.2.8 Design Sewage Quality

(Unit : mg/l)

Authority	Sewage Treatment Works	Scenario-1								
		BOD			T-N			T-P		
		2000	2005	2015	2000	2005	2015	2000	2005	2015
Harare	Crowborough	500	500	500	90	100	100	11	11	11
	Firle	550	550	550	90	90	90	11	11	11
	Marlborough	200	200	200	40	40	40	4	4	4
	Donnybrook	600	600	600	150	150	150	17	16	15
Harare Expansion	Harare South	500	800	800	90	60	80	10	10	11
	Harare East	650	650	900	150	150	60	17	16	10
Chitungwiza	Zengeza	600	600	600	140	140	110	15	15	13
Norton	Norton	600	750	1,000	110	80	60	12	9	7
Ruwa	Ruwa	500	500	500	110	100	100	13	11	10

Authority	Sewage Treatment Works	Scenario-2								
		BOD			T-N			T-P		
		2000	2005	2015	2000	2005	2015	2000	2005	2015
Harare	Crowborough	500	500	500	90	100	100	11	11	11
	Firle	550	550	550	90	90	90	11	11	11
	Marlborough	200	200	200	40	40	40	3	3	4
	Donnybrook	600	600	600	150	150	150	17	16	15
Harare Expansion	Harare South	700	1,000	1,000	60	40	40	10	9	9
	Harare East	600	600	900	150	150	60	17	16	10
Chitungwiza	Zengeza	600	600	600	140	140	110	15	15	13
Norton	Norton	700	1,000	1,400	100	70	50	12	9	7
Ruwa	Ruwa	600	600	600	110	100	100	14	13	14

Note: Sewage Quality of SS = BOD x 1.15

12.2.4 Design Criteria and Planning for Sewage Collection System

Before the planning of trunk and lateral sewers and pump stations, the design condition of the sewage collection system, the hydraulic and structural criteria for sewers and the pump stations were established as follows (details shown in Section 12.2, Chapter 2, Supporting Report):

Collection system :	Separate system
Equation for flow calculation of sewer :	Manning formula
In-pipe velocity :	Minimum velocity ; 0.60 - 0.75 m/sec
	Maximum velocity ; 3.0 m/sec
Earth cover of sewers :	600 - 900 mm
Minimum size of sewers :	150 mm (100 mm in any cases)
Type of pump station :	capacity of more than 5 m^3/day;
	Conventional type
	capacity of less than 5 m^3/day ;
	Manhole type

As discussed in Section 12.2, Chapter 2, Supporting Report, a separate system is adopted for sewage collection with emphasis on water pollution control and effective utilisation of the existing sewers.

At present, most of the urban areas, excluding part of low residential areas in Harare, Norton and Ruwa, are served by sewerage systems. However, the existing capacity of the systems will not accommodate the projected future sewage quantity. Consequently, the following expansion plan will be required aside from the rehabilitation of the existing facilities.

1) Main interceptors to collect sewage from the expanded service areas without giving additional loads to the existing sewers.
2) Lateral sewers and house connections to mitigate the load in the existing sewer systems, parallel to the existing trunk or semi-trunk sewers.
3) Augmentation of sewage pump stations, as required, though a gravity system is given priority.

The four urban areas concerned have their respective land use plans. An outline of the sewer expansion plans for the urban areas are prepared for the years 2005 and 2015.

The expansion area for the lateral sewers by treatment area is shown in Table 12.2.9, and the required trunk sewers and pump stations by treatment area by scenario are shown in Table 12.2.10 and Table 12.2.11.

Table 12.2.9 Expansion Area for the Lateral Sewers

(unit : km^2)

Authority	Sewage Works	2000	2005	2015
		Expansion Area	Expansion Area	Expansion Area
Harare	Crowborough	6.75	39.31	12.78
	Firle	13.11	12.48	6.55
	Marlborough	0.00	0.00	7.29
	Donnybrook	0.00	0.00	2.36
Harare Expansion	Harare South	27.36	28.63	31.51
	Harare East	11.10	0.00	14.76
Chitungwiza	Zengeza	1.75	0.00	20.56
Norton	Norton	2.99	6.56	31.38
Ruwa	Ruwa	7.02	7.57	3.86

Note : Required expansion service area ; Refer to land use plan in Section 5

The following is an explanation of the trunk sewers and pump stations in their respective service areas.

(1) Harare City

1) Crowborough

There is an expansion plan for the future land use of the residential and industry/commercial areas. Of the total development area of about 58.8 km^2, 51.3 km^2 is planned to be covered by a gravity type sewerage system, while the remaining 7.5 km^2 in the Muzururu River sub-basin will use a pumped system.

The alignment of the proposed trunk sewers and pump station is shown in Figure 12.2.5 and Table 12.2.10, and the flow calculation of the trunk sewers is shown in Table 12.2.4.1, Section 12.2, Chapter 2, Supporting Report. The capacity calculations of the proposed pump stations, are included in Table 12.2.4.8, Section 12.2, Chapter 2, Supporting Report.

Table 12.2.10 (1) Required Trunk Sewers by Treatment Area

(Scenario-1)

Name of Treatment Area (Authority)	2005			2015		
	Material	Diameter (mm)	Length (m)	Material	Diameter (mm)	Length (m)
Crowborough (Harare)	ACP	500	7,600			
	ACP *	600	1,200			
	ACP	800	5,800			
	RCP	900	1,700			
	RCP	1,100	5,100			
	RCP	1,200	4,700			
	RCP	1,350	9,500			
Total	-	-	35,600	-	-	-
Firle (Harare)	RCP	1,000	13,900	ACP	800	3,400
	SP *	1,100	1,700			
	RCP	1,200	15,700			
Total	-	-	31,300	-	-	3,400
Harare South (Harare Expansion)	ACP	700	3,000			
	ACP	800	3,900			
	RCP	1,350	6,800			
	RCP	1,500	4,000			
	RCP	1,800	2,800			
Total	-	-	20,500	-	-	-
Harare East (Harare Expansion)	RCP	900	4,900	RCP	1,100	6,700
	RCP	1,350	400			
Total	-	-	5,300	-	-	6,700
Norton (Norton)	ACP	300	1,900	ACP *	350	1,600
	ACP	450	2,600	ACP	500	2,100
	ACP *	500	1,200	ACP	700	2,100
	ACP	700	1,700	ACP	800	4,900
	RCP	900	6,400			
	RCP	1,100	1,800			
Total	-	-	15,600	-	-	10,700
Ruwa (Ruwa)	ACP *	200	1,600			
	ACP *	250	1,800			
	ACP	350	2,500			
	ACP *	400	2,400			
	ACP	450	6,100			
	ACP	600	3,400			
	ACP	800	1,500			
	ACP *	800	2,200			
	RCP	1,000	1,300			
Total	-	-	22,800	-	-	-
Name of Treatment Area (Authority)	2000			2015		
	Material	Diameter (mm)	Length (m)	Material	Diameter (mm)	Length (m)
Zengeza (Chitungwiza)	ACP *	600	3,700	ACP *	450	2,200
	ACP	800	9,900	ACP	600	12,900
	RCP	900	500	ACP	700	3,900
				ACP *	800	1,800
				RCP	1,000	300
Total	-	-	14,100	-	-	21,100

Note : ACP ; Asbestos Cement Pipe
RCP ; Reinforced Concrete Pipe
SP ; Steel Pipe
* ; Force Main Pipe

Table 12.2.10 (2) Required Trunk Sewers by Treatment Area

(Scenario-2)

Name of Treatment Area (Authority)	2005			2015		
	Material	Diameter (mm)	Length (m)	Material	Diameter (mm)	Length (m)
Crowborough (Harare)	ACP	400	7,600			
	ACP *	500	1,200			
	ACP	700	5,800			
	ACP	800	1,700			
	RCP	1,000	5,100			
	RCP	1,100	4,700			
	RCP	1,200	9,500			
Total	-	-	35,600	-	-	-
Firle (Harare)	RCP	1,000	13,900	ACP	800	3,400
	SP *	1,000	1,700			
	RCP	1,200	15,700			
Total	-	-	31,300	-	-	3,400
Harare South (Harare Expansion)	ACP	600	6,900			
	RCP	1,100	6,800			
	RCP	1,200	4,000			
	RCP	1,350	2,800			
Total	-	-	20,500	-	-	-
Harare East (Harare Expansion)	RCP	900	4,900	RCP	1,100	6,700
	RCP	1,350	400			
Total	-	-	5,300	-	-	6,700
Norton (Norton)	ACP	250	1,900	ACP *	300	1,600
	ACP	400	2,600	ACP	450	2,100
	ACP *	450	1,200	ACP	500	2,100
	ACP	600	1,700	ACP	600	4,900
	ACP	800	6,400			
	RCP	900	1,800			
Total	-	-	15,600	-	-	10,700
Ruwa (Ruwa)	ACP *	150	3,400			
	ACP	200	2,500			
	ACP *	250	2,400			
	ACP	300	6,100			
	ACP	350	3,400			
	ACP	500	1,500			
	ACP *	500	2,200			
	ACP	600	1,300			
Total	-	-	22,800	-	-	-
Name of Treatment Area (Authority)	2000			2015		
	Material	Diameter (mm)	Length (m)	Material	Diameter (mm)	Length (m)
Zengeza (Chitungwiza)	ACP *	800	3,700	ACP *	500	2,200
	RCP	900	9,900	ACP	700	12,900
	RCP	1,000	500	RCP	900	3,900
				SP *	1,000	1,800
				RCP	1,200	300
Total	-	-	14,100	-	-	21,100

Note : ACP ; Asbestos Cement Pipe
RCP ; Reinforced Concrete Pipe
SP ; Steel Pipe
* ; Force Main Pipe

Table 12.2.11 (1) Required Pump Stations by Treatment Area

(Scenario-1)

Treatment Area	Sign	2000							
		Design Flow (m^3/min)	Screen Type -	No. of Grit Chamber (unit)	Pump Diameter (mm)	Capacity (m^3/min/unit)	Total Head (m)	Pump Power (kw)	Unit Number (unit (stand by))
Zengeza	P1	20.04	Manual	2	200	5.00	40.00	55	5(1)

Treatment Area	Sign	2005							
		Design Flow (m^3/min)	Screen Type -	No. of Grit Chamber (unit)	Pump Diameter (mm)	Capacity (m^3/min/unit)	Total Head (m)	Pump Power (kw)	Unit Number (unit (stand by))
Crowborough	-	25.38	Manual	2	250	6.40	20.00	37	5(1)
Firle	-	71.34 (2015)	Manual	6	350	14.30	30.00	110	4(1)
Harare South	-	29.58	Manual	3	250	7.50	20.00	37	5(1)
Norton	P2	14.04 (2015)	Manual	2	200	4.70	25.00	37	2(1)
Ruwa	P1	2.76	Manual	2	100	1.40	35.00	15	3(1)
	P2	7.92	Manual	2	150	2.70	40.00	30	4(1)
	P3	1.80	Manual	2	150	1.80	20.00	11	2(1)
	P4	33.90	Manual	2	250	6.80	20.00	37	6(1)

Treatment Area	Sign	2015							
		Design Flow (m^3/min)	Screen Type -	No. of Grit Chamber (unit)	Pump Diameter (mm)	Capacity (m^3/min/unit)	Total Head (m)	Pump Power (kw)	Unit Number (unit (stand by))
Firle	-	71.34 (2015)	Manual	6	350	14.30	30.00	110	2
Zengeza	P2	8.82	Manual	2	150	3.00	25.00	22	4(1)
	P3	36.84	Manual	3	250	7.40	35.00	75	6(1)
Norton	P1	5.40	Manual	2	150	2.70	15.00	11	3(1)
	P2	14.04 (2015)	Manual	2	200	4.70	25.00	37	2

Table 12.2.11 (2) Required Pump Stations by Treatment Area

(Scenario-2)

Treatment Area	Sign	2000							
		Design Flow (m^3/min)	Screen Type -	No. of Grit Chamber (unit)	Pump Diameter (mm)	Capacity (m^3/min/unit)	Total Head (m)	Pump Power (kw)	Unit Number (unit (stand by))
Zengeza	P1	30.78	Manual	3	250	6.20	40.00	75	6(1)

Treatment Area	Sign	2005							
		Design Flow (m^3/min)	Screen Type -	No. of Grit Chamber (unit)	Pump Diameter (mm)	Capacity (m^3/min/unit)	Total Head (m)	Pump Power (kw)	Unit Number (unit (stand by))
Crowborough	-	17.58	Manual	2	250	6.00	20.00	37	4(1)
Firle	-	63.96 (2015)	Manual	6	350	12.80	30.00	110	4(1)
Harare South	-	15.24	Manual	2	200	4.00	20.00	22	5(1)
Norton	P2	9.00 (2015)	Manual	2	150	3.00	25.00	22	2(1)
Ruwa	P1	1.02	Manual	2	100	1.00	35.00	11	2(1)
	P2	2.94	Manual	2	100	1.50	40.00	22	3(1)
	P3	0.66	Manual	2	100	0.70	20.00	3.7	2(1)
	P4	12.48	Manual	2	200	4.20	20.00	22	4(1)

Treatment Area	Sign	2015							
		Design Flow (m^3/min)	Screen Type -	No. of Grit Chamber (unit)	Pump Diameter (mm)	Capacity (m^3/min/unit)	Total Head (m)	Pump Power (kw)	Unit Number (unit (stand by))
Firle	-	63.96 (2015)	Manual	6	350	12.80	30.00	110	2
Zengeza	P2	13.56	Manual	2	200	4.50	25.00	30	4(1)
	P3	56.58	Manual	6	300	11.40	35.00	110	6(1)
Norton	P1	3.48	Manual	2	100	1.80	15.00	7.5	3(1)
	P2	9.00 (2015)	Manual	2	150	3.00	25.00	22	2

2) Firle

Of the total development area of about 32.0 km2 for the residential and industry/commercial areas, 15.0 km^2 is planned to covered by a gravity type sewerage system, while the rest of 17.0 km^2 in Lake Chivero and a part of the Mukuvisi River Sub-basins, pumped system.

The alignment of the proposed trunk sewers and the pump station is shown in Figure 12.2.5 and Table 12.2.10, and the flow calculation of the trunk sewers are shown in Table 12.2.4.2, Section 12.2, Chapter 2, Supporting Report. The capacity calculation of the proposed pump station, is included in Table 12.2.4.9, Section 12.2, Chapter 2, Supporting Report.

3) Marlborough and Donnybrook

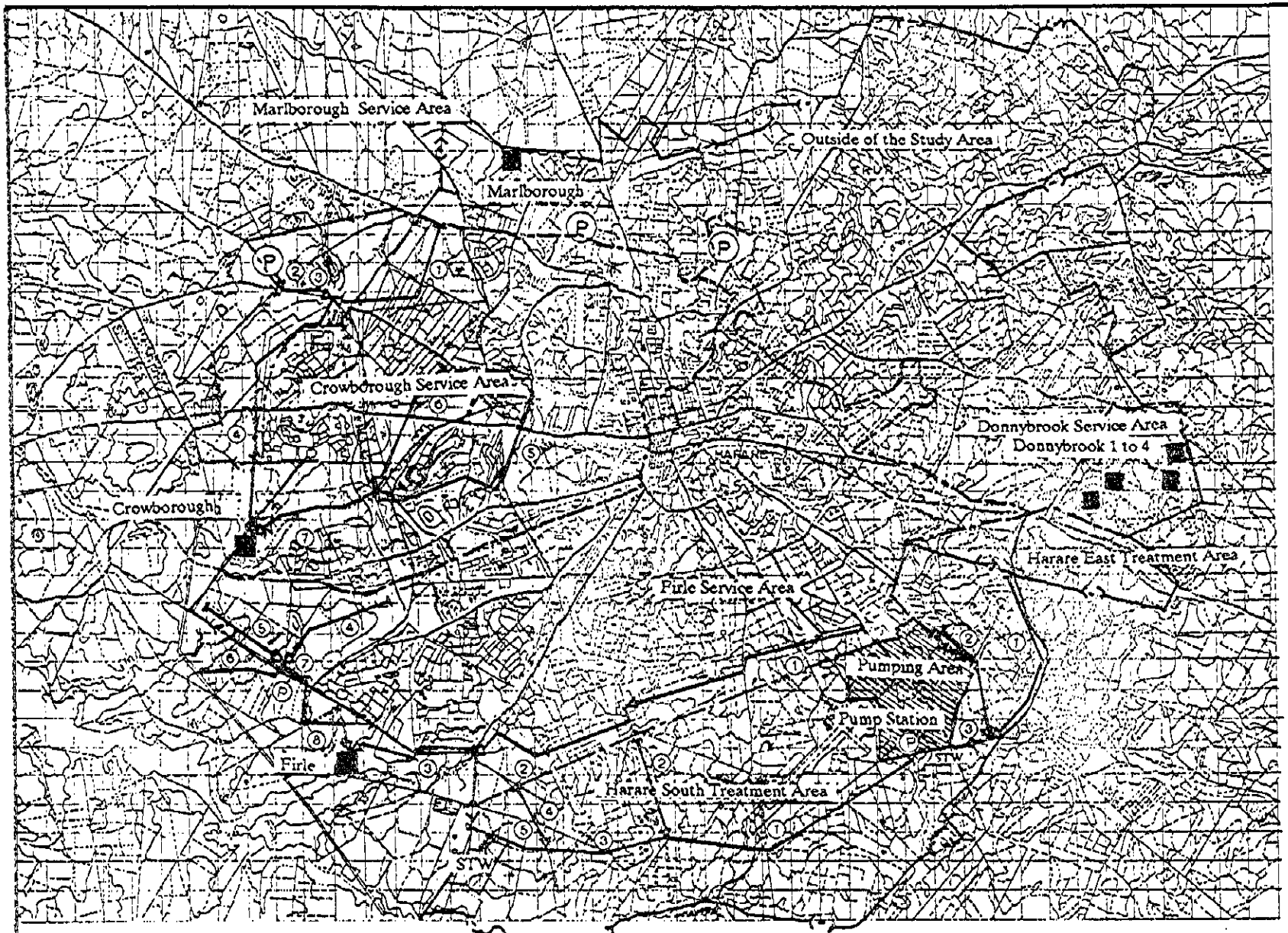
The Marlborough and Donnybrook STWs have expansion plans for their future sewerage service areas for residential areas in 2015. These areas will be covered by lateral sewers because the expansion areas and the generated sewage amounts are small.

4) Harare South

The sewerage service area in Harare South, located from Hatfield toward its southern area up to the Manyame river, is with about 87.5 km^2 as of the year 2015. The area will accommodate Harare Airport, residential areas and industry/commercial areas.

