b. Pollution load substances settled during dry season is flushed out during rainy season.

c. Some extent of pollution load reduction ratio is assumed in the calculation before reaching to rivers. It may be regarded that inaccuracy of assumptions of those reduction ratios are adjusted in the calculation of self-purification coefficients of lakes.

Using these pollution load and the water balance, pollution load run-off models for present pollution analysis of lakes were formulated as presented in Figures 9.4.3 to 9.4.5 for COD, T-N and T-P, respectively (refer to details in Figure 9.4.2 to 9.4.4, Section 9.4, Chapter 2, Supporting Report).

9.5 Present Water Pollution Analysis

9.5.1 General

In the pollution analysis of rivers, pollution load remaining ratios of respective rivers were identified in terms of BOD_5 under the condition of dry season. These ratios were adopted in future pollution analysis. While, for pollution analysis of lakes, Self-purification Coefficients (Vollenweider Model) of respective lakes were computed in terms of T-N, T-P and COD under the annual average condition. These coefficients were also adopted in future pollution analysis.

9.5.2 Rivers

The self-purification coefficient of river is usually computed in the similar pollution analysis to express the self-purification capacity of rivers referring to pollution load discharge location (refer to Figure 9.2.1 and Section 9.5, Chapter 2, Supporting Report). However, sufficient data on time of flow, flow rate and water quality for each sub-section of rivers are essential for the analysis. Because of the lack of these data in the study area and limited period for the study, pollution load remaining ratios of each river section were roughly computed.

Pollution load remaining ratios of respective rivers were computed using pollution load run-off model as presented in Table 9.5.1. Muzururu River shows comparatively high self-purification capacity, i.e. 6% of pollution load remaining ratios, while Manyame River (downstream) and Marimba River show rather low self-purification capacity, i.e. 36% and 32%, respectively.

These remaining ratios imply not only self-purification capacity of the river, but also adjustment factor on assumptions of concentration ratios and generated pollution loads. Pollution load remaining ratios for the application to future pollution analysis were modified as presented in Table 9.5.2.

Table 9.5.2 Pollution Load Remaining Ratio of Rivers

River	Calculated PLRR	Applied
Manyame R. (upstream)	18.6%	20%
Ruwa R.	17.4%	20%
Nyatsime R.	29.3%	30%
Mukuvisi R.	18.6%	20%
Manyame R. (downstream)	35.9%	35%
Marimba R.	31.5%	30%
Muzururu R.	6.0%	10%
Gwebi R.	21.7%	20%

9.5.3 Lakes/Dams

Based on the pollution load run-off models presented in Figures 9.4.3 to 9.4.5, self-purification coefficients of lakes for each pollutant were computed as presented in Tables 9.5.3 to 9.5.5. Calculation results are summarised in Table 9.5.6. These values were adopted for future pollution analysis of lakes.

Table 9.5.6 Self-purification Coefficients of Lakes

Coefficients*	Seke & Harava Dams	Lake Chivero	Lake Manyame
σN	0.18797	0.04270	0.01151
σP	0.20574	0.00868	0.02769
σCOD	0.07551	0.00908	0.00440
$\alpha(N)$	82.5%	100.2%	42.9%

*: Self-purification coefficients in following formula (refer to Tables 9.5.3 to 9.5.5);

$N = L(N) / ((\rho w + \sigma N) \times V)$

$P = L(P) / ((\rho w + \sigma P) \times V)$

$COD = L(COD) / ((\rho w + \sigma COD) \times V) + \Delta COD$

$\Delta COD = \alpha(N) \times T\text{-}N \times 17.73$

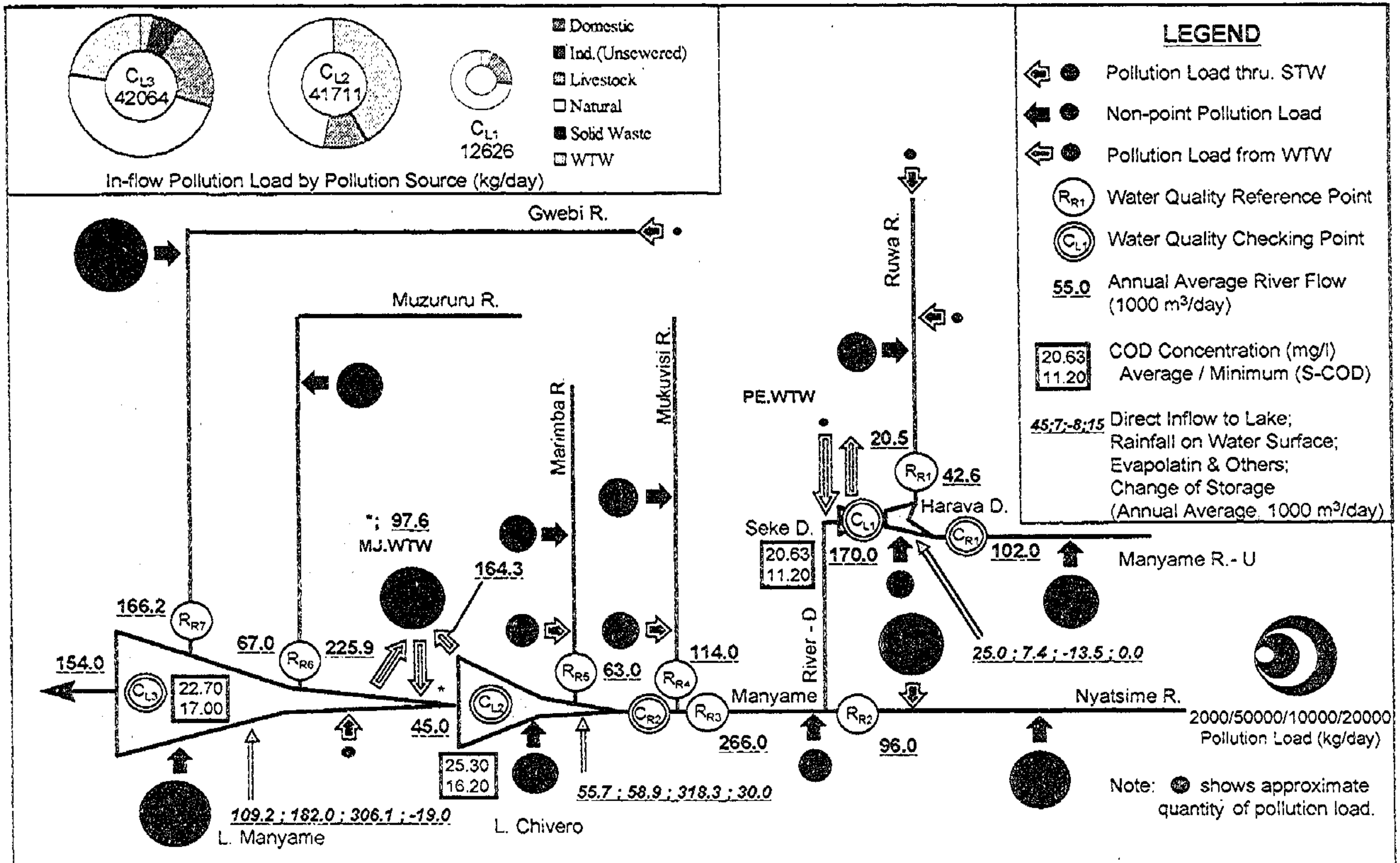

Figure 9.4.3 Pollution Load Run-off Model for Present Water Pollution Analysis (COD)