The generated sewage is to be collected by gravity according to topography towards the south of the service area. A main interceptor is required along the planned road to connect to the proposed STW. The STW is planned to be constructed near the city boundary. The planned area for the airport, the eastern part of the service area, is necessary to provide a pumping system due to unfavorable topographical conditions.

The alignment of proposed trunk sewers is shown in Figure 12.2.5 and Table 12.2.10, and the flow calculation of the trunk sewers are shown in Table 12.2.4.3, Section 12.2, Chapter 2, Supporting Report. The capacity calculation of the proposed pump station is included in Table 12.2.4.10, Section 12.2, Chapter 2, Supporting Report.



Trunk Sewers for Crowborough Treatment Area

Sewer No.	L (m)	D (mm)
1	6,800	800
2	1,200	600
3	1,700	900
4	9,500	1,350
5	7,800	500
6	5,100	1,100
7	4,700	1,200

Trunk Sewers for Firle Treatment Area

Sewer No.	L (m)	D (mm)
1	9,200	1,000
2	6,900	1,200
3	4,800	1,200
4	4,700	1,000
5	3,400	800
6	400	1,200
7	1,700	1,100
8	2,900	1,200

Trunk Sewers for Harare South Treatment Area

Sewer No.	L (m)	D (mm)
1	6,800	1,350
2	3,900	900
3	4,000	1,500
4	3,000	700
5	2,800	1,800

Trunk Sewers for Harare East Treatment Area

Sewer No.	L (m)	D (mm)
1	6,700	1,100
2	4,900	900
3	400	1,300

Figure 12.2.5 SEWERAGE COLLECTION SYSTEM IN HARARE

5) Harare East

The Harare East area covers the industrial areas of Harare, the Venterburg district and the Epworth Local Board. The main trunk sewers are planned to use gravity and flow towards the south-east up to the proposed STW located in Glenwood. The proposed two main trunk sewers cover the industrial area of the city and the residential area of Epworth, Respectively.

The requirements of the proposed trunk sewers are shown in Table 12.2.10 and the flow calculation of the trunk sewers are shown in Table 12.2.4.4, Section 12.2, Chapter 2, Supporting Report, and the alignment of the sewerage system is shown in Figure 12.2.5.

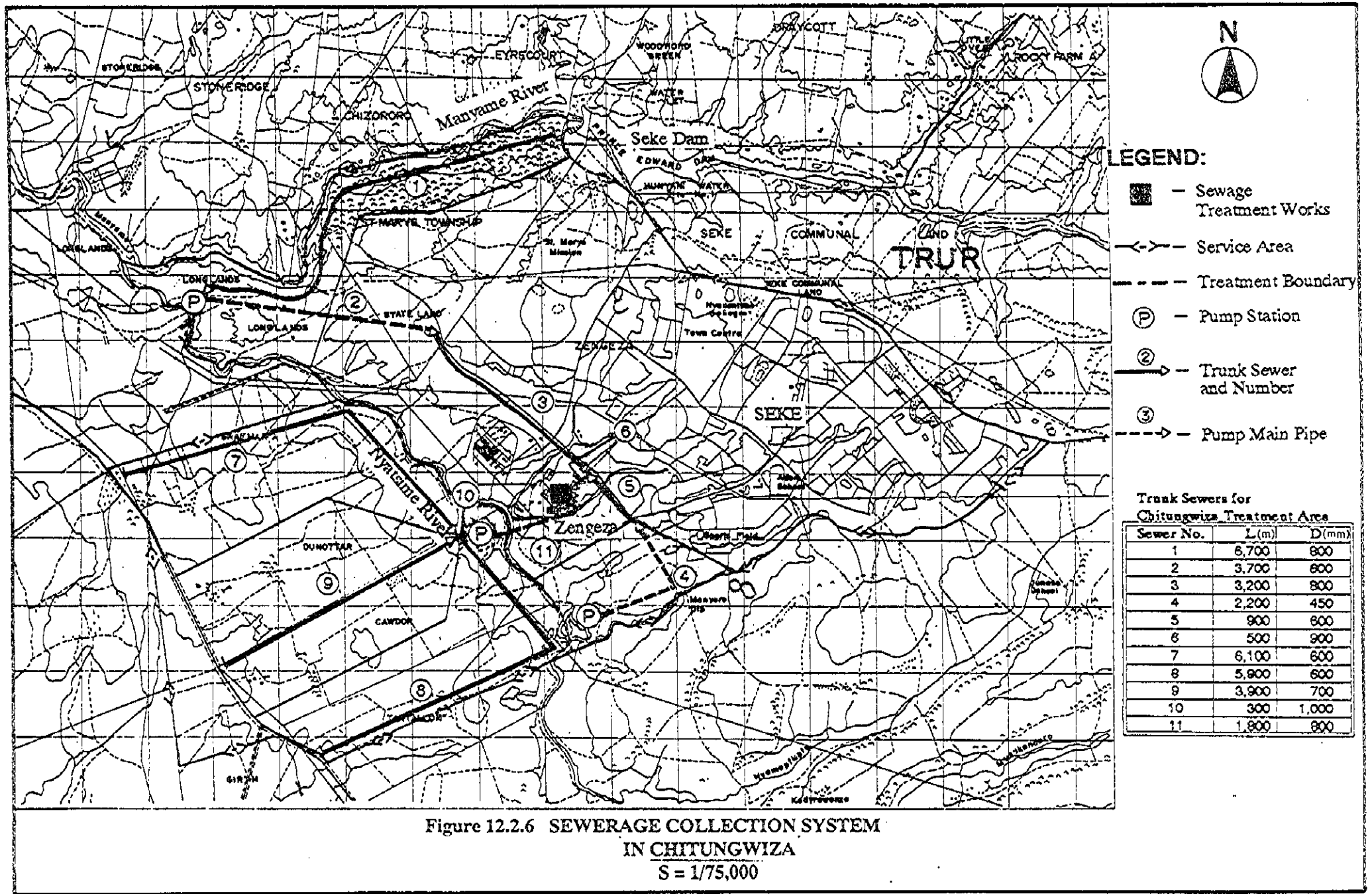
(2) Chitungwiza Municipality

There is an expansion plan for the future land use of the residential and industrial areas towards the south-west, the left bank area of Nyatsime River, of the service area. The total development area of about 22.3 km^2 is planned to be covered by combined gravity and pumped systems. In the expansion area, three pump stations (P1 to P3) are planned due to unfavorable topographical conditions.

The alignment of the proposed trunk sewers and the pump stations are shown in Figure 12.2.6 and Table 12.2.10, and the flow calculations of the trunk sewers are shown in Table 12.2.4.5, Section 12.2, Chapter 2, Supporting Report. The capacity calculations of the proposed pump stations are shown in Table 12.2.4.11 to 12.2.4.13, Section 12.2, Chapter 2, Supporting Report.

(3) Norton Town

Of the total development area of about 41.0 km^2 for the residential, industry/commercial and institutional areas, 33.0 km^2 is planned to be covered by a gravity type sewerage system, while the remaining 8.0 km^2 will use a pumped system. In the expansion area, two pump stations (P1 and P2) are planned on the east side of the town center.



Trunk Sewers for Chitungwiza Treatment Area

Sewer No.	L(m)	D(mm)
1	6,700	800
2	3,700	800
3	3,200	800
4	2,200	450
5	900	600
6	500	900
7	6,100	600
8	5,900	600
9	3,900	700
10	300	1,000
11	1,800	800

Figure 12.2.6 SEWERAGE COLLECTION SYSTEM IN CHITUNGWIZA
S = 1/75,000

The alignments of the proposed trunk sewers and the pump stations are shown in Figure 12.2.7 and Table 12.2.10, and the flow calculations of the trunk sewers are shown in Table 12.2.4.6, Section 12.2, Chapter 2, Supporting Report. The capacity calculations of the proposed pump stations are shown in Table 12.2.4.14 to 12.2.4.15, Section 12.2, Chapter 2, Supporting Report.

(4) Ruwa Local Board

The expansion area for future land use is covered for the residential and industrial areas. The total development area about 18.45 km^2 is planned to be covered by combined gravity and pumped systems. In the expansion area, four pump stations (P1 to P4) are planned due to the hilly nature of the terrain.

The alignments of the proposed trunk sewers and the pump stations are shown in Figure 12.2.8 and Table 12.2.10, and the flow calculations of the trunk sewers are shown in Table 12.2.4.7, Section 12.2, Chapter 2, Supporting Report. The capacity calculations of the proposed pump stations is shown in Table 12.2.4.16 to 12.2.4.19, Section 12.2, Chapter 2, Supporting Report.

12.2.5 Sewage Treatment Facility

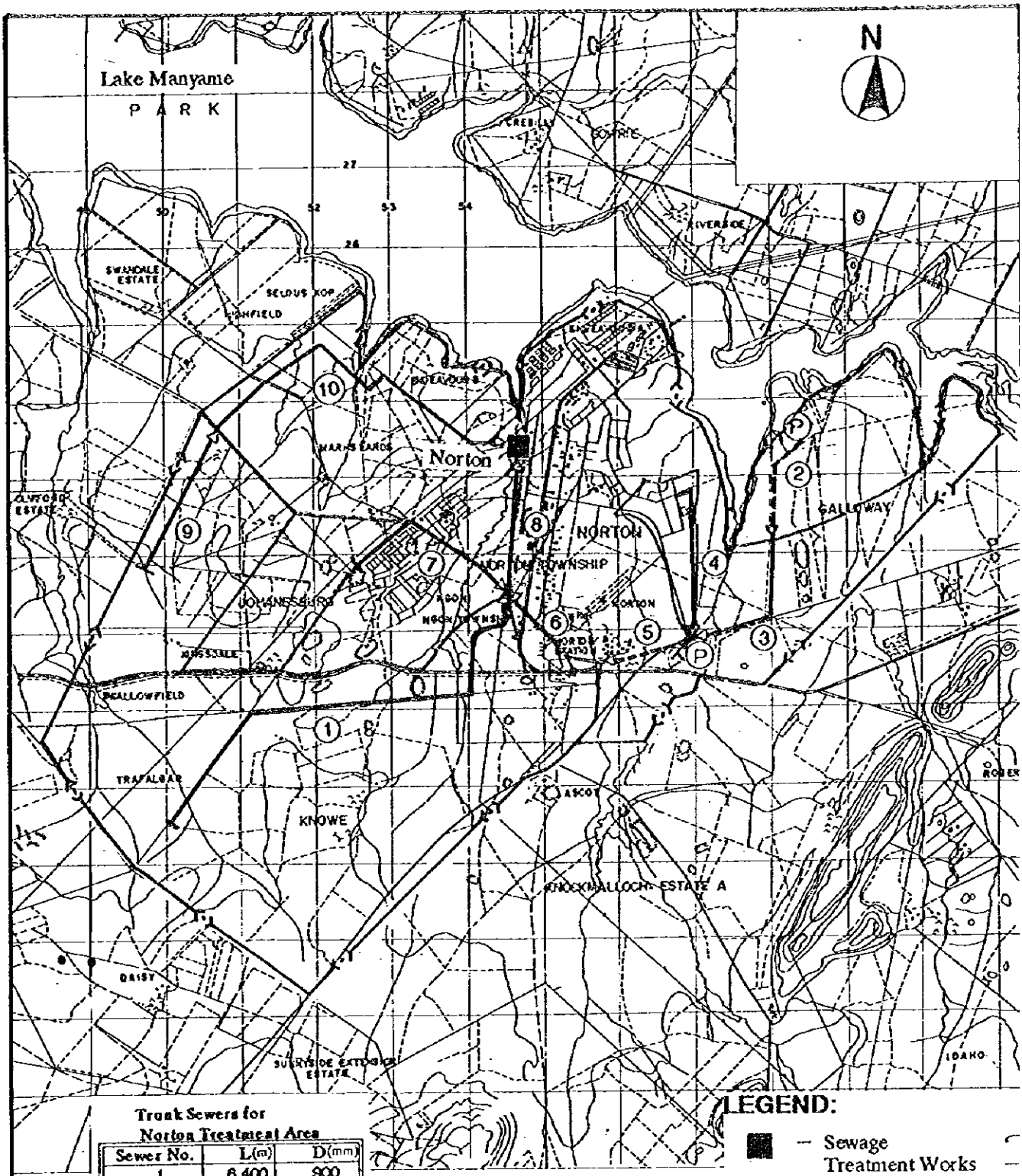
(1) General Description of Sewage Treatment Process

Sewage treatment is mainly biological process, the sewage treatment processes commonly used are shown in Table 4.2.6.

The sewage treatment processes currently used in local authorities are the following three types:

- WSP + Irrigation
- TF + Irrigation
- BNR

The above three systems have been used for a long time in this country, and they are being properly operated and maintained. Each system is functioning effectively, so these systems will continue to be used.

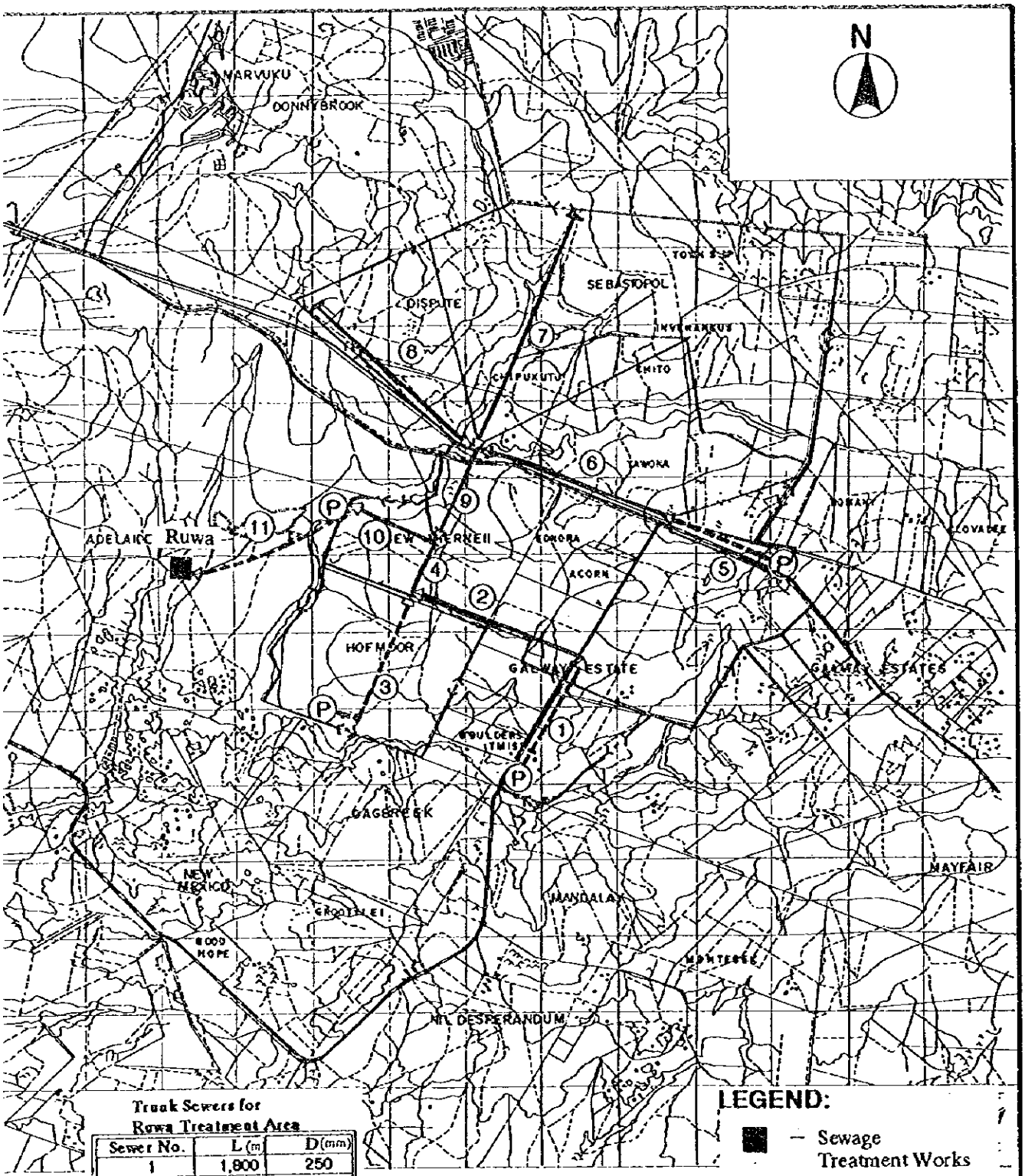


Trunk Sewers for Norton Treatment Area

Sewer No.	L(m)	D(mm)
1	6,400	900
2	1,600	350
3	2,100	700
4	1,900	300
5	1,200	500
6	1,700	700
7	2,600	450
8	1,800	1,100
9	2,100	500
10	4,900	800

Figure 12.2.7 SEWERAGE COLLECTION SYSTEM IN NORTON

S = 1/75,000



Trunk Sewers for Ruwa Treatment Area

Sewer No.	L (m)	D (mm)
1	1,900	250
2	2,500	350
3	2,400	400
4	700	600
5	1,600	200
6	2,700	600
7	3,300	450
8	2,800	450
9	1,500	900
10	1,300	1,000
11	2,200	900

LEGEND:

- Sewage Treatment Works
- Service Area
- Treatment Boundary
- (P) Pump Station
- ④ Trunk Sewer and Number
- ⑤ Pump Main Pipe

Figure 12.2.8 SEWERAGE COLLECTION SYSTEM IN RUWA

S = 1/75,000

Prior to the selection of an appropriate treatment system for sewage and sludge at the STW, general conditions were studied. The factors to be considered for the selection of the treatment methods are: 1) receiving water body and/or land 2) effluent standard 3) raw sewage quality and 4) STW site conditions. Other considerations include low construction cost , and economical and easy O & M for the facilities.

1) Receiving water body and/or land

Receiving waters to receive the effluent discharged from the planned treatment works are connected to the Manyame river and its tributaries. Some effluent is re-used for irrigation.

2) Effluent standard

The quality of treated effluent discharged to the river and reused for irrigation is controlled by the stringent regulation. Table 12.2.12 and Table 12.2.13 show the effluent regulation on the representative items for discharge to river and reuse for irrigation, respectively.

Table 12.2.12 Effluent Regulation for Discharge into River (Zone II)

Item	Unit	Regulation
pH	-	between 6.0 to 9.0
Temperature	°C	≤ 35
COD	mg/l	≤ 60
Nitrogen Total	mg/l	≤ 10.0

Table 12.2.13 Effluent Regulation for Irrigation Reuse

Objective	Unit	Regulation	
		Conventional Works	Pond System
(A) Surface irrigation of non-edible crops, pastures & orchards/plantations.	mg/l	BOD≤70	DO≥1 at all times
(B) Spray irrigation of ditto.	mg/l	BOD≤30	BOD≤30
(C) Surface or spray irrigation of the above plus pastures for dairy cattle, and cut flowers.	mg/l	BOD≤10 E. Coli≤10/100ml	DO≥1 at all times at all times E. Coli≤10/100ml
(D) Public amenities, playing field, etc.	same as (C) above, plus chlorination		

3) Characteristics of Raw Sewage

The sewage comprises not only sewage from household, commercial, business and institutional areas, but also wastewater from industry. Especially, raw sewage flowing into treatment works at Crowborough, Zengeza and Norton is very highly affected by industrial wastewater. Average BOD concentration of raw sewage is approximately 500-600mg/l.

4) STW site condition

Major concerns of the authorities are land acquisition and environmental measures in the surrounding areas of the STWs. Additional cost and arrangements for land acquisition will be taken into account according to the local conditions.

5) Low construction cost, and economical and easy O & M

Secondary treatment methods adopted in Zimbabwe include WSP, TF and BNR. BNR is most expensive both in construction and O & M, while WSP composed of simplified process is the lowest in O & M cost. However, WSP requires a large area and a great deal of earth work is necessary.

Alternative sewage treatment methods for future expansion of the existing STWs are recommended to include WSP, TF and BNR. These treatment methods are commonly used with sufficient experience in Zimbabwe. The features of these methods are as follows:

1) WSP

Advantage

- Easy in O & M since no mechanical and electrical equipment are needed
- Stable to load fluctuation of sewage
- No sludge treatment facilities is needed

Disadvantage

- A large area is needed
- Generation of odor at anaerobic pond

2) TF

Advantage

- Stable to load fluctuation of sewage

- Easier and cheaper in terms of O & M compared to BNR
- No return sludge equipment is needed

Disadvantage

- Effluent with much more suspended solids (SS) than BNR
- Lower treatment efficiency than activated sludge treatment method
- Generation of odor and fly
- A large area requirement compared to BNR
- Sludge treatment facility is needed

3) BNR

Advantage

- Organic substances, nitrogen and phosphorus can be removed with a high efficiency
- Treatment efficiency is high
- Smallest area required among alternatives
- Less environmental impact than other methods in terms of odor and water pollution/eutrophication

Disadvantage

- Mechanical and electrical equipment is needed
- O & M cost is comparatively high
- requirement of manpower training for O & M

Regarding to the sludge treatment and disposal, the following four methods are being used:

- AP+SDB (Sludge Drying Bed)+Reuse
- No-treatment (sludge from PST, SST)+SDB+Reuse
- AP and no-treatment (sludge from SST)+irrigation
- SDT (Sludge Digestion Tank)+irrigation

Sludge treatment depends on each STW conditions. In view of large differences among facilities, sludge treatment equipment for model cases will be in the simplest form, with a combination of sludge thickening and sludge drying as the standard approach.

The combinations of wastewater treatment, sludge treatment and disposal methods considered for model cases are as follows:

- WSP+no sludge treatment facilities (sludge drying in AP)
- TF+Thickening+SDB
- BNR+Thickening+SDB

General flow systems for the three treatment methods are shown in Figure 12.2.9.

(2) Selection of Sewage Treatment Process by STW

The City of Harare constructed two units of BNR with a treatment capacity of 36,000 m^3/day and is implementing additional BNR to treat 72,000 m^3/day at the Firle STW. Furthermore, there is another existing BNR with a capacity of 18,000 m^3/day at Crowborough STW. The City Council also has a plan to expand its facilities with a capacity of 25,000 m^3/day.

On the other hand, Chitungwiza, Norton and Ruwa have not yet taken up any measures to meet the effluent regulation.

In general, there are three (3) possible options which are able to meet the effluent regulation as follows:

1) Wastewater Stabilization Pond (WSP) + Irrigation
   The treatment system comprises anaerobic pond, facultative pond, maturation pond provided with irrigation area. The irrigation areas is required to reuse the treated effluent and remove of nutrients.

2) Trickling Filter (TF) + Irrigation
   The system consists of primary sedimentation tank or anaerobic pond, trickling filter, secondary sedimentation tank or maturation pond in addition to irrigation area. The irrigation areas has the same nature as that of WSP.

3) Biological Nutrient Removal (BNR)
   The system consists of primary sedimentation tank, biological reactor and secondary sedimentation tank.

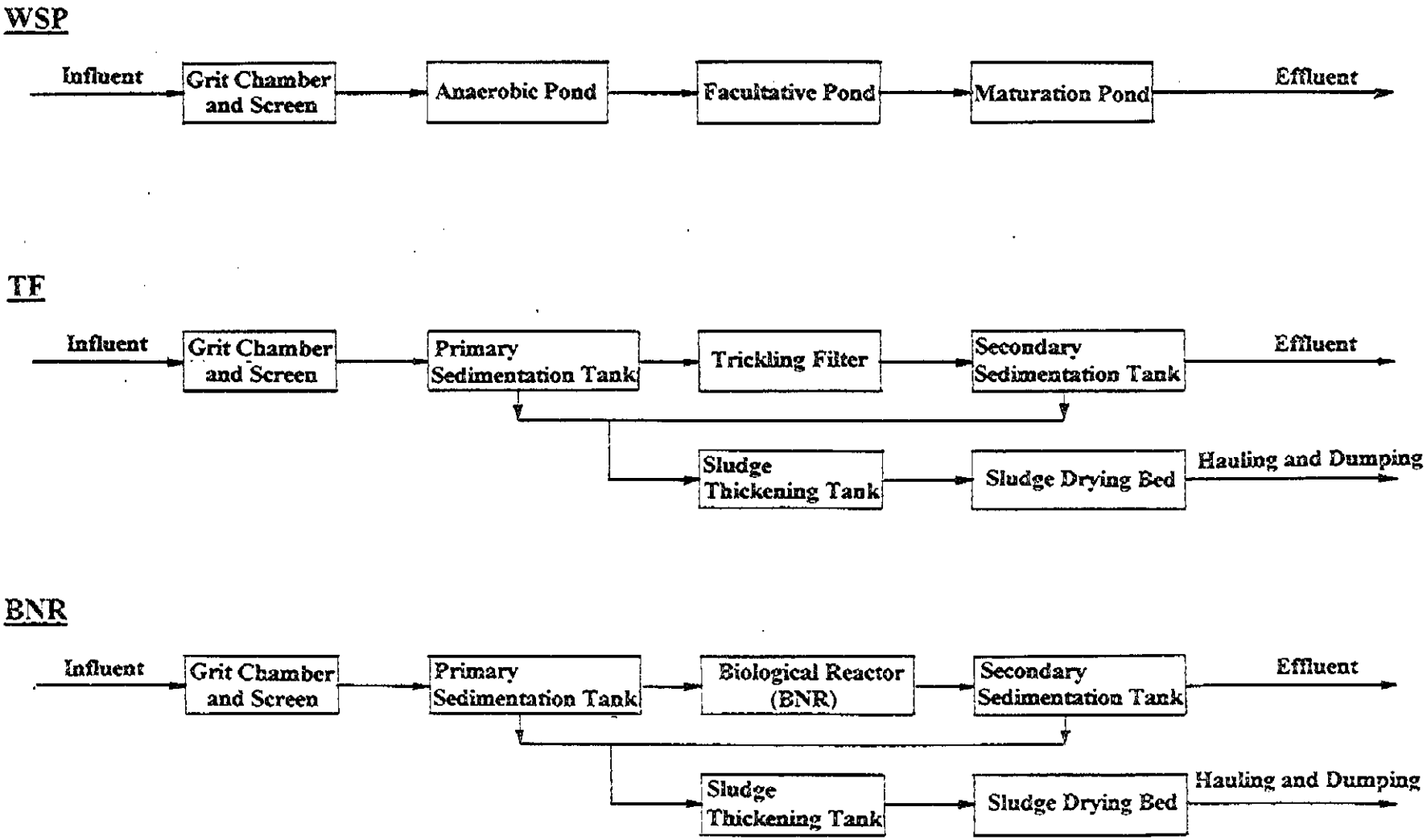


Figure 12.2.9 Sewage Treatment Flow Sheet

In the Study Area, inflow sewage load fluctuates largely throughout the year. During the wet season, sewage inflow into the STWs increases approximately three (3) times of the average dry weather flow (ADWF), being influenced by a mixture of storm water run-off. The technical ability of the above options are therefore preliminarily evaluated in terms of two different seasons. The following are the pre-conditions for the evaluation :

- Time fluctuation ratio
  Dry season : ADWF
  Wet season : 100 - 300 % of ADWF
- BOD concentration of raw sewage : 500 mg/l (typical domestic sewage)

Technical Evaluation of the Options

	Dry Season	Wet Season
1)	WSP + Irrigation BOD load is to be removed mainly by anaerobic and facultative ponds. The substantial portions of nutrients would be removed in the irrigation area.	In order to minimize running cost to pump effluent to the pasture lands, adequate number of storage pond shall be constructed so that the treated effluent be retained during the wet season and be used for the irrigation during the dry period. With provision of the storage pond, the effluent regulation could be met.
2)	TF + Irrigation BOD load is to be removed through trickling filter process. The nutrients will be removed by re-use of nutrients in the farm lands.	The same as the WSP.
3)	BNR BOD load and nutrients substances are to be removed to meet the effluent regulation.	Assuming the increase of inflow by 3 times of ADWF, a retention time through reactor may be reduced to 8 hours. Although about 90 % of BOD load would be removed, the nutrients would remain unremoved. In order to settle this problem the treated effluent would be required to be stored temporarily in storage pond. The reuse for irrigation to remove the nutrients is necessary.

It could be concluded that, in general, the three options can technically satisfy the effluent regulation during the dry season but, during the wet season, they require additional treatment process to further polish the treated effluent to the level of the effluent regulation.

In the light of the above preliminary evaluation of the three different treatment systems and present sewage treatment system, the following basic guideline could be used for planing of sewage works expansion plan.

1) Harare

Although the treated effluent is reused for irrigation at present, it seems to be difficult to expand the irrigation area due to rapid urbanization in the peripheral areas. In a long run, it is obliged to adopt more sophisticated method to properly meet with the effluent standards. At this stand point, it is adequate that Harare has been implementing the tertiary treatment method.

2) Chitungwiza

The authority is currently facing two constraints : one is to release the treated effluent into the river throughout the year to maintain riparian water right and aqua-ecology and the other is difficulty in land acquisition for case of construction of diversion facilities to the Nyatsime River. Taking such constraints into account, a combination of different treatment processes would be preferable including the BNR, trickling filter in addition to the expand irrigation area. The capacity of BNR shall be carefully be determined in due consideration of the water quality to be discharged and operation cost.

3) Norton and Ruwa

It would be considered to be appropriate to adopt a combination of trickling filter and stabilization pond under the limited resources which both the authorities are now encountering.

(3) Expansion Plan of Sewage Treatment Works

The expansion plan of STWs will be prepared for urban areas of Harare, Norton, Ruwa and Epworth for the intermediate year (2005) and target year (2015) and for Chitungwiza for the target years 2000, 2005 and 2015 with Scenario-1

1) Pollution load removal ratio by sewage treatment method

The removal ratio of the BNR is referred to the experience at STWs. While for WSP and TF, common ratio used for designing purpose are to be adopted, although present ratios at existing STWs are lower than designed under overloaded conditions. The removal ratios of BOD, T-N and P-P are shown in Table 12.2.14 assuming that the ratios of T-P and P-P are the same (refer to Section 4.2.)

Table 12.2.14 Removal Ratio by Sewage Treatment Method

Treatment Method	Removal Ratio (%)		
	BOD	T-N	P-P
WSP	90	50	30
TF	90	30	30
BNR	95	80	75

2) Design sewage quantity and quality

Table 12.2.15 shows the design sewage quantity and quality for STWs by the values calculated.

Table 12.2.15 Design Sewage Quantity and Quality

Sewage Works	Design Sewage Quantity (m^3/day)		Design Sewage Quality (mg/l)					
	Year 2005	Year 2015	Year 2005			Year 2015		
	-	-	BOD	T-N	P-P	BOD	T-N	P-P
Crowborough	148,100	178,900	500	100	11	500	100	11
Firle	248,100	309,700	550	90	11	550	90	11
Marlborough	2,000	4,800	200	40	4	200	40	4
Donnybrook	7,900	12,300	600	150	16	600	150	15
Harare South	63,600	92,100	800	60	10	800	80	11
Harare East	6,300	37,600	650	150	16	900	60	10
Zengeza	38,700	70,200	600	140	15	600	110	13
Norton	12,400	41,300	750	80	9	1,000	60	7
Ruwa	13,200	18,400	500	100	11	500	100	10

3) Selection of expansion facilities by STW

The treatment methods of expansion facilities by STW are decided considering the size of treatment capacity, site condition, O & M, and finance as presented below.

- Crowborough : Biological Nutrient Removal (BNR)
- Firle : Biological Nutrient Removal (BNR)
- Marlborough : Wastewater Stabilization Pond (WSP)
- Donnybrook : Wastewater Stabilization Pond (WSP)
- Harare South : Biological Nutrient Removal (BNR)
- Harare East : Biological Nutrient Removal (BNR)
- Zengeza : Biological Nutrient Removal (BNR)
- Norton : Trikling Filter (TF)
- Ruwa : Wastewater Stabilization Pond (WSP)

4) Required sewage treatment facilities by STW

The required sewage treatment facilities in target years are shown in Table 12.2.16 and their facilities in Scenario-2 are also shown in Table 12.2.17 for reference for the calculation of cost estimates in Section 13. The BNR method may be supplemented the polishing pond after the secondary sedimentation tank in consideration with further strict effluent standard in the future.

5) Layout of expansion facilities by STW

Prior to the expansion plan, design criteria for STW is established taking into accounts of the "Sanitation Manual Design Procedures" and the experience of other countries as shown in Section 12.2.5, Chapter 2, Supporting Report.

Expansion layout plans are prepared for STW on the assumption that the treatment methods chosen by each facility would be used. The total plan has been produced employing the design sewage quantity in 2015 (Scenario-1). Up to the year 2005, some facilities are expected to undergo expansion. Table 12.2.18 shows that capacity of the facilities in at present, 2005 and 2015. The calculations for the capacity required in the final target year are shown in Tables 12.2.5.1 to Table 12.2.5.9 in Section 12.2.5, Chapter 2, Supporting Report. Layout plans by STW by target years are as shown in Figures 12.2.10 to Figure 12.2.18.

Table 12.2.16 (1) Required Sewage Treatment Facilities by Sewage Treatment Work (Scenario-1)

Authority	Sewage Works	Present Condition		Design Sewage Quantity		Required Treatment Facility		Required Treatment Method	
		Design Capacity	Influent Flow	2005	2015	2005	2015	2005	2015
		(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	-	-
Harare	Crowborough	54,000	55,311	148,100	178,900	94,100	124,900	BNR	BNR
	Firle	72,000	132,291	248,100	309,700	176,100	237,700	BNR	BNR
	Marlborough	2,000	2,000	2,000	4,800	0	2,800	WSP	WSP
	Donnybrook	5,500	5,497	7,900	12,300	2,400	6,800	WSP	WSP
Harare Expansion	Harare South	-	-	63,600	92,100	63,600	92,100	BNR	BNR
	Harare East	-	-	6,300	37,600	6,300	37,600	BNR	BNR
Norton	Norton	3,400	2,700	12,400	41,300	9,000	37,900	TF	TF
Ruwa	Ruwa	5,300	2,865	13,200	18,400	7,900	13,100	WSP	WSP

Table 12.2.16 (2) Required Sewage Treatment Facilities for Zengeza Sewage Treatment Work (Scenario-1)

Authority	Sewage Works	Present Condition		Design Sewage Quantity			Required Treatment Facility			Required Treatment Method		
		Design Capacity	Influent Flow	2000	2005	2015	2000	2005	2015	2000	2005	2015
		(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	-	-	-
Chitungwiza	Zengeza	20,400	36,405	37,500	38,700	70,200	17,100	18,300	49,800	BNR	BNR	BNR

Table 12.2. 17 (1) Required Sewage Treatment Facilities by Sewage Treatment Work (Scenario-2)

Authority	Sewage Works	Present Condition		Design Sewage Quantity		Required Treatment Facility		Required Treatment Method	
		Design Capacity	Influent Flow	2005	2015	2005	2015	2005	2015
		(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	-	-
Harare	Crowborough	54,000	55,311	92,700	124,200	38,700	70,200	BNR	BNR
	Firle	72,000	132,291	205,300	277,900	133,300	205,900	BNR	BNR
	Marlborough	2,000	2,000	2,000	2,600	0	600	WSP	WSP
	Donnybrook	5,500	5,497	8,400	11,700	2,900	6,200	WSP	WSP
Harare Expansion	Harare South	-	-	47,100	47,400	47,100	47,400	BNR	BNR
	Harare East	-	-	6,300	37,600	6,300	37,600	BNR	BNR
Norton	Norton	3,400	2,700	7,600	26,500	4,200	23,100	TF	TF
Ruwa	Ruwa	5,300	2,865	4,300	5,700	0	400	WSP	WSP

Table 12.2.17 (2) Required Sewage Treatment Facilities for Zengeza Sewage Treatment Work (Scenario-2)

Authority	Sewage Works	Present Condition		Design Sewage Quantity			Required Treatment Facility			Required Treatment Method		
		Design Capacity	Influent Flow	2000	2005	2015	2000	2005	2015	2000	2005	2015
		(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)	-	-	-
Chitungwiza	Zengeza	20,400	36,405	45,500	58,100	107,700	25,100	37,700	87,300	BNR	BNR	BNR

Table 12.2.18 Expansion Plan by STWs in 2005, 2015 (Scenario-1)