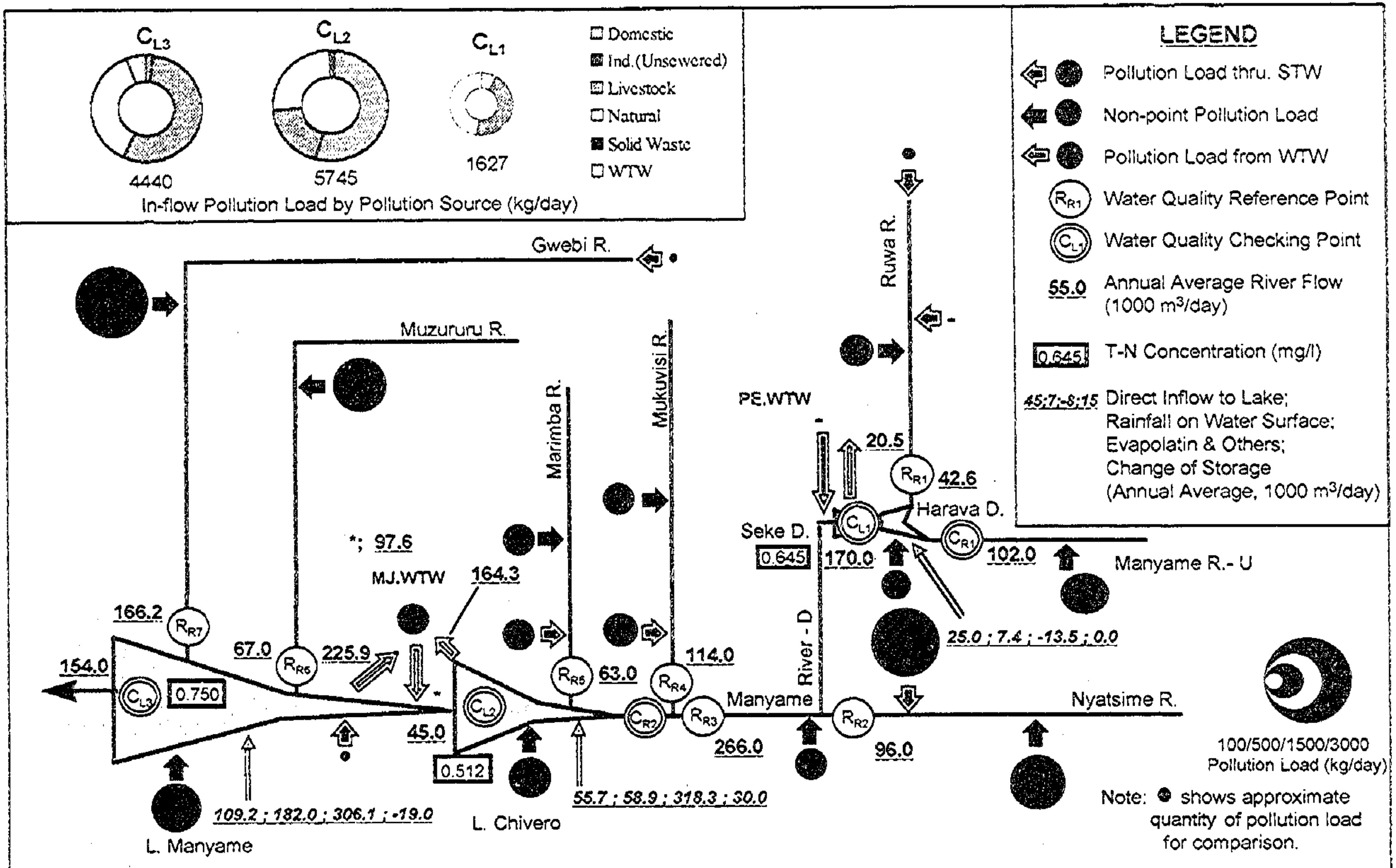

Figure 9.4.4 Pollution Load Run-off Model for Present Water Pollution Analysis (T-N)

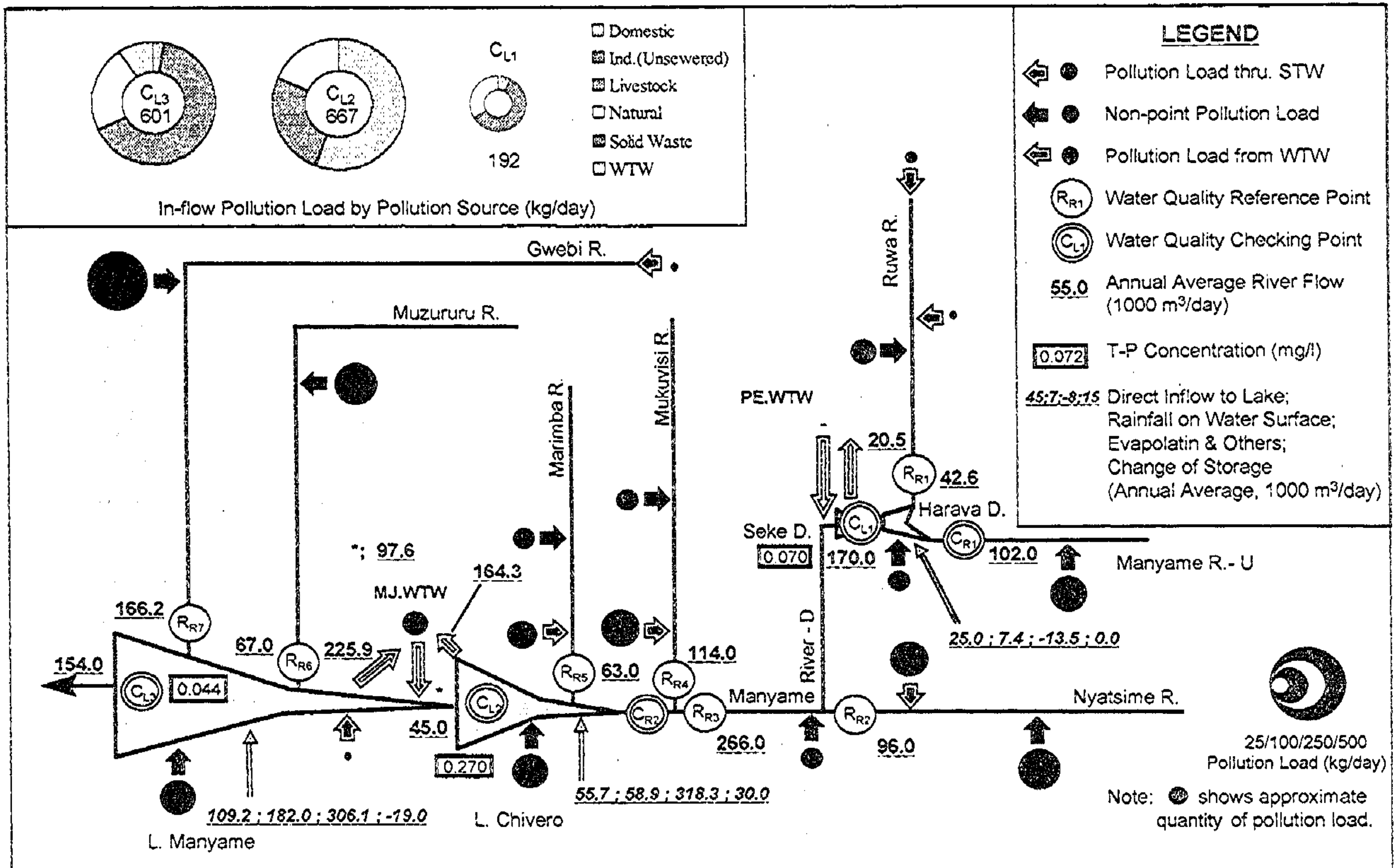

Figure 9.4.5 Pollution Load Run-off Model for Present Water Pollution Analysis (T-P)