Authority	STW	Treatment Method	Items	Unit Number and Treatment Capacity by Target Year					
				Present		2005		2015	
Harare	Crowborough	TF,BNR	existing	3 units	54,000	3 units	54,000	3 units	54,000
		BNR	expansion	-	-	6 units	93,600	8 units	124,900
		total		-	-	9 units	147,600	11 units	178,900
	Firle	TF,BNR	existing	4 units	72,000	4 unit	72,000	4 unit	72,000
		BNR	under const	(2 units)	(72,000)	2 units	72,000	2 units	72,000
		BNR	expansion	-	-	5 units	103,600	8 units	165,700
		total		-	-	12 units	247,600	14 units	309,700
	Marlborough	WSP	existing	1 unit	2,000	1 unit	2,000	1 unit	2,000
		WSP	expansion	-	-	-	-	1 unit	2,800
		total		1 unit	2,000	1 unit	2,000	2 unit	4,800
	Donnybrook	WSP	existing	4 units	5,500	4 units	5,500	4 units	5,500
		WSP	expansion	-	-	1 units	3,400	2 units	6,800
		total		4 units	5,500	5 units	8,900	6 units	12,300
	Harare South	-	existing	-	-	-	-	-	-
		BNR	expansion	-	-	3 units	69,100	4 units	92,100
		total		-	-	3 units	69,100	4 units	92,100
	Harare East	-	existing	-	-	-	-	-	-
		BNR	expansion	-	-	1 unit	9,400	4 units	37,600
		total		-	-	1 unit	9,400	4 units	37,600
Chitungwiza	Zengeza	TF	existing	1 unit	20,400	1 unit	20,400	1 unit	20,400
		BNR	expansion	-	-	2 units	24,900	4 units	49,800
		total		1 unit	20,400	3 units	45,300	5 units	70,200
Norton	Norton	TF	existing	1 unit	3,400	1 unit	3,400	1 unit	3,400
		TF	expansion	-	-	1 unit	9,500	4 units	37,900
		total		1 units	3,400	2 units	12,900	5 units	41,300
Ruwa	Ruwa	WSP	existing	1 unit	5,300	1 unit	5,300	1 unit	5,300
		WSP	expansion	-	-	3 units	9,800	4 units	13,100
		total		1 unit	5,300	4 units	15,100	5 units	18,400