Table 9.5.1 Pollution Load Remaining Ratio of Rivers (Present, BOD, Dry Season)

Water Quality Checking Points	Sub-basin	Run-off BOD Load at Upstream (kg/day)	Concentrated BOD Load in Sub-basin (kg/day)	Total BOD Load (kg/day)	BOD Concentration at Downstream (mg/l)	Flow Rate at Downstream (m3/day)	Run-off BOD Load at Downstream (kg/day)	Pollution Load Remaining Ratio (%)
C_{R1}	1. Manyame R. (Upstream)	0	183	183	1.1	31,000	34	18.6%
R_{R1}	2. Ruwa River	0	297	297	3.8	13,600	52	17.4%
C_{L1}	3. Seke & Harava Dams	86	77	163	1.6	40,000	64	-
R_{R2}	4. Nyatsime River	0	243	243	2.1	33,900	71	29.3%
R_{R4}	5. Mukuvisi River	0	581	581	2.0	54,000	108	18.6%
C_{R2} R_{R3}*	6. Manyame R. (Downstream)	135	71	206	1.0	73,900	74	35.9%
R_{R5}	7. Marimba River	0	580	580	8.7	21,000	183	31.5%
C_{L2}	8. Lake Chivero	365	968	1,333	2.4	16,000	39	-
R_{R6}	9. Muzururu River	0	167	167	0.5	20,000	10	6.0%
R_{R7}	10. Gwebi River	0	369	369	1.6	50,200	80	21.7%
C_{L3}	11. Lake Manyame	129	1,146	1,275	2.0	211,000	413	-

Note: 1. Before confluence of Mukuvisi River.

2. Run-off BOD load at upstream for the Manyame River (downstream) is the pollution load from Prince Edward WTW.

3. Total BOD Load of Manyame River (downstream) includes Run-off Load from Nyatsime River.

Table 9.5.3 Water Pollution Analysis of Lakes (Present, Seke and Harava Dams)

Volume of Dams:		12,406,000		m3
Inflow Water Volume:		190,500		m3/day
Rivers;	Manyame;		102,000	m3/day
	Ruwa;		42,600	m3/day
Direct Inflow;			25,000	m3/day
Rainfall;			7,400	m3/day
Evaporation & Others;			13,500	m3/day
Outflow Water Volume:		190,500		m3/day
Manyame River;			170,000	m3/day
Prince Edward WTW;			20,500	m3/day

Detention Time of Dam Lake: 65.1 days

Pollution Load Inflow: (kg/day)

	T-N	T-P	COD
Manyame	874	101	7,102
Ruwa	471	57	3,536
Direct	282	34	1,988
Total	1,627	192	12,626

Present Water Quality: (mg/l)

T-N	T-P	COD	Min. COD (soluble COD)
0.645	0.070	20.63	11.20

Formula for Pollution Analysis: (Vollenweider Model)

N = L(N) / ((rw+sN) x V)

P = L(P) / ((rw+sP) x V)

COD = L(COD) / ((rw+sCOD) x V) + DCOD

where;			
N:	Concentration of Nitrogen of lake (g/m3)	=	0.645
P:	Concentration of Phosphorus of lake (g/m3)	=	0.070
COD:	Concentration of COD of lake (g/m3)	=	20.63
L(N):	Quantity of inflow Nitrogen to lake (g/day)	=	1,627,000
L(P):	Quantity of inflow Phosphorus to lake (g/day)	=	192,000
L(COD):	Quantity of inflow COD to lake (g/day)	=	12,626,000
rw:	Rate of change of water (1/day)	=	0.015355
sN:	Self-purification (reduction) coefficient for Nitrogen		
sP:	Self-purification (reduction) coefficient for Phosphorus		
sCOD:	Self-purification (reduction) coefficient for inflow COD		
V:	Volume of lake (m3)	=	12,406,000
DCOD:	Secondary produced COD		

Computation of Self-purification Coefficients:

sN = (L(N) / (N x V)) - rw = 0.18797

sP = (L(P) / (P x V)) - rw = 0.20574

sCOD = (L(COD) / (COD x V)) - rw = 0.07551 (adopted Min.COD)

Computation of Conversion Rate for DCOD:

DCOD = a(N) x T-N x 17.73 or a(P) x T-P x 128.70

where;	
a(N);	Conversion rate of Nitrogen to DCOD
17.73;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity
a(P);	Conversion rate of Phosphorus to DCOD
128.70;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit phosphorus quantity
DCOD;	Average COD - Minimum COD (COD without effect of phytoplankton)

a(N) = ((COD - Min.COD) / (T-N x 17.73))
= 82.5%

a(P) = ((COD - Min.COD) / (T-P x 128.70))
= 104.7%

N / P = 9.2 < 20 and P = 0.07 >0.02

Nitrogen is regarded to be the Restriction Factor for secondary production of COD.
Conversion Rate of a(N) will be adopted for Future Pollution Analysis.

Table 9.5.4 Water Pollution Analysis of Lakes (Present, Lake Chivero)

Volume of Dams:		257,181,000		m3
Inflow Water Volume:		239,300		m3/day
Rivers;	Manyame;		266,000	m3/day
	Mukuvisi;		114,000	m3/day
	Marimba;		63,000	m3/day
Direct Inflow;			55,700	m3/day
Rainfall;			58,900	m3/day
Evaporation & Others;			(318,300)	m3/day
Outflow Water Volume:		239,300		m3/day
Lake Manyame;			45,000	m3/day
Morton Jaffray WTW;			164,300	m3/day
Water Level Increase:			30,000	m3/day

Detention Time of Lake: 1,075 days

Pollution Load Inflow: (kg/day)

	T-N	T-P	COD	
Manyame	3,807	325	25,120	Seke + Nyatsime + Manyame
Mukuvisi	669	144	5,906	
Marimba	546	95	5,122	
Direct;	723	102	5,564	
Total	5,745	667	41,711	

Present Water Quality: (mg/l)

T-N	T-P	COD	Min. COD (soluble COD)
0.512	0.270	25.30	16.20

Formula for Pollution Analysis: (Vollenweider Model)

N = L(N) / ((rw+sN) x V)

P = L(P) / ((rw+sP) x V)

COD = L(COD) / ((rw+sCOD) x V) + DCOD

where;				
	N:	Concentration of Nitrogen of lake (g/m3)	=	0.512
	P:	Concentration of Phosphorus of lake (g/m3)	=	0.270
	COD:	Concentration of COD of lake (g/m3)	=	25.30
	L(N):	Quantity of inflow Nitrogen to lake (g/day)	=	5,745,000
	L(P):	Quantity of inflow Phosphorus to lake (g/day)	=	667,000
	L(COD):	Quantity of inflow COD to lake (g/day)	=	41,711,000
	rw:	Rate of change of water (1/day)	=	0.000930
	sN:	Self-purification (reduction) coefficient for Nitrogen		
	sP:	Self-purification (reduction) coefficient for Phosphorus		
	sCOD:	Self-purification (reduction) coefficient for inflow COD		
	V:	Volume of lake (m3)	=	257,181,000
	DCOD:	Secondary production COD		

Computation of Self-purification Coefficients:

sN = (L(N) / (N x V)) - rw = **0.04270**

sP = (L(P) / (P x V)) - rw = **0.00868**

sCOD = (L(COD) / (COD x V)) - rw = **0.00908** (adopted Min.COD)

Computation of Conversion Rate for DCOD:

DCOD = a(N) x T-N x 17.73 or a(P) x T-P x 128.70

where;		
	a(N);	Conversion rate of Nitrogen to DCOD
	17.73;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity
	a(P);	Conversion rate of Phosphorus to DCOD
	128.70;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit phosphorus quantity
	DCOD;	Average COD - Minimum COD (COD without effect of phytoplankton)

a(N) = ((COD - Min.COD) / (T-N x 17.73))
= **100.2%**

a(P) = ((COD - Min.COD) / (T-P x 128.70))
= 26.2%

N / P = 1.9 < 20 and P = 0.27 >0.02

Nitrogen is regarded to be the Restriction Factor for secondary production of COD.

Conversion Rate of a(N) will be adopted for Future Pollution Analysis.

Table 9.5.5 Water Pollution Analysis of Lakes (Present, Lake Manyame)

Volume of Lake:	480,236,000		m3
Inflow Water Volume:	360,900		m3/day
Rivers; Lake Chivero;		45,000	m3/day
Muzururu		67,000	m3/day
Gwebi		166,200	m3/day
Direct Inflow;		109,200	m3/day
Rainfall;		182,000	m3/day
Evaporation & Others;		(306,100)	m3/day
Morton Jaffray WTW;		97,600	m3/day
Outflow Water Volume:	360,900		m3/day
Manyame River;		154,000	m3/day
Morton Jaffray WTW;		225,900	m3/day
Water Level Decrease:		(19,000)	m3/day
Detention Time of Lake:	1,331		days

Pollution Load Inflow: (kg/day)

	T-N	T-P	COD
Lake Chivero;	23	12	1,139
Muzururu	1,022	139	6,228
Gwebi	2,199	291	14,296
Direct;	1,196	159	20,402
Total	4,417	601	42,064

Present Water Quality: (mg/l)

T-N	T-P	COD	Min. COD (soluble COD)
0.750	0.044	22.70	17.00

Formula for Pollution Analysis: (Vollenweider Model)

$N = L(N) / ((rw+sN) \times V)$

$P = L(P) / ((rw+sP) \times V)$

$COD = L(COD) / ((rw+sCOD) \times V) + DCOD$

where;

N:	Concentration of Nitrogen of lake (g/m3)	=	0.750
P:	Concentration of Phosphorus of lake (g/m3)	=	0.044
COD:	Concentration of COD of lake (g/m3)	=	22.70
L(N):	Quantity of inflow Nitrogen to lake (g/day)	=	4,417,000
L(P):	Quantity of inflow Phosphorus to lake (g/day)	=	601,000
L(COD):	Quantity of inflow COD to lake (g/day)	=	42,064,000
rw:	Rate of change of water (1/day)	=	0.000752
sN:	Self-purification (reduction) coefficient for Nitrogen		
sP:	Self-purification (reduction) coefficient for Phosphorus		
sCOD:	Self-purification (reduction) coefficient for inflow COD		
V:	Volume of lake (m3)	=	480,236,000
DCOD:	Secondary production COD		

Computation of Self-purification Coefficients:

$sN = (L(N) / (N \times V)) - rw =$ 0.01151

$sP = (L(P) / (P \times V)) - rw =$ 0.02769

$sCOD = (L(COD) / (COD \times V)) - rw =$ 0.00440 (adopted Min.COD)

Computation of Conversion Rate for DCOD:

$DCOD = a(N) \times T\text{-}N \times 17.73$ or $a(P) \times T\text{-}P \times 128.70$

where;

a(N);	Conversion rate of Nitrogen to DCOD
17.73;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity
a(P);	Conversion rate of Phosphorus to DCOD
128.70;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit phosphorus quantity
DCOD;	Average COD - Minimum COD (COD without effect of phytoplankton)

$a(N) = ((COD - Min.COD) / (T\text{-}N \times 17.73))$

= 42.9%

$a(P) = ((COD - Min.COD) / (T\text{-}P \times 128.70))$

= 100.7%

N / P = 17.0 < 20 and P = 0.04 >0.02

Nitrogen is regarded to be the Restriction Factor for secondary production of COD.

Conversion Rate of a(N) will be adopted for Future Pollution Analysis.

CHAPTER 10

FUTURE WATER POLLUTION ANALYSIS

CHAPTER10 FUTURE WATER POLLUTION ANALYSIS

10.1 General

Future water pollution analysis was undertaken to predict the water quality at water quality checking points using a simulation model established through the present water pollution analysis. Flow diagrams for future water pollution analysis of rivers and lakes are presented in Figures 9.1.1 and 9.1.2, respectively.

Water pollution loads cover both human and natural pollution loads generated by point and non-point sources. Flow model of entire study basin for future water pollution analysis was established using daily average flow rate during last 10 years as discussed in the sub-section 7.2. Since population projection was conducted in two scenarios, future water pollution analysis was carried out for each scenario. The adopted flow models for each scenario are illustrated in Figures 10.1.1 to 10.1.4.

The projection of water quality is usually conducted assuming the condition without any countermeasures for pollution load reduction. In this study, however, development of two sewage treatment works was assumed for future pollution analysis, confirming with the local authority that they have high possibility to be implemented in the future. In addition, augmentation of the existing sewerage systems in application of BNR process was assumed.

10.2 Frame Values and Pollution Load by Sub-basin

10.2.1 Domestic/Commercial/Institutional Sewage

The population in the years 2005 and 2015 projected in sub-section 6.2 were distributed to sewered and unsewered areas for two scenarios as shown in Tables 10.2.1 to 10.2.2, respectively. Wastewater quantities by sub-basin were calculated for each scenario as summarised in Tables 10.2.3 to 10.2.4. Generated and discharged pollution loads were calculated by sewered/unsewered area applying unit pollution load of domestic sewage discussed in sub-section 8.2 (refer to Section 10.2, Chapter 2, Supporting Report).