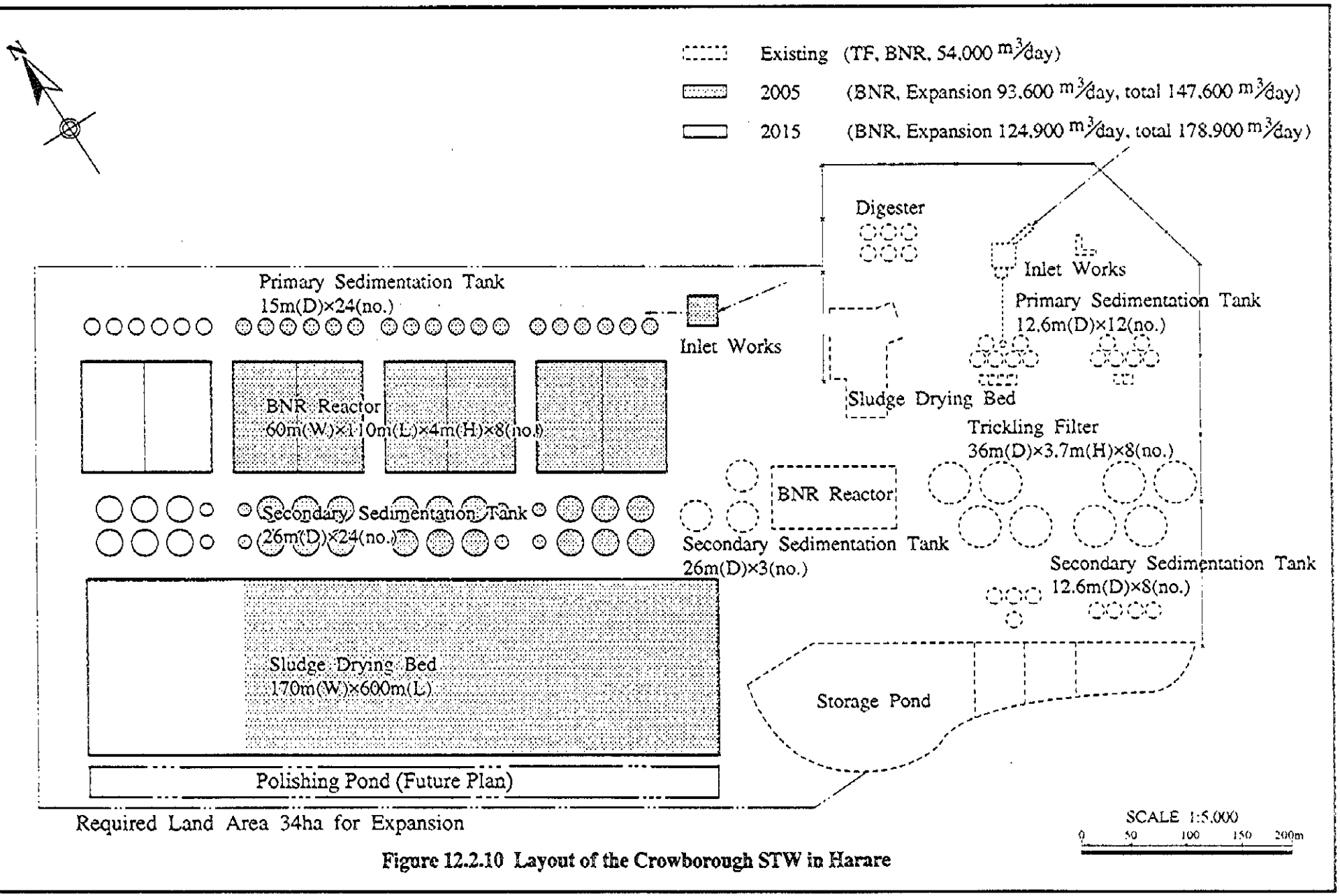


Figure 12.2.10 Layout of the Crowborough STW in Harare

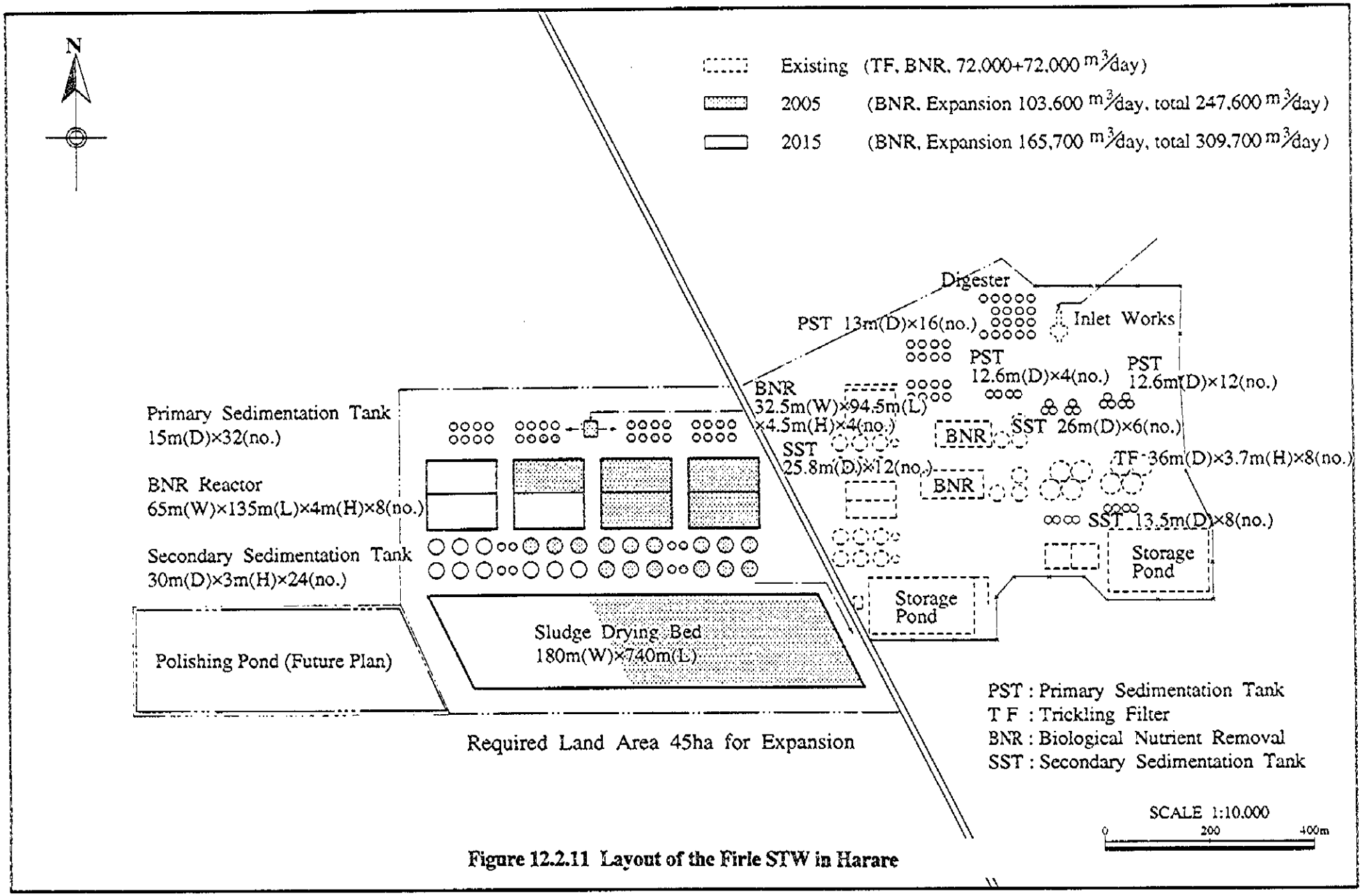


Figure 12.2.11 Layout of the Firle STW in Harare

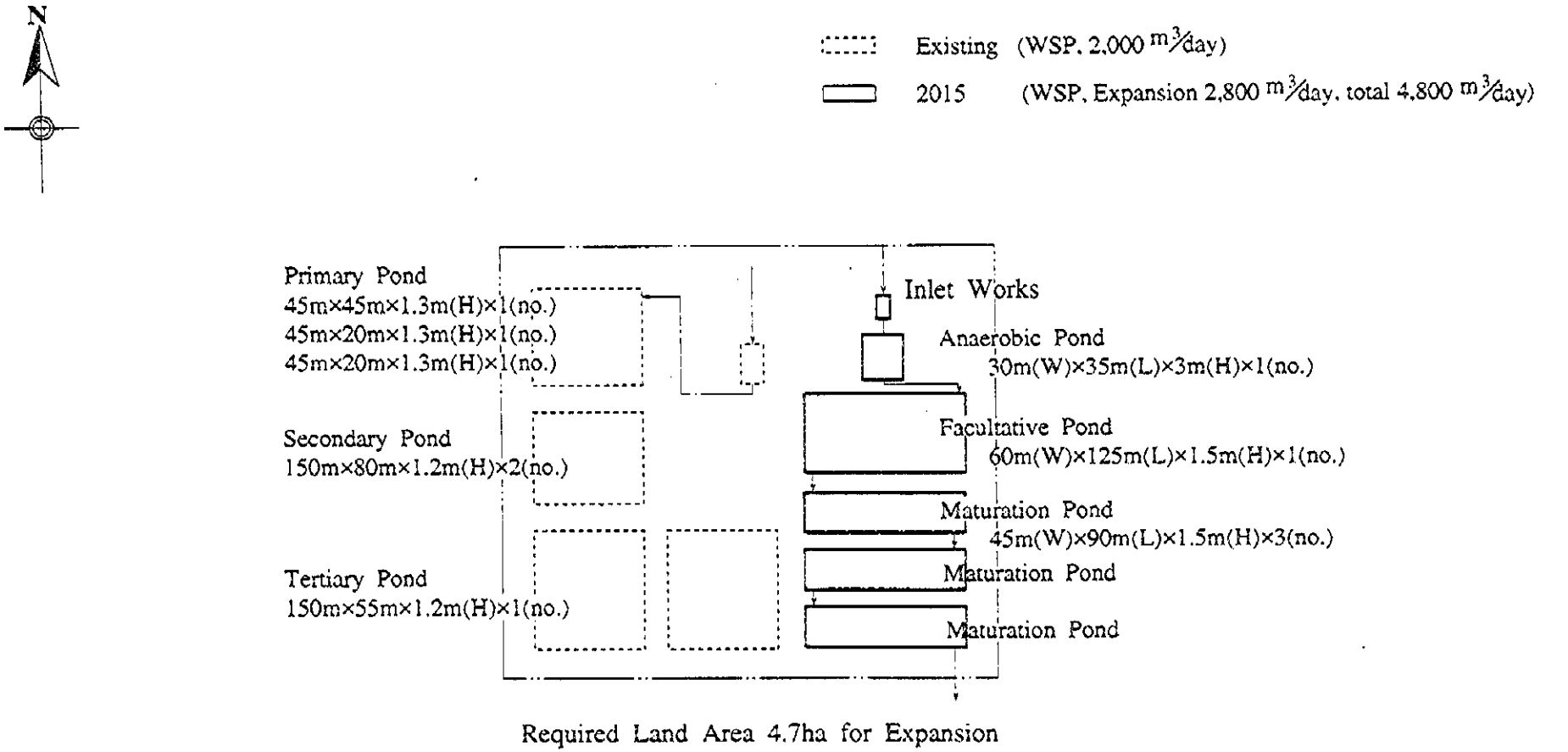


Figure 12.2.12 Layout of the Marlborough STW in Harare

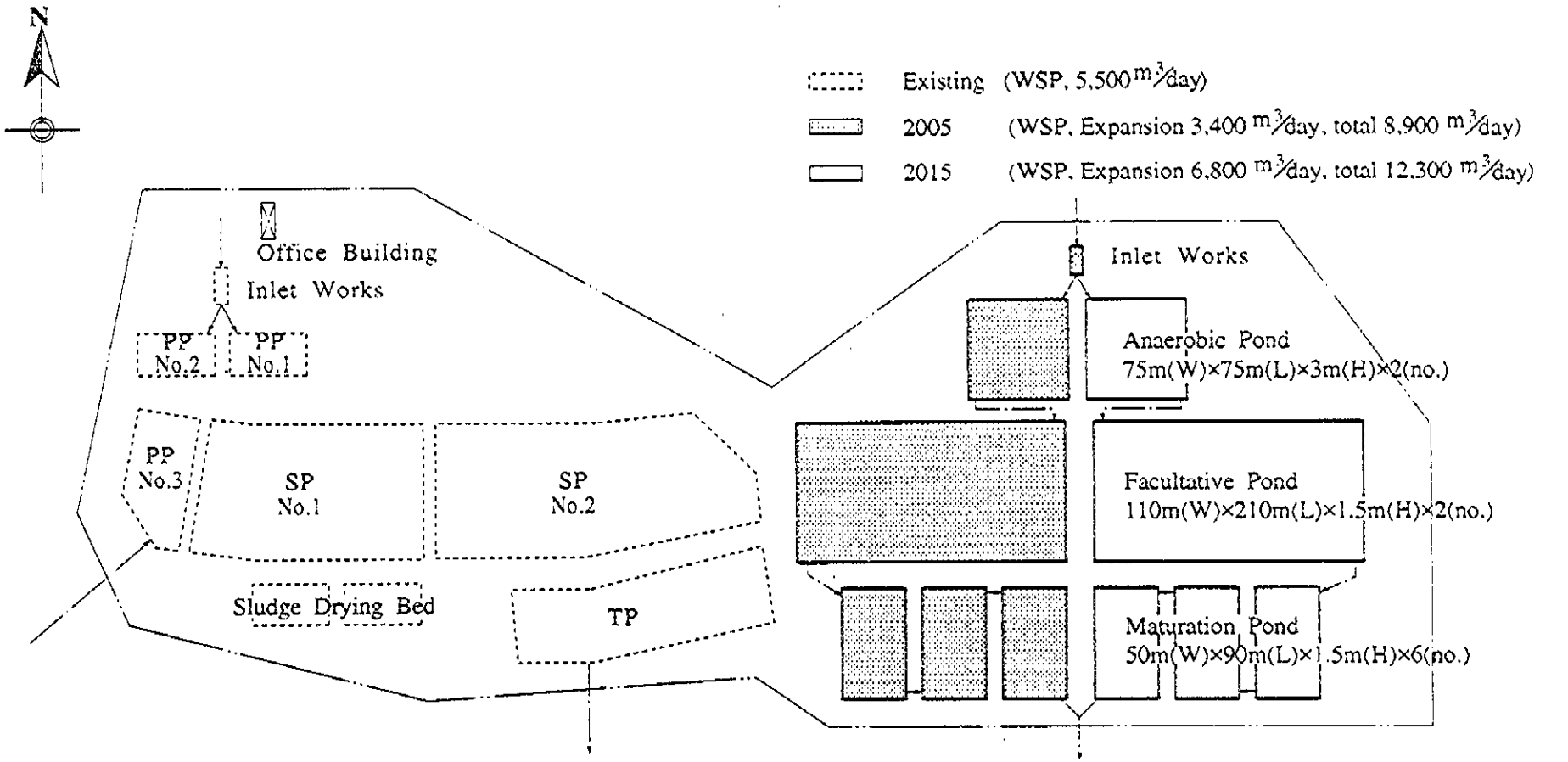


Figure 12.2.13 Layout of the Donnybrook (Block 2) STW in Harare

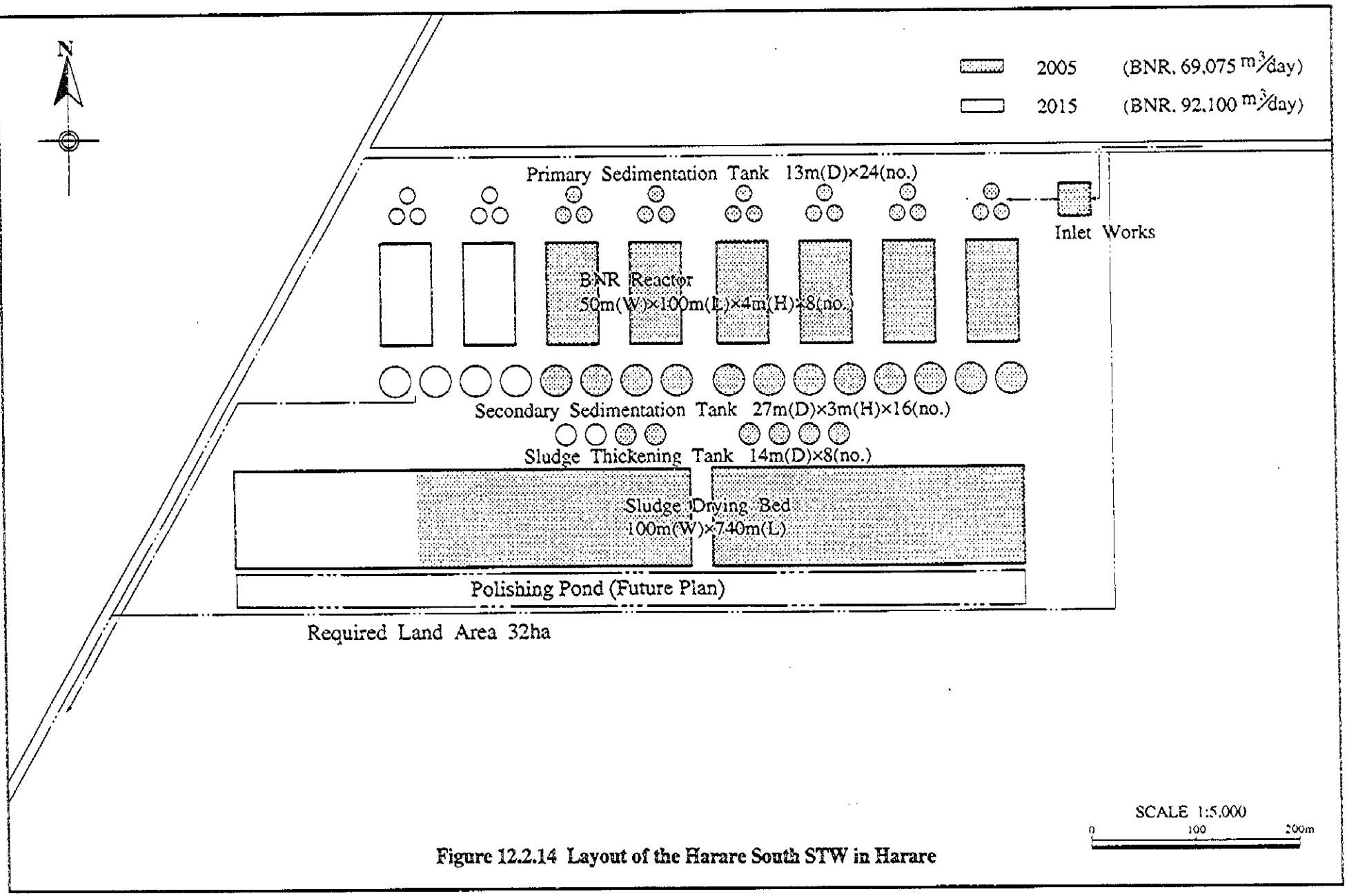


Figure 12.2.14 Layout of the Harare South STW in Harare

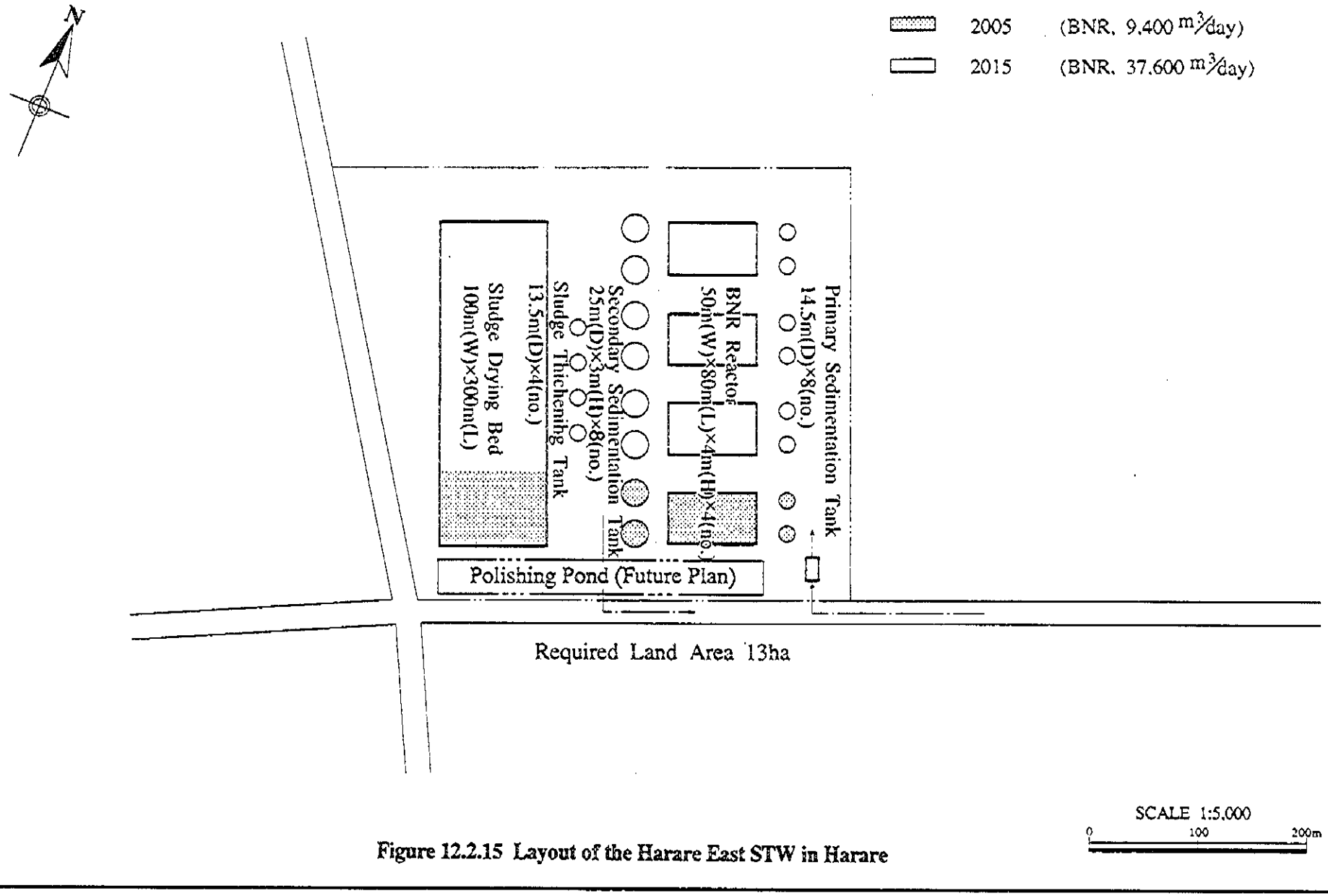


Figure 12.2.15 Layout of the Harare East STW in Harare

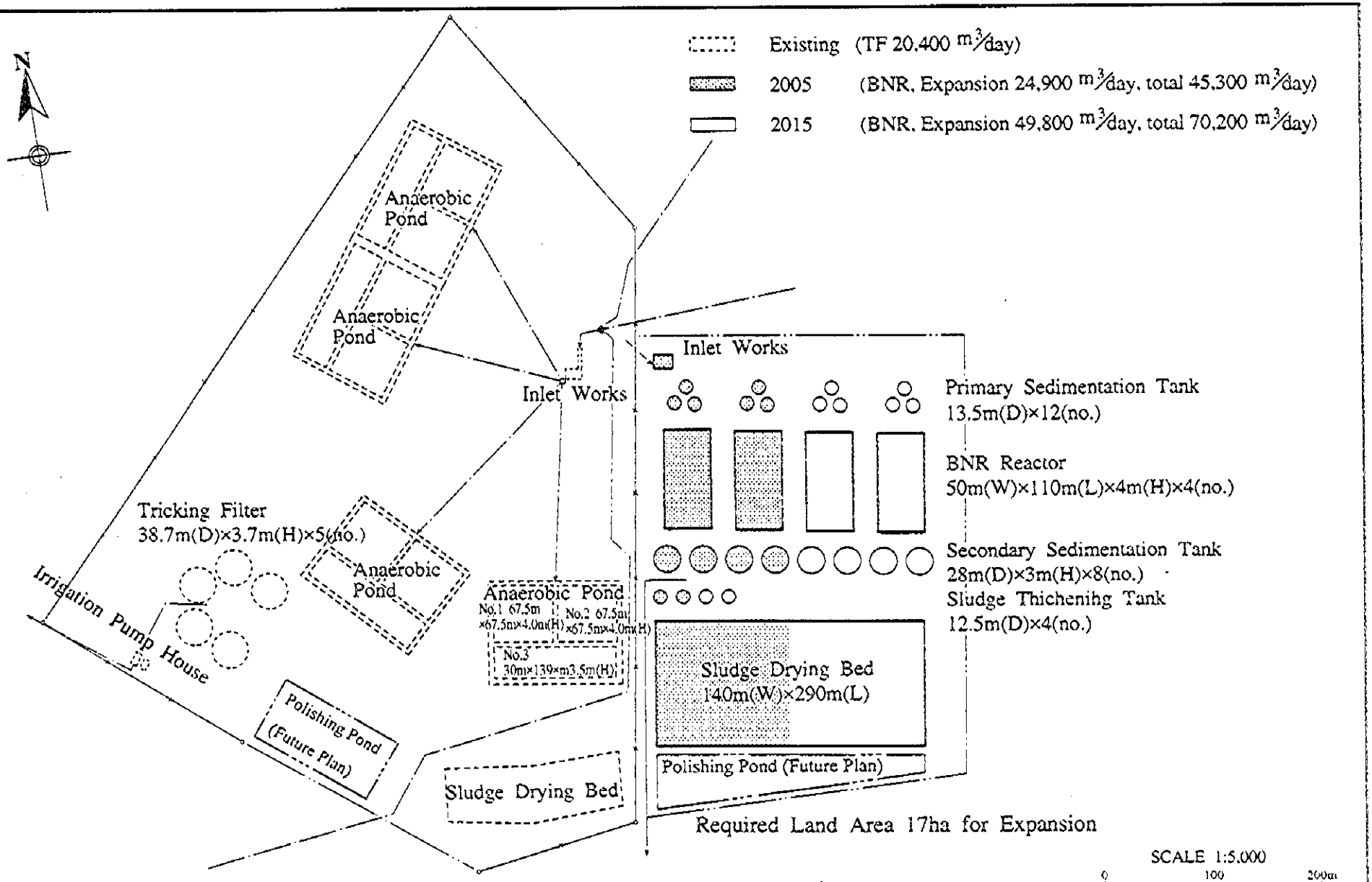


Figure 12.2.16 Layout of the Zengeza STW in Chitungwiza

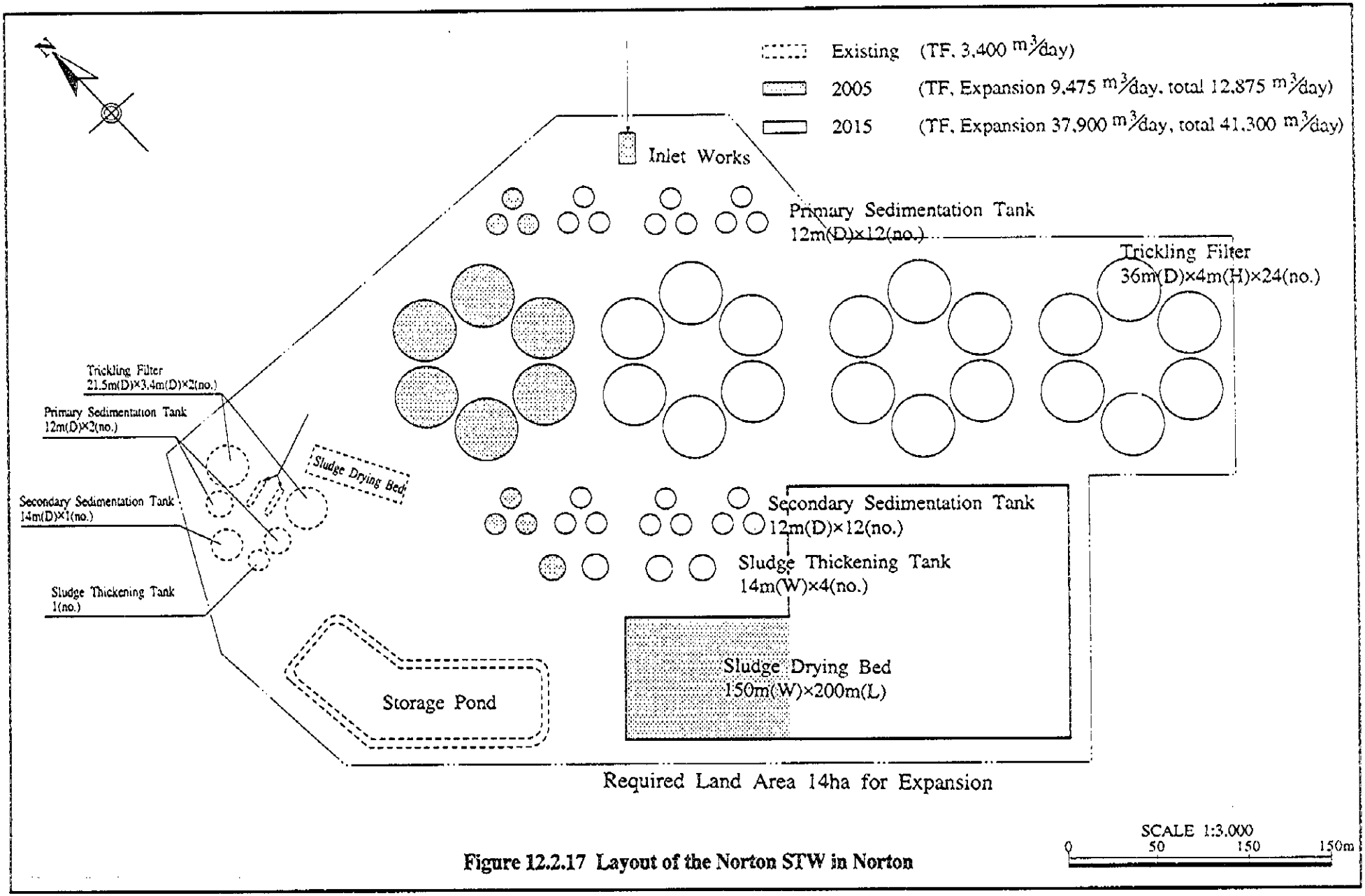


Figure 12.2.17 Layout of the Norton STW in Norton

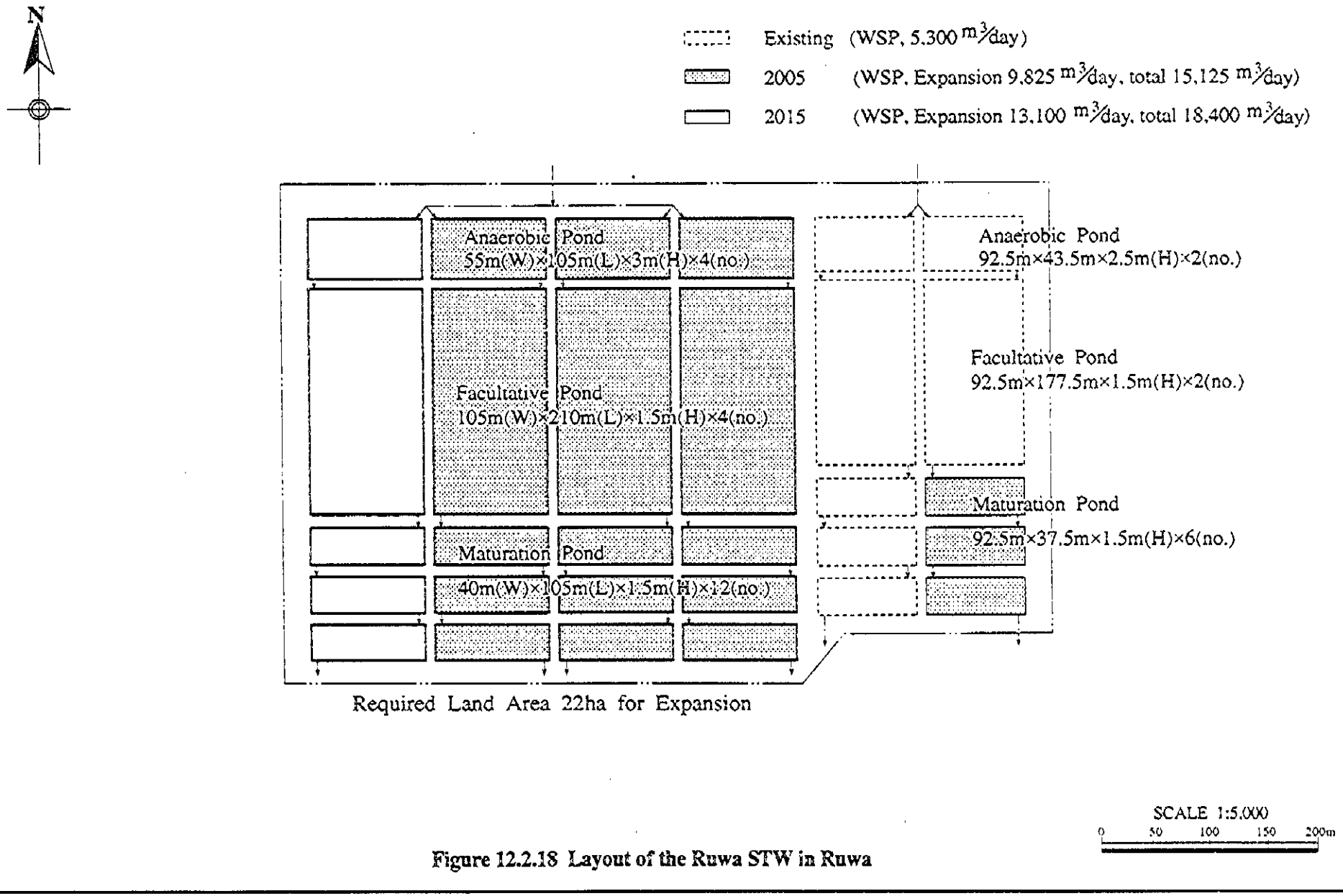


Figure 12.2.18 Layout of the Ruwa STW in Ruwa

There are plans being considered for the Crowborough STW, Zengeza STW and Norton STW. However, in the interest of simplification, these have been omitted from the expansion layout plan, because there are many uncertain elements in STW expansion, such as changes in treatment process and/or combination of multiple processes due to the availability of land. For simplicity, the expansion plans are prepared based on the principle of one treatment system in each STW.

12.3 Industrial/Slaughterhouse Wastewater Treatment

Excluding some large-scale factories, namely pulp factory in Norton and chemical factory in Harare, industrial wastewater with high concentration of organic substances is discharged into the public sewerage systems. The wastewater adversely affects treatment efficiency at the STWs. The pre-treatment facility is a requisite to be provided at respective factories before discharging the effluent into public sewers in compliance with assumed quality standards.

The results of effluent quality examination on 45 types of industry conducted through this study revealed that (refer to Sub-section 3.5), the concentration of BOD, T-N and T-P is high in the effluent caused by Processed Foodstuffs, Slaughterhouse and Pulp & Paper related Products. The pre-treatment facility is necessary for these types of industry. The pre-treatment method for the industry is recommended referring to the experience at Tilcor industrial complex as shown below.