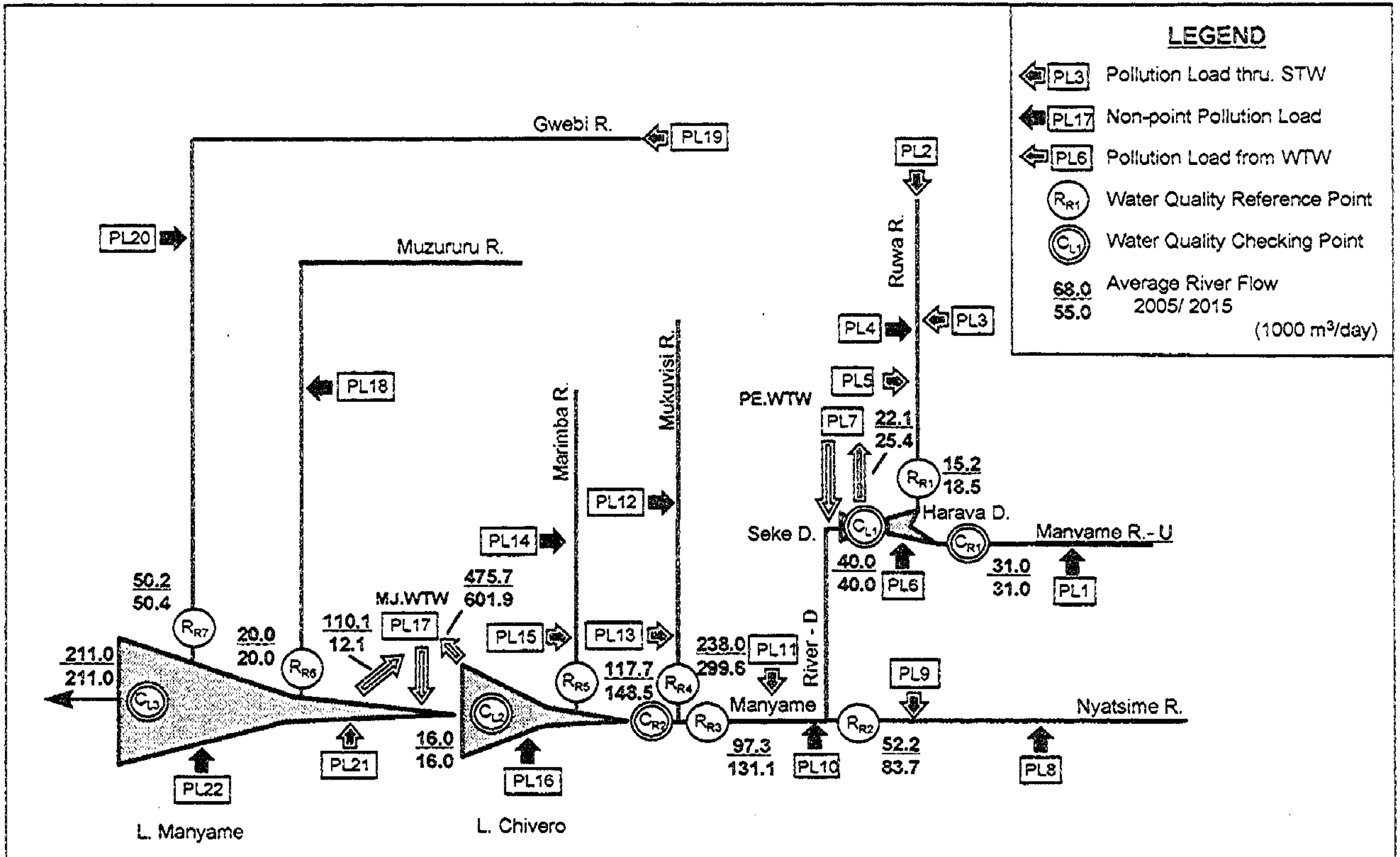

Figure 10.1.1 Flow Model for Future Water Pollution Analysis (for Rivers, Scenario 1, Dry Season)

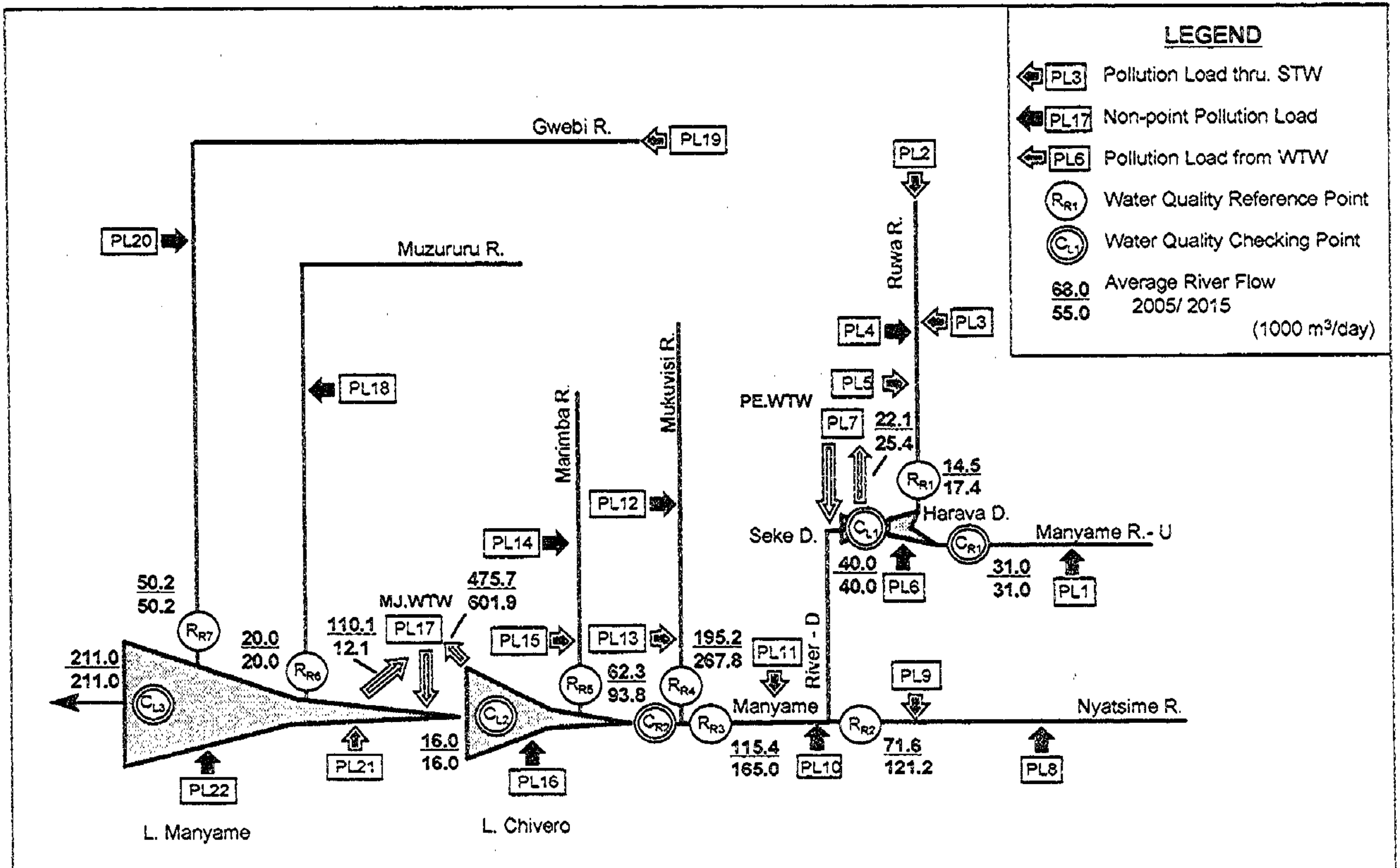

Figure 10.1.2 Flow Model for Future Water Pollution Analysis (for Rivers, Scenario 2, Dry Season)