(1) Processed Foodstuffs/Slaughterhouse, Pulp & Paper related Products

Raw industrial wastewater	:	BOD 2,500 ~ 5,000 mg/l (assumption)
Target treated effluent quality	:	BOD less than 600 ~ 1,000 mg/l
Treatment method	:	Anaerobic Pond and Facultative Pond

Standard Pre-treatment Flow Sheet

→ Anaerobic Pond → Facultative Pond → Public Sewer System

12.4 Solid Waste Collection and Disposal

The open dumping of solid wastes is commonly practiced in the vicinity of the residential area. These wastes and their leachate flowing into public water bodies cause a pollution problem.

The projection of leachate quantity and quality at the dumping site are made using current records (refer to sub-section 10.2). The future volume of solid waste generated in the urban areas and required disposal area are planned to increase in proportion to the population growth.

The leachate quantity and quality are projected as shown in Table 12.4.1 and Table 12.4.2 adapting the values calculated in Table 8.4.11.

Table 12.4.1 Leachate Quantity at Solid Waste Dumping Site

Authority	Scenario-1 (m^3/day)		Scenario-2 (m^3/day)	
	2005	2015	2005	2015
Harare	720	1,290	680	860
Chitungwiza	140	220	120	160
Norton	80	150	110	210
Ruwa and Epworth	40	70	60	100

Table 12.4.2 Leachate Quality at Solid Waste Dumping Site

BOD (mg/l)	T-N (mg/l)	T-P (mg/l)
500	250	N.A

Note : N.A; not available

Considering small capacity of leachate treatment required, the WSP may be adopted. The removal ratios in terms of BOD, T-N and T-P are shown in Table 12.2.14. The standard of treatment system for leachate is shown below.

Standard Treatment System for Leachate

→ Anaerobic Pond →Facultative Pond → Maturation Pond → Public Water Body

12.5 Livestock and Other Pollution Sources

In the Study Area, it is difficult to reduce the all pollution generated by the livestock (cattle, sheep, goats, pigs and poultry) and other non-point sources considering the technical and economical status in Zimbabwe. However, from the point of view of the water pollution control, the following countermeasures should be taken for the above mentioned pollution.

(1) Stabilitation pond (sedimentation tank/pond) of discharge before flowing into nearby streams.
(2) Re-location of the livestock breeding area to the outside of the study basin.

12.6 Other Technical Countermeasures

Aside from technical countermeasures, the following are possible methods.

- Removal of the nutrients by fishery
- Removal of the nutrients by plants and dispose of the outside of the study basin

In addition, dredging of the sedimets accumulated at the bottom of lakes/dams is recommended to remove nutrients in the closed water body.

12.7 Basic Strategy for Institutional and Legal Arrangements

The pressure of the relatively high population growth at nearly 6 % per annum in urban area during the period of 1980-92 and the insufficiency in environmental protection and management have resulted in serious urban problems such as environmental degradation (especially water pollution), shortage in water supply, unemployment, etc., as well as poverty in rural areas. In order to solve these problems, a definitely deliberate and strategic approach is highly required, mobilising all development resources on the long-term perspectives.

Conservation and protection of sensitive ecosystems are vital to materialise the sustainable development, and the water pollution control is, among others, of particular importance to the urban areas in Zimbabwe.

12.7.1 Institutional Arrangements

(1) Overall Institutional Framework

The role of central government in water pollution control is mainly to provide technical guidance for the smooth implementation in planning, implementation and co-ordination of its development programmes and projects.

Water pollution control is the key element in the management of water quality, and thus the principal means for preserving and enhancing the quality of a nation's waters. How effectively these goals are achieved depends upon the institutional arrangements which are established for implementing a country's laws and policies at different political levels: national and local authorities.

Regardless the levels to which individual functions are assigned, the organisational structure must clearly delineate authority, responsibility, and resources for each of the political levels involved in order to assure successful development and implementation of control programs and projects.

The responsibilities at each level depend upon the legal/institutional framework and the function delegated, and resources assigned to the lower levels. In this respect, it is essential that the laws clearly define the responsibilities at each level.

Whatever the organisational structure, the responsible agency must be provided with sufficient staff, funds, and other resources to enable carrying out its assigned missions. It is essential that it be given full political and other government support on a continuing and long-term basis.

To ensure the coherent environmental protection and management, the joint and well-co-ordinated environmental policies by both the national and local authorities should be addressed for water pollution control with a basin-based approach in the Manyame river.

(2) Decentralisation and its Implications in Local Authorities

Water pollution control will only be successful, when the local authorities take the leading role in planning, implementation and co-ordination of the development programs/projects in the relevant sectors.

With resources for the public sector being constrained, it is now important to introduce cost-effective ways of delivering these services. Burden-sharing is an important aspect of cost-efficiency and often constitutes often an important component or prerequisite for the package of services to be provided in the public sector. To realise this, the Government of Zimbabwe strives to move in decentralisation direction.

With integration of the rural and district councils into "Rural District Councils (RDCs)" in 1988 by the Rural District Councils Act and establishment of "Urban Councils" in 1995 by the Urban Councils Act, Zimbabwe had a consistent and pan-territorial administrative system to make a major step forward in terms of developing local authorities at local level with similar tasks, responsibilities and revenue raising powers.

The actual implementation of the above two Acts requires considerable capacity building at local level. More importantly, the financial viability of the local authorities is of major concern, particularly if they are to a large extent made to rely on own-resources. A flexible system for resources allocation to local authorities is essential.

To push on the decentralisation, a more coherent public sector strategy may be needed, based on a clear vision. This concerns issues like what kinds of services should the public sector provide and what kinds of services it should not be concerned about.

In addition to the poor legislation, enforcement of the regulations at local level faces constraints such as shortage of human resources and insufficient and/or ineffective administrative power, or lack of land use plans. Local authorities can not monitor effluent discharges regularly as they do not have sufficient equipment, reagent for analysis and experts.

Generally, resource constraints are due to the limited capacity (system constraints) of the authorities to generate tax revenue, insufficient tax collection efforts, and failure to recover costs of services.

Sewage Treatment Works

The problems/constraints in the existing sewage treatment works are mainly due to financial constraints, lack of trained/professional staff and insufficient training programme of the respective sewage treatment works or the local authorities.

It should be recognised that solution of all issues in the existing sewage treatment works depends upon the institutional, administrative and financial consolidation of the local authorities concerned. Sewage treatment capacity in each works will be improved, when the local authorities would succeed in financial viability and capability building.

(3) Specific Shortcomings for Institutional Strengthening

Taking into account the present conditions and implications just noted, the following are some problems which the central government and local authorities have to tackle from now on.

1) Although there were the legal/institutional arrangements to accelerate the decentralisation, the structures of local authorities are still weak from the administrative and financial viewpoints.

2) In planning and implementing the water pollution control projects, the promotion and improvement may be necessary in relationships at various levels among the ministries/agencies and between the central and local authorities.

3) Particularly in the local authorities, the number of staff in charge of planning, implementing and managing water pollution control projects are very limited.

4) In general, capabilities of the staff in planning, implementing and managing water pollution control projects have not sufficiently been developed in local authorities.

5) In spite of the existence of an information system for water resources development including water pollution control, the basic and/or accurate data are not yet properly stored nor distributed to the concerned authorities.

(4) Policy Recommendations

1) To achieve environmentally sound and sustainable development, it is imperative to align the public administration and/or revamp the overall structure for environmental management.

2) The responsible agencies/authorities for water pollution control should, as much as possible, be provided with sufficient staff, funds, and other resources to enable carrying out their respective assigned missions.

3) To ensure the inter-agency co-ordination among all central government agencies, local authorities, communities, and the private & industrial sector concerned; the responsibilities, authorities, levels of activities and resources for each of the political level should be clearly delineated.

4) There is a need for all agencies/institutions at every levels to organise seminars, training workshops and/or in-house training for those tasked with and interested in water pollution control.

5) It is vital to encourage the private & industrial sector and the public to participate in water pollution control in order to improve general environmental management performance. This should be done through adequate institutional and organisational arrangements.

12.7.2 Legal Considerations

(1) Legal Framework

The basic purpose of laws and statutes on water pollution control is to protect water quality, both surface and underground, and to promote conservation of water resources. It is therefore necessary that such laws be established within the framework of the legal, political, social, cultural, and economic structures in the country.

National economic development efforts have required reforms of its administrative structures, management mechanism and socio-economic programmes. Public

administration has yet to be aligned with the needs of economic recovery and reform. Then, the laws and regulations need to be further developed and made more consistent.

1) Water resources development

In the area of water resources, the Government of Zimbabwe is implementing a reform programme of the water sector to improve equity in access to water, the management of water resources and administration of the Water Act.

In the "Water Act Review Board (WARB)" organised under the Department of Water Resources (MLWR), review studies have been carried out to amend the "Water Act of 1976".

In connection to the revision of this Act, a Bill is scheduled to be tabled in the 2nd Session of the 4th Parliament (1996) for the establishment of the "Zimbabwe National Water Authority" which will become responsible for the management of water resources in the country.

2) Water pollution control

Taking into consideration the current legal/institutional constraints of Zimbabwe, the effective legislation to be reviewed and amended should:

- be based on sound, up-to-date economic and scientific principles;
- provide a framework for setting but not establishing the standards, since the latter is part of the regulatory process; and
- provide for establishing meaningful penalties for non-conformance to standards.

The following provisions are to be included to assure the above reform programme:

- securing adequate funding;
- keeping up-to-date the information on the nature and characteristics of the pollution problem for programme planning purposes;

- establishing the full scope of measures for securing compliance, such as information and education programs, administrative readiness, and the legal capability for positive enforcement action;
- continuing surveillance and technical study of water resources; and
- technical review and assistance to local authorities, industrial and other users.

3) Environmental conservation and management

As described in Section 3.3.2, environmental laws and regulations are not yet well enacted and the environmental impact assessment (EIA) procedures are under trial stage. In addition, the environmental legislation, policies, standards and guidelines are too much fragmented.

In reality, sewage disposal problems can be eliminated or greatly lessened by proper regulation on the operation of collection system. Ineffective operation and maintenance of sewer can result in clogging, improper or illegal connections to the public system, and uncontrolled industrial waste discharges.

Where the impact of pollution is recognised, environmental law should be firmly established as a management and enforcement tool.

Environmental laws and policies are to provide a sound basis towards "sustainable development". Environmental strategies need for:

- assigning clear institutional responsibilities,
- complementary legislation that is consistent and simple,
- a capacity to deliver, and
- incorporation into national development planning.

It is pointed out that the lack of comprehensive environmental legislation led to such catastrophes as the recent fish deaths in Lake Chivero. The environmental law reform process addresses environmental standards and institutional arrangements of monitoring and enforcing these standards.

As a consequence, Zimbabwe has a vital need to enact a new "Environmental Management Act", in order to overcome the deficiencies in and fragmentation of the existing environmental laws. The institutional framework and the powers and duties of the administering authorities must be clearly articulated in the Act.

Besides, it is recommended that this Act incorporate the requirements for the Environmental Impact Assessment (EIA) as a part of its provisions. At the same time, it is also proposed to include general EIA requirements in other statutes concerned.

(2) Legal Measures for Prevention of Water Pollution

To tackle the legislative and administrative problems on water pollution control, the Water Act and relevant water regulations should be reviewed and updated to define the responsibilities of the national government, local authorities and business enterprises, and to clearly formulate the basic principles that should govern the promotion of environmental measures, so as to be able to implement water pollution measures in a comprehensive and unified manner.

1) Establishment of environmental water quality standards

The basic objective of pollution control is to reduce the concentration of pollutants to levels which will not interfere with beneficial utilisation of the receiving waters by subsequent users. Control of pollution is also necessary for the protection of the aquatic environment and the maintenance of acceptable quality in lakes, reservoirs and streams.

The Water Act does not address the problems of consistency in the application of standards for controlling water pollution. Besides, the environmental water quality standards are not yet established in Zimbabwe. In order to deal with imminent and potential pollution problems before they occur or become serious, and also to prepare the water pollution control plan, it is "must" to formulate as proposed for organic substances in Section 7.1 for environmental quality management.

The water quality standards for receiving bodies of water are to be coupled with rules regarding permissible quantities or strength of effluents.

The environmental water quality standards covering environmental and health items are preferably to be formulated as shown below:

- nine (9) heavy metals: cadmium, cyanide, organic phosphorus, lead, hexavalent chrome, arsenic, total mercury, alkyl mercury and PCBs;
- BOD, COD and DO for each type of water; and
- total nitrogen and total phosphorus to prevent eutrophication (for lakes and reservoirs).

2) Strengthening of effluent regulations

As described in Section 3.3.1 (2), there exist two sets of effluent regulations in Zimbabwe. The effluent standards are applied uniformly over a broad range of activities, but more strict controls have to be added to them in order to achieve a given quality in the receiving water.

It is also pointed out that the Water (Effluent and Wastewater) Regulations, 1977 cannot effectively control the pollution from sewage plants and water works, particularly since no safe drinking water standards have been enacted so as to impose minimum standards for drinking water.

The following are main issues to be considered and set in the effluent standards:

- Establishment of additional effluent standards
- Designation and/or expansion of control subjects
  - all polluters including factories and other facilities of a given type
- Expansion in total pollutant load control areas
  - introduction of a system of "specified facilities in designated areas"
- Addition of controlled pollutants
  - hazardous substances and others such as cadmium, organic acid, alkyl mercury, PCB, oil/grease, nitrogen as nitrates, total dissolved solids, pesticides, etc.

To conclude, the above two sets of regulations need to be reviewed and amended to incorporate technological changes and to address existing sources of industrial pollution.

3) Trade effluent control

Reduction of industrial wastewater loads into the public sewerage system will attenuate the pollution loads to be treated at the sewage treatment works.

The trade effluents in the urban local authority areas are controlled in accordance with the regulations mentioned in Section 3.3.1(3). In view of their contents and actual applications, it is advised to upgrade them to the status of "by-laws" in order to achieve a given percent reduction and enable the polluters to charge based on the quantity and quality of their discharge. For this respect, it is necessary to carry out the inventory survey to identify all industrial water pollution sources.

The trade effluent standards for discharge into public sewers are shown as a proposed example in Table 12.7.1, Section 12.7, Chapter 2, Supporting Report. Maximum concentration of BOD_5 and COD are set provisionally at 1,000 and 2,000 mg/l, respectively. The quality of the effluent discharged is dependent upon the quality and quantity of influent into the sewage works from the industrial and domestic sources. The toxic substances, such as heavy metals in the industrial discharges, are of particular importance in this regard.

For determining the parameters and their maximum permissible concentrations, it is necessary to carry out more detailed investigations and these would be periodically reviewed/revised in accordance with the changes of local factors like industrial development, urbanisation and so on in the river basin.

For references, Tables 12.7.1 and 12.7.2, Section 12.7, Chapter 2, Supporting Report show the trade effluent standards and parameters related to the health, respectively, which were proposed in Nakuru Sewage Works Rehabilitation and Expansion Project (in Kenya).

In addition, discharge of the following materials into public sewers must be prohibited.

- Calcium carbide
- Chloroform
- Condensing water
- Degreasing solvent of mono-di-trichloroethylene type
- Volatile petroleum products
- Inflammable solvents (e.g., carbon disulphide or any other products which produce inflammable vapours in the sewer)
- Substances likely to interfere with the free flow in the sewers or to damage the sewers (refuse, glass, sand, solid waste, fibbers, leather, textiles, plastic, cement, calcium hydroxide, bitumen)
- Others

As to the charge system, it is related with the volume and strength of industrial wastewater which adversely affect the quality of treated effluent at STWs. The present charge system based on the volume and strength of the wastewater in terms of the Potassium Permanganate consumption (Permanganate Value: PV) should be upgraded by institutionalising its procedure.

To comply with the "trade effluent control by-laws" as proposed above, the following measures would become necessary for the industries or manufacturers which discharge large volume of effluent:

- Wastewater pre-treatment, and
- process modifications for reducing waste generation and reuse-recycling of effluents.

Pre-treatment requires financial investment, land for pre-treatment facilities and construction of facilities. It is therefore important to set its compliance date considering the time and money necessary for design and construction of pre-treatment facilities and other factors.

In conclusion, all the water quality standards mentioned above should be integrated into the proposed by-laws on trade effluent control.

4) Effluent irrigation and soil pollution

In recent years, the flow of polluted urban and industrial wastewater into agricultural water bodies gives rise to problems in terms of soil pollution, reduction of agricultural production and so on.

The main sources of such pollution stem from the practice of effluent irrigation, leakage from manufacturing process facilities and/or their unsuitable treatment of toxic substances, inappropriate disposal of wastes, reuse of the sedimented sludge, etc.

In order to deal with the problem of agricultural land pollution, special measures for dealing with land should be taken by establishing standards for cadmium, copper, arsenic and their compounds. To work out the measures to conserve the quality of agricultural water, it is necessary to conduct surveys so as to designate the polluted farmlands for clean-up operations.

With respect to pollution of farm soils, the system for removal of the pollutants from farmlands should be institutionalised in a clear-cut manner based on the principle of "polluter pays".

To deal with this problem, a new set of environmental quality standards should be established together with updating of the Public Health (Effluent) Regulations.

5) Areawide total pollutant load controls

For the lakes (Manyame & Chivero) and reservoirs (Seke and Harava dams) in the Study Area, particularly with significant pollution sources in the hinterland, the rates of achieving environmental quality standards are quite low, because the loads of pollutants are significant and pollutants trend to accumulate. In addition, the inflow of nitrogen, phosphorus and other chemicals leads to the progress of so called "eutrophication".

In the said lakes and reservoirs, the generation of blue-bloom and freshwater red tides is detected. To further strengthen the measures for conservation of the water quality in such closed waters, it is important to institutionalise the "areawide total water pollutant load controls" for overall reduction in the loads of pollutants lowing into waters.

6) Solid waste management

Apart from the City of Harare, most of the existing dumps are located on the outskirts of towns. Almost all the local authorities selected tipping sites arbitrarily and some sites are situated near water courses and thus pose a threat in terms of water pollution.

The only way to rectify such problem is to relocate dumps to areas with suitable soils or incorporate measures to trap leacheate. Regular monitoring of water quality should be carried out. On the other hand, when selecting sites for new landfills, it is important to take preventive action in order to control surface and ground water from entering into the landfill. To prevent leachate pollution of soil and ground water, measures should be taken in the construction of landfill to minimise the load of liquids in the waste and to divert run-offs from higher elevations.

It is also vital that the local authorities concerned establish units within their waste management sections whose task is specifically to monitor pollution levels at tipping sites and transfer stations.

Taking into consideration the present legal/institutional situations on solid waste management, it is urgent need to enact the national legislation prescribing the landfill management procedure and conduct the Environmental Impact Assessment (EIA) prior to locating a dump in a given area. In addition, the ordinances and regulations regarding littering and improper disposal of solid waste and penalties for violation should be formulated and responsibilities of enforcement agencies should be clearly delineated.