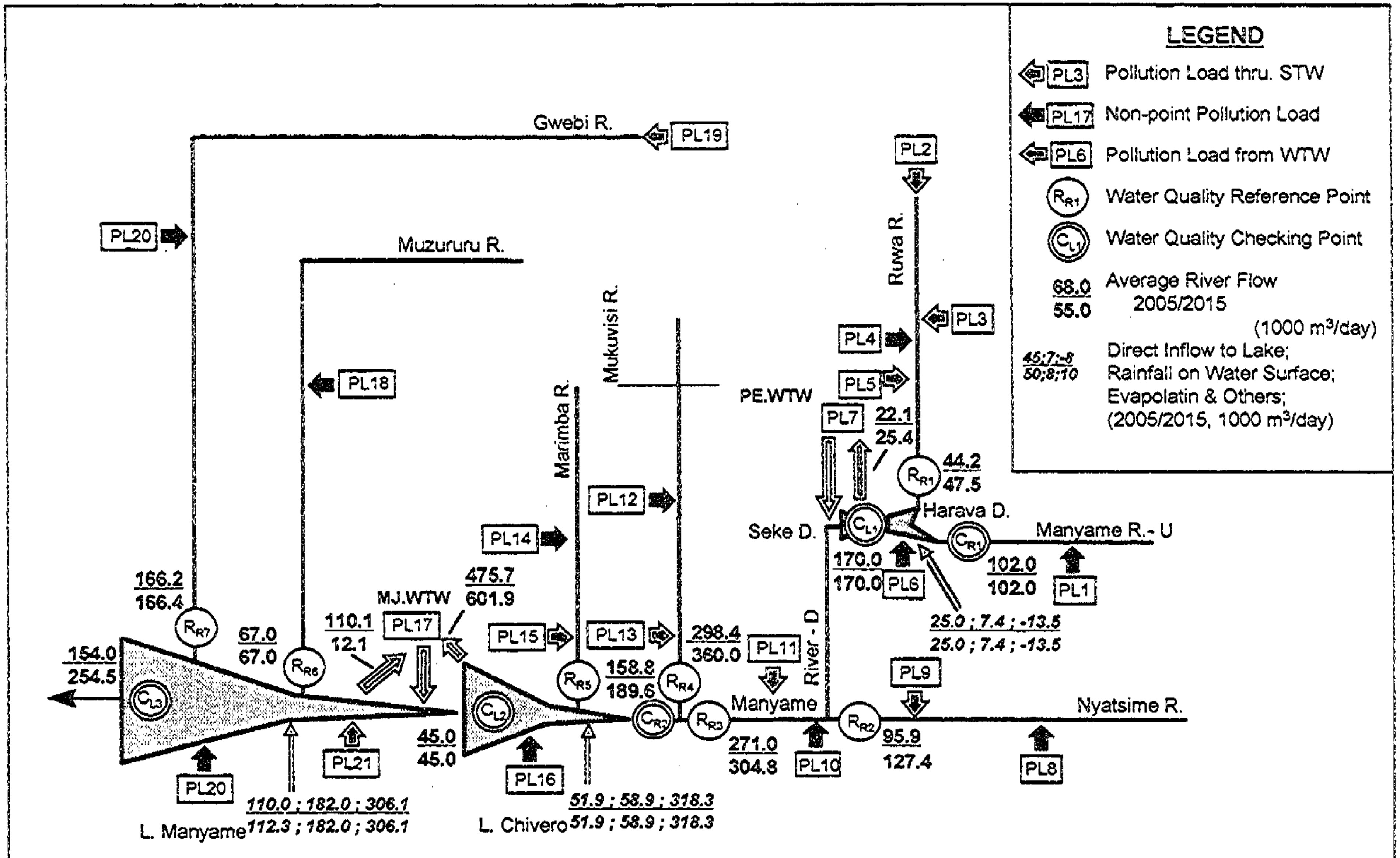

Figure 10.1.3 Flow Model for Future Water Pollution Analysis (for Lakes/Dams, Scenario 1)

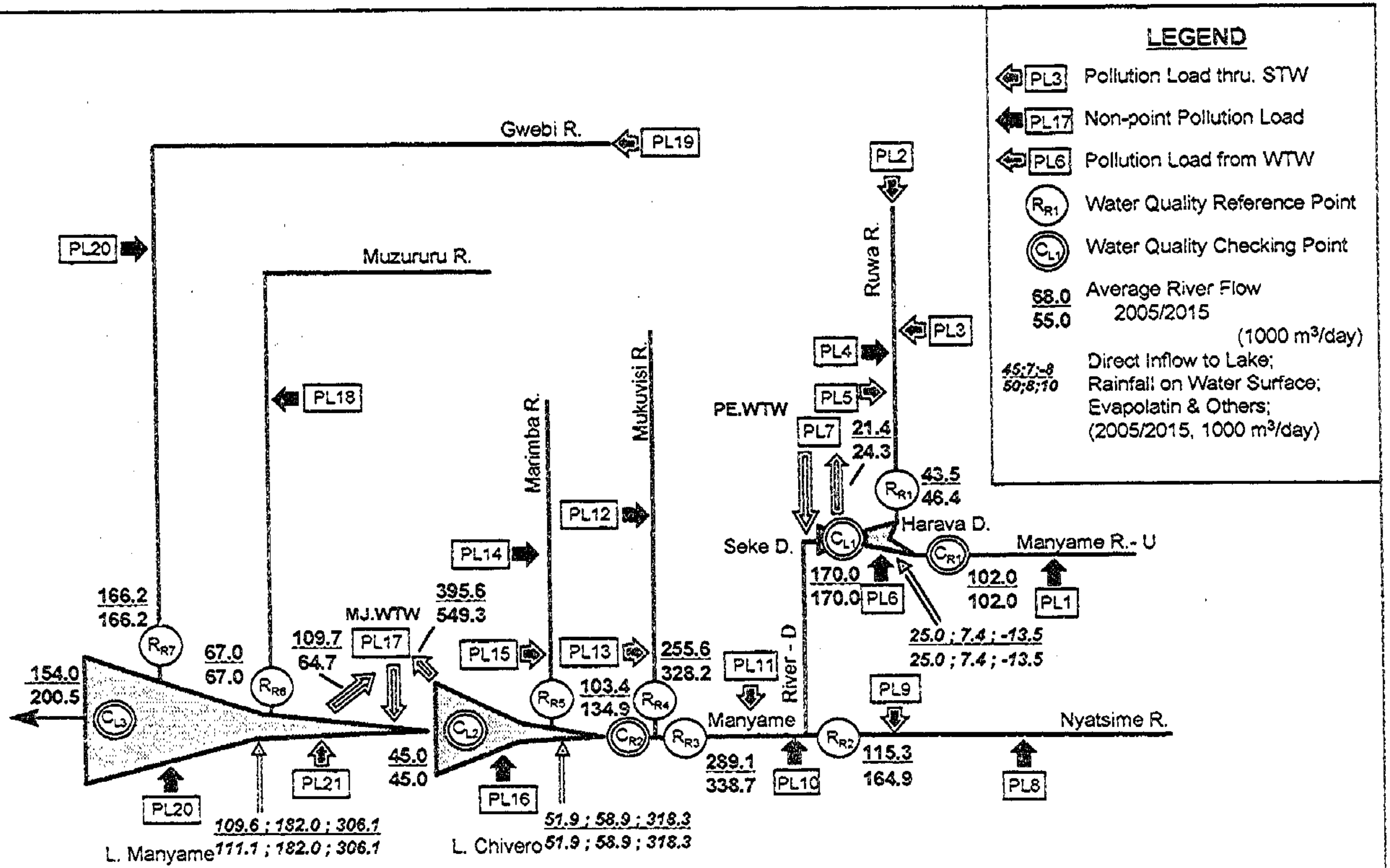

Figure 10.1.4 Flow Model for Future Water Pollution Analysis (for Lakes/Dams, Scenario 2)

Table 10.2.1 Population by Sewered/Unsewered by Sub-basin (Scenario 1)

YEAR 2005

Sub-basin/District	Total Population		Projected	Sewered Area				Unsewered Area			
	Sewered	Unsewered	Sewered %	Low	Medium	High	Total	Low	Medium	High	Total
1. Manyame River (U.stream) S/B	-	34,679	0.0%	-	-	-	-	-	-	34,679	34,679
2. Ruwa River S/B	232,426	12,502	94.9%	11,328	810	220,288	232,426	-	-	12,502	12,502
3. Seke & Harava Dams S/B	53,813	4,085	92.9%	3,960	-	49,853	53,813	-	-	4,085	4,085
4. Nyatsime River S/B	370,675	21,638	94.5%	-	15,075	355,600	370,675	-	-	21,638	21,638
5. Mukuvisi River S/B	786,247	52,132	93.8%	42,451	98,029	645,768	786,247	49,356	-	2,776	52,132
6. Manyame River (D.stream) S/B	202,610	5,201	97.5%	-	20,610	182,000	202,610	-	-	5,201	5,201
7. Marimba River S/B	861,729	3,218	99.6%	53,923	94,807	713,000	861,729	-	-	3,218	3,218
8. Lake Chivero S/B	162,000	9,871	94.3%	-	-	162,000	162,000	-	-	9,871	9,871
9. Muzururu River S/B	150,000	16,797	89.9%	-	-	150,000	150,000	-	-	16,797	16,797
10. Gwebi River S/B	12,576	68,802	15.5%	12,576	-	-	12,576	29,184	-	39,618	68,802
11. Lake Manyame S/B	62,358	22,410	73.6%	6,468	9,540	46,350	62,358	-	-	22,410	22,410
Grand Total	2,894,434	251,335	92.0%	130,706	238,870	2,524,859	2,894,434	78,540	-	172,795	251,335

YEAR 2015

Sub-basin/District	Total Population		Projected	Sewered Area				Unsewered Area			
	Sewered	Unsewered	Sewered %	Low	Medium	High	Total	Low	Medium	High	Total
1. Manyame River (U.stream) S/B	-	41,758	0.0%	-	-	-	-	-	-	41,758	41,758
2. Ruwa River S/B	311,215	15,055	95.4%	11,328	11,970	287,917	311,215	-	-	15,055	15,055
3. Seke & Harava Dams S/B	55,048	4,919	91.8%	3,960	-	51,088	55,048	-	-	4,919	4,919
4. Nyatsime River S/B	504,338	26,056	95.1%	2,568	37,170	464,600	504,338	-	-	26,056	26,056
5. Mukuvisi River S/B	847,082	52,699	94.1%	44,407	98,029	704,647	847,082	49,356	-	3,343	52,699
6. Manyame River (D.stream) S/B	545,210	6,263	98.9%	-	20,610	524,600	545,210	-	-	6,263	6,263
7. Marimba River S/B	996,585	3,875	99.6%	60,180	107,435	828,971	996,585	-	-	3,875	3,875
8. Lake Chivero S/B	194,800	11,887	94.2%	-	-	194,800	194,800	-	-	11,887	11,887
9. Muzururu River S/B	150,000	20,226	88.1%	-	-	150,000	150,000	-	-	20,226	20,226
10. Gwebi River S/B	21,324	81,486	20.7%	21,324	-	-	21,324	33,780	-	47,706	81,486
11. Lake Manyame S/B	118,290	26,984	81.4%	21,540	24,750	72,000	118,290	-	-	26,984	26,984
Grand Total	3,743,892	291,208	92.8%	165,307	299,963	3,278,623	3,743,892	83,136	-	208,072	291,208

Note: 1. Estimated population and land use are based on Section 12.2.3., Chapter 2, Supporting Report

2. Population in rural districts is categorised to high-density area.

Table 10.2.2 Population by Sewered/Unsewered by Sub-basin (Scenario 2)

YEAR 2005

Sub-basin/District	Total Population		Projected	Sewered Area				Unsewered Area			
	Sewered	Unsewered	Sewered %	Low	Medium	High	Total	Low	Medium	High	Total
1. Manyame River (U.stream) S/B	-	34,679	0.0%	-	-	-	-	-	-	34,679	34,679
2. Ruwa River S/B	170,655	12,502	93.2%	155	11	170,489	170,655	-	-	12,502	12,502
3. Seke & Harava Dams S/B	13,047	4,085	76.2%	580	-	12,467	13,047	-	-	4,085	4,085
4. Nyatsime River S/B	526,688	21,638	96.1%	-	21,420	505,268	526,688	-	-	21,638	21,638
5. Mukuvisi River S/B	826,611	39,123	95.5%	42,446	89,664	694,502	826,611	36,347	-	2,776	39,123
6. Manyame River (D.stream) S/B	151,465	5,201	96.7%	-	1,517	149,948	151,465	-	-	5,201	5,201
7. Marimba River S/B	678,007	3,218	99.5%	40,072	79,619	558,316	678,007	-	-	3,218	3,218
8. Lake Chivero S/B	-	9,871	0.0%	-	-	-	-	-	-	9,871	9,871
9. Muzururu River S/B	-	16,797	0.0%	-	-	-	-	-	-	16,797	16,797
10. Gwebi River S/B	13,068	130,696	9.1%	13,068	-	-	13,068	91,078	-	39,618	130,696
11. Lake Manyame S/B	27,362	22,410	55.0%	1,487	2,193	23,681	27,362	-	-	22,410	22,410
Grand Total	2,406,903	300,220	88.9%	97,807	194,423	2,114,672	2,406,903	127,425	-	172,795	300,220