The above legal/institutional framework will be clarified by enactment of the "Environmental Management Act" which is under preparation by the Ministry of Environment and Tourism (MET) and the "National Waste Act" which is recommended to be established in the Study Report on Zimbabwe Urban Solid Waste Management (August 1995).

(3) Development of Surveillance and Monitoring Systems and Strengthening Enforcement

Due to the rapid urbanisation and industrialisation, water pollution is aggravating in the Study Area and this not only causes deterioration of the living environment, but also seems to lead to grave consequences for the health and lives of the people as we can see many examples in the developed countries.

In parallel with the development of the legal system, the main method of dealing with the problem is to institute controls (implementation and enforcement) over the polluters and/or pollutants' sources for water pollution. To be effective, direct regulation (surveillance and monitoring) requires a wide variety of sources. The regulatory agencies and authorities must be equipped with a well-trained staff, control & monitoring means including analytical equipment/apparatus and the necessary supporting resources to strengthen the surveillance and monitoring systems.

With regard to the surveillance and monitoring for water pollution control, the following provisions are to be stipulated/prescribed in the relevant laws, regulations and standards:

- Monitoring of pollutant loads, water quality, and trade effluents, and their respective frequencies at the designated points,
- Obligation of the factories and business establishments to prepare reports on effluent and their periodical submission to the local authority concerned,
- Implementation of their on-the-spot inspections (without previous notice),
- Issuance of orders for improvements and powers for prosecution of defaulters,
- Enforcement of penalties including imprisonment: penal regulations should be severe enough to deter polluting activities,

- Necessity to prepare detailed water management plans at local authority level, and
- Others.

To sum up, the setting and enforcement of laws & regulations and detailed standards are a legally and administratively complex task which is both time consuming and open to legal challenges from affected industries and institutions.

12.7.3 Policy Directions for Water Pollution Control

The main problems/constraints for water pollution control in the Study Area are addressed collectively in the four (4) areas. The following are key strategies for improving pollution control:

(1) Pollution control enforcement

- enforcement of penalties,
- supporting the manufacturers to install pollution control facilities,
- improvement of solid waste management system,
- implementation of an environmental impact assessment (EIA),
- strengthening of manpower development, and/or
- factories relocation.

(2) Water quality monitoring

- strengthening monitoring capacity,
- monitoring of water quality, and
- training for water pollution control/management

(3) Strengthening of water pollution control administration

- legal and institutional arrangements to align all government agencies and local authorities concerned in a committee or board which is mandated to deal with all issues about water pollution control,
- Improvement of fiscal administration, especially the revenue generation in local authorities concerned, and
- Human resources development at all administration levels and in every management area.

(4) Water pollution awareness

- promotion of education on water pollution control and public relations,
- strengthening of citizen's participation, and
- establishment of environmental information system to disseminate information such as preventive measures of water pollution at community level.

12.7.4 Proposed Management for Water Pollution Control

(1) Overall Management Framework

There is no solo organisational arrangement for water pollution control. Whatever structure is adopted, it must assure effective use of personnel and resources by all of the agencies involved - national, provincial, and local. An integrated approach involving all agencies is essential.

Figure 12.7.1 shows the proposed institutional set-up for water pollution control focusing on the Study Area.

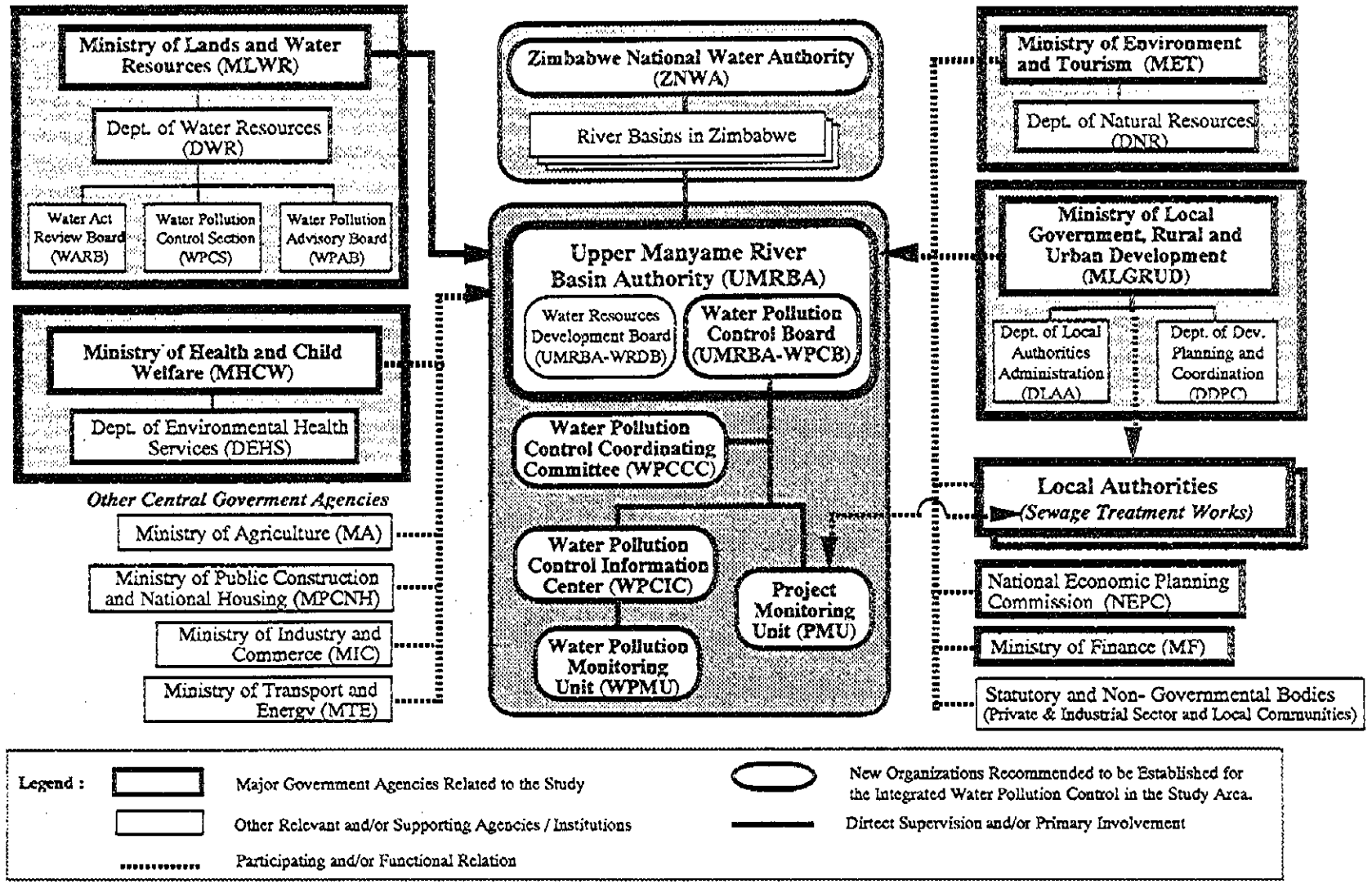


Figure 12.7.1 Proposed Institutional Set-up for Water Pollution Control in Zimbabwe
(Focusing on the Water Pollution in the Study Area)

The Upper Manyame River Basin Authority (UMRBA) may be established by the central government and be given sufficient powers to administer broad policies. The UMRBA shall consist of two (2) boards: 1) Water Resources Development Board and 2) Water Pollution Control Board.

Considering the optimal utilisation of water resources and integrated water pollution control in the upper Manyame river basin, it is essential to make keep close contacts among all agencies concerned, because their activities are inter-related and complementary.

The Water Pollution Control Board (WPCB) in question may be created by taking over the functions/tasks of the existing Water Pollution Advisory Board (WPAB) under the Department of Water Resources (DWR)/MLWR. However, the WPCB shall be made up of high-ranking individuals appointed from both within and outside the government and be chaired by the Minister of Lands and Water Resources (MLWR). The functions of this Board are:

- to formulate a basic policy on environmental management and water pollution control in the area;
- to review annual and multi-year projects/programmes;
- to supervise the implementation of the water pollution control projects/programmes;
- to promote institutional and financial capabilities in its management system; and
- to provide directive to the Water Pollution Control Co-ordinating Committee.

As an advisory executing arm of the Board, the "Water Pollution Control Co-ordinating Committee (WPCCC)" shall be established:

- to review annual working plan with budget allocation;
- to co-ordinate the overall water pollution control activities in the area, including the development projects;
- to review all water pollution issues in the area and prepare advisory matters for the WPCB.

As a core working office, the "Water Pollution Control Information Centre (WPCIC)" shall be established under the WPCB-WPCCC. The WPCIC shall play important roles in

implementing water pollution control projects. Main functions of WPCIC to be effected through WPCB-WPCCC are the following:

- to collect and store all the data and information necessary for implementation and management of water pollution control projects;
- to review and update the Master Plan prepared by JICA occasionally;
- to formulate the development projects and undertake their screening, co-ordination, monitoring and evaluation;
- identify fund sources for implementation of the projects; and
- integrate the above for submission to WPCB through WPCCC.

To ensure the collection of basic data/information for water pollution control, it is proposed to establish/strengthen the "Water Pollution Monitoring Unit (WPMU)" as a integral part of the WPCIC.

For implementation of a priority project, it is proposed to establish, under the Water Pollution Control Board (WPCB), a "Project Monitoring Unit (PMU)". The WPCB shall appoint the project manager of the PMU through the recommendation of the Water Pollution Control Co-ordinating Committee (WPCCC).

Besides, the organisational structures need to be sensitive to major and significant changes and flexible enough to make adjustments when the need arises.

(2) Management Structure for Implementing the Water Pollution Control Projects

In addition to establishment of the inter-agency organisation proposed for water pollution control in Study Area, it is a prerequisite to strengthen the organisation of the implementing agencies consisting of Ministry of Local Government, Rural and Urban Development (MLGRUD) and the local authority concerned for implementing the priority sewage project(s).

In the case that the programme or project has to be implemented in a number of local government areas and requires a good deal of co-ordination works, a "Project Co-ordination Unit (PCU)" will be established, as a task oriented office, under the supervision of its Department of Development Planning and Co-ordination (DDPC). Figure 12.7.2 shows the proposed structure for implementation of sewage projects.

At the local authority level, a "Project Co-ordination Committee (PCC)" shall be set up in the urban council concerned to manage/supervise the construction works of the sewage projects. Since both the central implementing agency and local authority are in shortage of the well experienced technical and financial experts, they may be hired on the contract basis from the consulting firms.

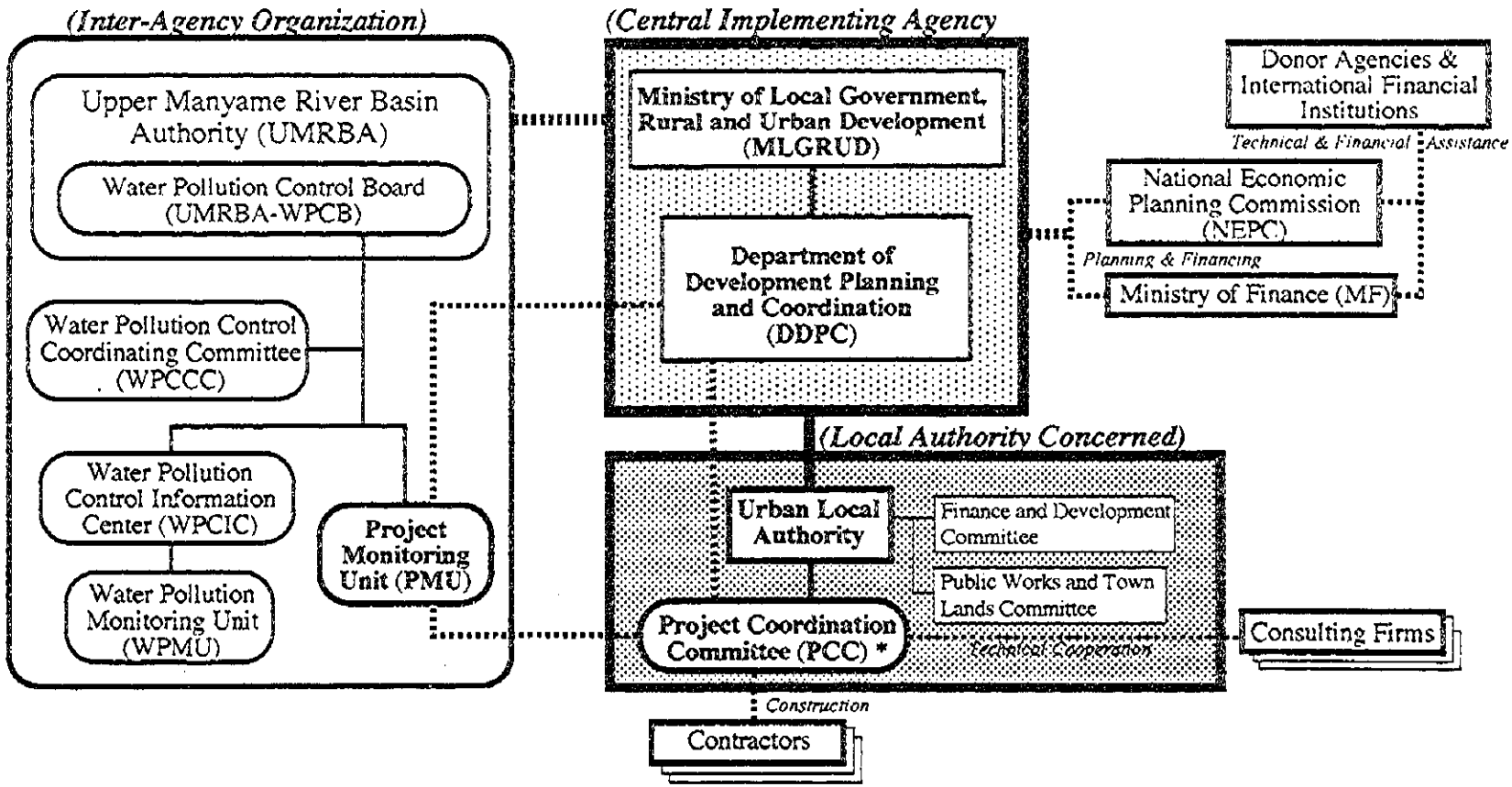
To ensure the smooth implementation of the projects, it is important to allocate enough budget to enable the agency and authority involved to employ the qualified capable personnel.

(3) Implementation of the Institutional Supporting Programme

To enable the Water Pollution Control Information Centre (WPCIC) to assume specific roles of water pollution control in the area, it is recommended to implement simultaneously an "Institutional Supporting Programme". The Programme comprises the following major components:

1) To assist the UMRBA-WPCIC activities and ensure the smooth implementation of the water pollution control projects, this programme shall entail a dispatch of an experienced development expert in the central office to the WPCIC for a period of five years.

2) Principal ministries/agencies (e.g. MLWR, MLGRUD, MET, MHCW, NEPC, MF) and institutions concerned shall assign/dispatch the experts in planning, implementing and managing the water pollution control projects to the WPCIC. They shall undertake the counterpart training.



Note : * Project Coordination Committee (PCC) consists of the representatives of Town Clerk, Director of Engineering Services Department, Director of Health Department, Municipal Treasurer and others.

Source : JICA Study Team

Figure 12.7.2 Proposed Structure for Implementation of the Priority Sewage Project

3) This program shall assist this decentralised management system for 10 years mainly by means of providing the salary of experts and certain local staffs and necessary equipment like personal computers and pollution examination instruments/kits.

4) To deal with a large volume of data and information, it is required to standardise the document formats as simple as possible, while the equipment and instruments for filing/keeping system shall be provided with appropriate instructions and procedures.

5) While the water pollution control in the river basin is a joint responsibility of the central and local governments, especially at the initial stage, its effectiveness and success will depend largely on their skills and resources. To realise the expected satisfactory results, it is vital to provide training seminars and workshops with a view to disseminate all water pollution related information to the interested people.

(4) Manpower Development

The shortage of adequately trained personnel at all levels of government has been a major obstacle in Zimbabwe. The problems in water pollution management are very complex, because their solution requires the multidisciplinary team approaches utilising several disciplines, i.e. engineering, biological sciences, chemistry, physical sciences, mathematics, operational research, systems analysis, financial analysis, economics, computer technology and its applications, social sciences, and others.

At all levels, it is essential to have highly-skilled professional capability, plus a comprehensive grasp of the water pollution control field. In addition, an adequate supporting technical and administrative staff is required. At the local level, since the staff constitute the direct providers of many services to the public, they must have expertise in establishing and maintaining those local services which have been delegated by the national and provincial governments.

Along with personnel resources, the organization shall also be provided with other needs, such as laboratories, field facilities and instrumentation.

Capability building also constitutes a very important element in the implementation of the water pollution control projects. To ensure the long-term success of the projects, it is important to strengthen the institutional capability of the authorities concerned.

To satisfy such requirements, the Zimbabwe Institute of Public Administration and Management (ZIPAM) was established in 1984 and this Institute has contributed, to a large extent, to enhance the institutional building of the country.

Since the capability of the local authority (such as Chitungwiza Municipal Council) to undertake the sewerage projects is still limited in every aspects, most of activities for project implementation shall necessarily be carried out through interagency co-ordination.

To ensure the smooth implementation of the projects, the following training programme should be carried out both for the administrative and technical personnel, particularly for the staff undertaking the operations & maintenance of the sewage treatment works and water quality monitoring. At all levels, it is essential to have highly-skilled professional capability, plus a comprehensive grasp of the water pollution control field.

For the officers in charge of the project management, it is advised to strengthen their managerial and administrative capabilities through :

1) Management trainings in ZIPAM and/or utilising the other available training programmes;
2) Seminars for the personnel concerned, by inviting the consultants and experts specialised in each field; and
3) Trainings in foreign countries (ex. under the project typed technical assistance).

The training programme shall include, but not be limited to :

- Financial and budget management for implementation of the sewerage project,

- Environmental health management,
- Environmental impact assessment appreciation,
- General strategies for water pollution control :
  - Legal and institutional framework for water pollution control and environmental management,
  - preventive measures for water pollution including direct regulation and economic incentives,
  - measures to be taken for pollution control enforcement (ex. procedure to set and enforce the regulatory standards and sanctions/penalties),
- General guidance on the sewerage project to be implemented prior to its construction (i.e. responsibilities, authorities, levels of activities of the local authority),
- Charge structure and sewerage tariff system,
- Charge collection system,
- Accounting and budgeting systems and their standardisation,
- Need to consider the recurrent costs in planning and budgeting, and
- Manpower development to assure the smooth operations and maintenance of the sewage treatment works.

To the staff directly engaging in the operation and maintenance of the sewage treatment works, the following training programmes shall be provided.

1) Training courses designed and offered by IWSD or a similar programme available in the other institutions,
2) Seminars and workshops for improvement of the operation and maintenance, and
3) Intensive training course on water quality monitoring.

The principal training courses which must be provided for the technical staff shall include, but no be limited to:

- Cost-effective management of the sewage treatment works,
- Operation and maintenance of the sewage treatment facilities,
- Procurement system of the materials and supplies necessary to maintain and repair the treatment facilities and equipment,
- Routine capital purchases: office machines, computers, major machinery, and similar items, and

- Preventive measures and cost-effective means to reduce water pollution,
- Monitoring system for water pollution control.

The approach to determining the training needs vary according to the educational background and occupational skills of each staff concerned, regulatory requirements and local circumstances. The manpower development programmes mentioned above are suitable for general guidance purposes, but decisions on final programmes and courses should be made on an individual case-by-case basis.

Consideration should be given to contracting with outside groups, such as local consulting or special services firms, to carry out specialised tasks of short duration and of a non-repetitive nature, especially at the initial stage. This may eliminate the need for acquiring costly specialised personnel on the staff for which there is no long-term use.

Finally, in the case that the project is to be implemented with the external source, it is advised to initiate communications with that source as early as possible, so as to gain not only technical assistance from the agency staffs, but also financial support in the form of grants or loans through a series of stages in the project cycle.

(5) Policy Guidelines

(Central Government Level)

1) Due to the Economic Reform Programme, the central government is obliged to reduce the external expenditure (or fiscal deficit) and not in a position to increase the number of its proper staff. Therefore, increase of their staff may be realised by hiring consultants when a specific project be implemented by establishing the task oriented office.

(Local Authority Level)

2) At the local level, the staffs constitute the direct providers of many services to the public. Hence, the staff must have expertise in establishing and maintaining those local services which have been delegated by the central government.

3) Authorities, responsibilities, levels of activities, and of relationships among the agencies charged with management of water pollution control shall change constantly. The organisational structures need to be sensitive to major and significant changes and flexible enough to make adjustments when the need arises.

4) Frequent retraining and upgrading of skills are essential to maintain an efficient work force.

5) Expeditious decision making should be facilitated through the streaming of the organisational structures and holding of regular meetings with the staff in charge.

6) Local authorities should standardise their accounting and budgeting systems so that they are comparable. In parallel with this, it is important to formulate rules and regulations necessary for standardised accounts and budgets.

(Sewage Treatment Works)

7) Sewage treatment services can be made more efficient through proper operation and management, and training of manpower.

The Director of Engineering Department or Manager of Sewerage Branch undertakes the overall control of the sewage treatment works. The absence of a sub-management level structure and the general lack of trained professionals give the above director and manager the extensive responsibilities.

Overall divisional or sectional performance could be enhanced by modifying the management structure so that there is a shift in some of the responsibilities to a sub-management level.

8) Mainly due to financial constraints, the sewage treatment works (STWs) in the urban local authorities concerned can not assign enough number of personnel. In case of Zengeza STW, the plant is operated with about 60% (65 persons) of the total required staff number (110 persons) (refer to Appendix 3.1).

It is therefore recommended to improve the authority's capabilities, especially to plan and finance the projects. This will enable more accurate perspective of future development of the facilities and manpower requirements.

(6) Alternative Ways of Management of the Sewage Treatment Works

Due to the adoption of the economic structural adjustment programme, local authorities had a pressure to commercialise their activities, including water supply, sewerage and solid waste management. In order to be self-sufficient, local authorities need to charge commercial/progressive rates for these services.

Commercialisation (or privatisation) has several forms. There are at least the following four (4) types of contractual arrangements through which the private sector can participate in municipal sewage treatment and its management.

1) Service Contract
   - Fairly limited in scope and covers a specific activity such as maintenance of the facilities/equipment and training

2) Management Contract
   - Usually covers the full range of operations
   - The local authority bears the full commercial risk

3) Lease Contract
   - Commercial risks are shifted to the contractor
   - Private firm rents facilities from the public authority which remains responsible for investments
   - the lessee finance only working capital for operation and maintenance

4) Concessions
   - All commercial risks are shifted to the contractor

An important consideration in the decision to privatise or contract out the sewage treatment activities and its management (partially or totally) is the local authority's ability to develop a competitive environment so that no single company dominates its privatised services.

Several economic and social issues need to be addressed in the decision to privatise sewage treatment activities and its management. These issues relate to how privatisation will impact efficiency, ownership of the plant, labour, cost recovery, and environmental concerns. Possible disadvantages of privatisation are mainly concerned with potential loss of control on the part of the public agency (local authorities).

In conclusion, privatisation is not a general panacea for financial problem. In the urban local authorities concerned, it is possible that partial privatisation of the sewage treatment services will be introduced up to the year 2015. The principal issues which should be addressed in such agreement include :

1) level of service, especially with regard to reliability, safety, public health risks, and future expansions;
2) future increases in costs resulting from factors which cannot initially be fully determined;
3) environmental concerns (aesthetics, noise, and odour);
4) future transfer of ownership of the facilities;
5) resolution of disagreements between the parties; and
6) utilisation of future financial assistance which might become available from outside sources.

12.8 Monitoring and Feedback System for Water Pollution Control

12.8.1 General Improvement Needs

(1) Review of Water Act

The whole water pollution control sector needs to be reviewed. The pollution control programmes have tended to be rigidly sectoral but there is a need for a more intersectoral and participatory approach so as to achieve coordination.

The Acts controlling water pollution have been in operation for a long time and are now out dated. The fines in all the Acts (Water Act, Urban Council's Act, Health Act, etc.) are now too low and the polluters find it cheaper to pay the fine and continue polluting.

The Acts are being revised to match the present day conditions. For example the part in the Water Act dealing with pollution is being reviewed. The revisions are as follows:

- remove the specific fines laid down for polluting public or private water, so that the Water-Pollution Advisory Board can review these sums from time to time to allow for inflation.

- relate fines to the type of pollutant being discharged, and link them to the average profits made by the offender in the process of polluting

- give the pollution control officers powers to issue tickets to offenders, especially for less serious/uncomplicated types of pollution, such as discharges of oil from both registered and unregistered garages

- make it a legal requirement for polluters to pay for cleaning up the environmental degradation resulting from their activities. The cleaning of the environment should be demanded in addition to a fine.

- stipulate that anyone discharging into a water course must keep a record of the quality of both the effluent and the receiving water

These changes will help develop a fair and effective system of penalties and incentives which will encourage sustainable development and focus the burden on the polluter.

The number of Water Pollution Control personnel in the sector Agencies are too few for the job. There are only established posts for water pollution control officers in the Department of Water Resources to cover the whole country, compared with 6 inspectors in the City of Harare's Trade Waste Inspectorate.

The prosecution route is very circuitous and slow. At times it is slowed down by the Attorney General: after the water pollution control officers have done all they can to solve the problem with the offender, the Attorney General gives the offender another grace period. At times the Attorney General does not appear to regard even major long-term pollution as a serious offense.

(2) Review of Sampling Points and Water Quality Indices

The sampling stations along the rivers need to be re-registered because much development has occurred since they were established and some which were baseline stations now serve as trend stations. New stations need to be introduced and some old stations should be removed.

The selection of sampling points is crucial to the monitoring program. The sites should be representative of the water body, and provide accurate information about changes in water quality. There are several types of sampling points that are being used in the natural water quality monitoring programs, as shown below:

- Baseline stations are typically located in the headwater of lakes or undisturbed, upstream river stretches. Baseline stations establish the natural water quality conditions, provide a basis for comparison with stations which experience significant and direct human impact (represented by trend and global flux stations), and test for the influence of the long-range transport of contaminants and the effects of climatic change.

- Trend stations are typically located in major river basins, large lakes, or major aquifers. They test for long-term changes in water quality, and provide a basis for

statistical identification of the possible causes of measured conditions or identical trends.

The sampling points should be determined taking into account of the current and future water uses, the location and number of existing monitoring stations for water quality and flow rate. Proposed sampling points are shown in Figure 12.8.1.

Water quality indices for water quality examination should be considered taking into account environmental water quality standard. Recommended water quality indices are shown in Table 12.8.1.

Table 12.8.1 Recommended Water Quality Indices for Water Bodies

Type	Point Number	Items	Frequency	Water Quality Indices
Baseline Station	CR1, CR2	Environmental Items	one time a month	Temp., pH, BOD, SS, DO, T-N, T-P, Coliform group
		Health Related Items	two times a year	Arsenic, Cadmium, Chromium, Cyanide, Lead, Mercury, Selenium, Carbon tetracholoride, 1,2-dichloroethane, 1,1-dichloroethylene, Dichloromethane, Cis-1,2-dichloroethylene, Tetrachloroethlene, Trichloroethiene, Benzene, 1,3-diehloropropene
	RR6, RR7	Environmental Items	one time a month	Temp., pH, BOD, SS, DO, T-N, T-P, Coliform group
Trend Station	CL1, CL2, CL3	Environmental Items	one time a month	Temp., pH, COD_{Mn}, SS, DO, T-N, T-P, Coliform group
		Health Related Items	two times a year	Arsenic, Cadmium, Chromium, Cyanide, Lead, Mercury, Selenium, Carbon tetracholoride, 1,2-dichloroethane, 1,1-dichloroethylene, Dichloromethane, Cis-1,2-dichloroethylene, Tetrachloroethlene, Trichloroethiene, Benzene, 1,3-diehloropropene
	RR1, RR2, RR3, RR4, RR5	Environmental Items	one time a month	Temp., pH, BOD, SS, DO, T-N, T-P, Coliform group

12.8.2 National Agencies

The national agencies which deal with water pollution are scattered in various ministries and institutions. Combining all these sector agencies into one environmental unit would be a mammoth task and in many instances counter productive, since most of the agencies operate optimally within the system of the sector ministries.

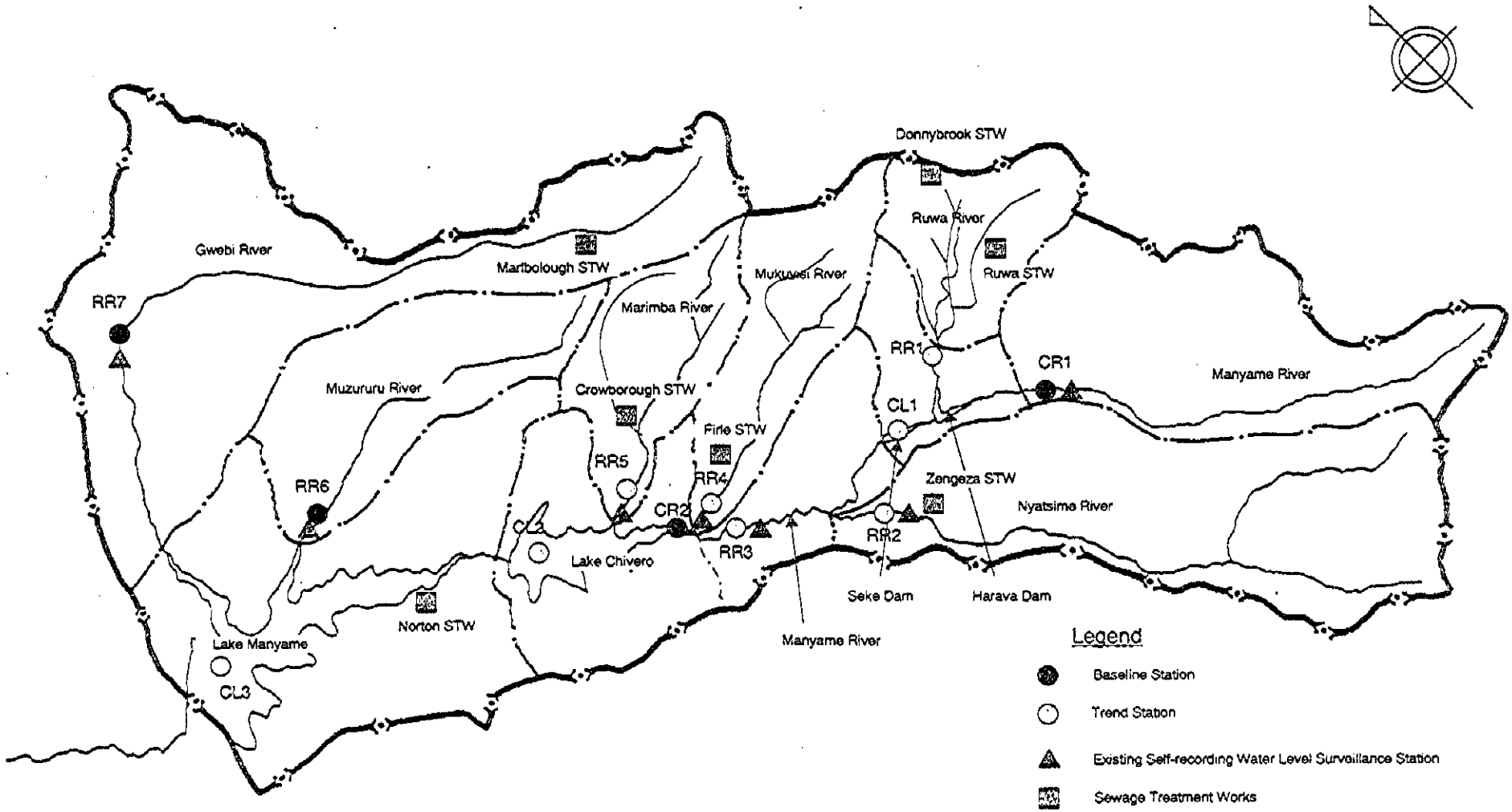


Figure 12.8.1 The Proposed Sampling Points in the Water Bodies

However, a more unified approach to water pollution control is required and the best way would be to have a framework of environmental legislation administered by a body responsible for the co-ordination of the activities of the agencies in their respect sector ministries. This will achieve greater coordination of efforts and resources will no longer be wasted.

A unified approach will remove the duplication of the efforts of the sampling stations as well, since one set can be used and a national data base created with laid down feedback systems for all involved.

In future it is hoped to undertake the following:

- Expand the water quality monitoring programme to include lakes, dams and/or reservoirs.

- Carry out a further study on the eutrophicaion of the Lake Chivero which supplies Harare's potable water, and the effect of the water hyacinth and Cyanobacteria (blue-green algae).

- Investigate the toxins produced by algae in the Lake Chivero.

- Investigate the best way to monitor and control non-point-source pollution from stormwater run-off and farming activities; investigate nutrient enrichment introduced by irrigation seepage water, run-off water from fields, livestock feedlots and erosion.

- Improve the current limited ability to carry out the Environmental Impact Assessment studies for new and established projects.

12.8.3 Local Authorities

In addition to the above, an assessment of the local authorities in the study area covers the following observations:

- As to the assignment of concerned agencies for water quality monitoring, basically the public water body should be monitored by DWD (MLWR) and effluent discharge from the sewage treatment plants and factories which are major pollution sources should be monitored by the City of Harare and other local authorities.

- Introduction of a registration system for the pretreatmet facilities located at industrial/commercial sites which will built in the future.

- The Urban Councils Act needs reviewing. The City of Harare has only six inspectors to man the whole of Harare and this is causing many industries to operate unchecked.

- There is uncoordinated control of development and many industries are being established where they should not be.

- There is no co-ordination between the City Health Department and the Trade Waste Inspectorate which is needed to present a common front in combating water pollution.

- The sampling along rivers and at manholes (once in 2 months) is not adequate and it is recommended that auto-samplers be installed. This will also mean the automation of the laboratory.

- Funds available for the work of the Inspectorate are limited and should be increased.
- A proper data base, possibly linked with other institutions needs to be created.
- The City of Harare should be able to carry out the Environmental Impact Assessments and Audits.

12.9 Community Involvement

According to the long-term development strategies envisaged by the "Zimbabwe Vision 2020", every communities and individuals are expected to be empowered, so that they can play a significant role in the socio-economic development, especially in its control process.

In order to ensure the sustainable development of the country, there is a need for the government to establish enabling legal and policy frameworks to facilitate community involvement in natural resources management. To this end, it is required to make a national consensus on the importance of the involvement of local communities at all stages of conservation and development programmes/projects.

As a first step, public participation in the development, revision, and enforcement of regulations, standards, effluent limitations, planning, and programming needs to be provided for and encouraged by specific authorisation in the law.

In parallel with introduction of the legal counter-measures, it is vital to awake or make realise the people about the importance of water pollution control in order to secure their sanitary living environment. Improving living environment in urban areas is increasingly important as the urbaniszation proceeds rapidly in the Study Area.

As one of the components of the "Institutional Supporting Programme" suggested to be implemented in Section 12.7.4 (2), the proposed "Water Pollution Control Information centre (WPCIC)" shall undertake, together with the local authorities, the dissemination of water pollution related information to the private & industrial sector and the public as well.

To materialize the people's participation in water pollution control process throughout all the stages of project implementation: regulation, planning, construction, O&M and monitoring, it is a prerequisite to establish and strengthen the said "Water Pollution Control Information centre (WPCIC)" which is, as one of its functions, designated to play a role as "communication centre" for networking the sewage treatment works (or local authorities concerned), private & industrial sector and the public.

On the other hand, for the purpose of information dissemination on water pollution control, it is vital to accelerate the "community development" to enable organise people's participation in the environmental management. To facilitate the communication between government agencies, communities and the private & industrial sector, an information network should be established by the WPCIC initiative. All information disseminated through this network will contribute, to a large extent, to the mitigation of water pollution control.

Effective means of communication vary depending on the kind of information and entities involved. Face-to-face communications and seminar/workshop will be effective for people/community levels. For a wider communication, radio may be most effective as most of households in the Study area already own radios. A mobile communication system with TV and video would offer another effective tool for the central government and local authorities to disseminate various messages.

Since the Study Area covers the most developed area (the capital, City of Harare) and its surrounding regions in the upper Manyame river basins, it has major assets for environmental education as described in Section 3.1.5.

To realize the expected satisfactory results in water pollution control, the WPCIC and sewage treatment works (local authorities) should provide training seminars and workshops to disseminate all water pollution related information to the interested people, especially such as:

- rational use of scare water resources,
- relation between water pollution and health,
- preventive measures of water pollution,
- monitoring system for water pollution control,
- roles/functions of central government and local authorities and their involvement in water pollution control,
- measures to be taken for pollution control enforcement,
- sewerage tariff structure and system,
- significance of sewerage charge payment, and
- need to consider the recurrent costs in planning and budgeting.

In addition to the above, incentive measures shall also be considered to the co-ordinated effective community activities in water pollution control and for the higher rate of charge collection.