YEAR 2015

Sub-basin/District	Total Population		Projected	Sewered Area				Unsewered Area			
	Sewered	Unsewered	Sewered %	Low	Medium	High	Total	Low	Medium	High	Total
1. Manyame River (U.stream) S/B	-	41,758	0.0%	-	-	-	-	-	-	41,758	41,758
2. Ruwa River S/B	215,680	15,055	93.5%	153	161	215,366	215,680	-	-	15,055	15,055
3. Seke & Harava Dams S/B	16,342	4,919	76.9%	751	-	15,591	16,342	-	-	4,919	4,919
4. Nyatsime River S/B	758,507	26,056	96.7%	3,862	55,902	698,742	758,507	-	-	26,056	26,056
5. Mukuvisi River S/B	1,068,077	50,395	95.5%	53,691	108,314	906,073	1,068,077	47,052	-	3,343	50,395
6. Manyame River (D.stream) S/B	216,697	6,263	97.2%	-	551	216,146	216,697	-	-	6,263	6,263
7. Marimba River S/B	877,690	3,875	99.6%	47,516	102,633	727,541	877,690	-	-	3,875	3,875
8. Lake Chivero S/B	-	11,887	0.0%	-	-	-	-	-	-	11,887	11,887
9. Muzururu River S/B	-	20,226	0.0%	-	-	-	-	-	-	20,226	20,226
10. Gwebi River S/B	16,917	165,608	9.3%	16,917	-	-	16,917	117,902	-	47,706	165,608
11. Lake Manyame S/B	32,947	26,984	55.0%	3,440	3,953	25,554	32,947	-	-	26,984	26,984
Grand Total	3,202,857	373,026	89.6%	126,330	271,515	2,805,013	3,202,857	164,954	-	208,072	373,026

Note: 1. Estimated population and land use are based on Section 12.2.3., Chapter 2, Supporting Report

2. Population in rural districts is categorised to high-density area.

Table 10.2.3 Projected Wastewater Quantity by Sewered/Unsewered Area by Sub-basin (Scenario 1)

Year 2005

Sub-basin/District	Generated/Discharged Wastewater Quanity (m3/day)											
	Sewered Area						Unsewered Area					
	Domestic			Com. & Inst.	Indust-rial	Total	Domestic			Com. & Inst.	Indust-rial	Total
	Low	Medium	High				Low	Medium	High			
1. Manyame River (Upstream) S/B	-	-	-	-	-	-	-	-	2,254	-	-	2,254
2. Ruwa River S/B	3,568	170	14,319	559	3,545	22,161	-	-	813	-	-	813
3. Seke & Harava Dams S/B	1,247	-	3,240	20	-	4,508	-	-	266	-	-	266
4. Nyatsime River S/B	-	3,166	23,114	1,898	1,401	26,280	-	-	1,406	-	-	1,406
5. Mukuvisi River S/B	13,372	20,586	41,975	55,931	37,932	169,796	15,547	-	180	-	325	16,053
6. Manyame River (D.stream) S/B	-	4,328	11,830	-	39,533	55,691	-	-	338	-	-	338
7. Marimba River S/B	16,986	19,909	46,345	13,965	11,392	108,597	-	-	209	-	-	209
8. Lake Chivero S/B	-	-	10,530	-	-	10,530	-	-	642	-	-	642
9. Muzururu River S/B	-	-	9,750	-	-	9,750	-	-	1,092	-	-	1,092
10. Gwebi River S/B	3,961	-	-	-	-	3,961	9,193	-	2,575	-	-	11,768
11. Lake Manyame S/B	2,037	2,003	3,013	353	3,386	10,792	-	-	1,457	-	3,451	4,908
Grand Total	41,172	50,163	164,116	72,726	97,189	422,066	24,740	-	11,232	-	3,776	39,748

Year 2015

Sub-basin/District	Generated/Discharged Wastewater Quanity (m3/day)											
	Sewered Area						Unsewered Area					
	Domestic			Com. & Inst.	Indust-rial	Total	Domestic			Com. & Inst.	Indust-rial	Total
	Low	Medium	High				Low	Medium	High			
1. Manyame River (Upstream) S/B	-	-	-	-	-	-	-	-	2,923	-	-	2,923
2. Ruwa River S/B	3,568	2,514	20,154	776	30,274	57,287	-	-	1,054	-	-	1,054
3. Seke & Harava Dams S/B	1,247	-	3,576	26	-	4,849	-	-	344	-	-	344
4. Nyatsime River S/B	809	7,806	32,522	3,869	10,740	41,137	-	-	1,824	-	-	1,824
5. Mukuvisi River S/B	13,988	20,586	49,325	78,545	41,762	204,206	15,547	-	234	-	325	16,106
6. Manyame River (D.stream) S/B	-	4,328	36,722	-	41,557	82,607	-	-	438	-	-	438
7. Marimba River S/B	18,957	22,561	58,028	19,613	11,392	130,551	-	-	271	-	-	271
8. Lake Chivero S/B	-	-	13,636	-	-	13,636	-	-	832	-	-	832
9. Muzururu River S/B	-	-	10,500	-	-	10,500	-	-	1,416	-	-	1,416
10. Gwebi River S/B	6,717	-	-	-	-	6,717	10,641	-	3,339	-	-	13,980
11. Lake Manyame S/B	6,785	5,198	5,040	851	18,042	35,916	-	-	1,889	-	3,451	5,340
Grand Total	52,072	62,992	229,504	103,679	153,767	587,405	26,188	-	14,565	-	3,776	44,529

Note: 1. Estimated population and land use are based on Section 12.2.3., Chapter 2, Supporting Report
2. Population in rural districts is categorised to high-density area.

Table 10.2.4 Projected Wastewater Quantity by Sewered/Unsewered Area by Sub-basin (Scenario 2)

Year 2005

Sub-basin/District	Generated/Discharged Wastewater Quanity (m3/day)											
	Sewered Area						Unsewered Area					
	Domestic			Com. & Inst.	Indust-rial	Total	Domestic			Com. & Inst.	Indust-rial	Total
	Low	Medium	High				Low	Medium	High			
1. Manyame River (Upstream) S/B	-	-	-	-	-	-	-	-	2,254	-	-	2,254
2. Ruwa River S/B	49	2	11,082	190	3,545	14,868	-	-	813	-	-	813
3. Seke & Harava Dams S/B	183	-	810	20	-	1,013	-	-	266	-	-	266
4. Nyatsime River S/B	-	4,498	32,842	1,910	1,401	37,341	-	-	1,406	-	-	1,406
5. Mukuvisi River S/B	13,370	18,829	45,143	49,240	37,932	164,514	11,449	-	180	-	325	11,955
6. Manyame River (D.stream) S/B	-	319	9,747	-	39,533	49,598	-	-	338	-	-	338
7. Marimba River S/B	12,623	16,720	36,291	12,292	11,392	89,317	-	-	209	-	-	209
8. Lake Chivero S/B	-	-	-	-	-	-	-	-	642	-	-	642
9. Muzururu River S/B	-	-	-	-	-	-	-	-	1,092	-	-	1,092
10. Gwebi River S/B	4,116	-	-	-	-	4,116	28,690	-	2,575	-	-	31,265
11. Lake Manyame S/B	468	461	1,539	123	3,386	5,978	-	-	1,457	-	3,451	4,908
Grand Total	30,809	40,829	137,454	63,776	97,189	366,745	40,139	-	11,232	-	3,776	55,147

Year 2015

Sub-basin/District	Generated/Discharged Wastewater Quanity (m3/day)											
	Sewered Area						Unsewered Area					
	Domestic			Com. & Inst.	Indust-rial	Total	Domestic			Com. & Inst.	Indust-rial	Total
	Low	Medium	High				Low	Medium	High			
1. Manyame River (Upstream) S/B	-	-	-	-	-	-	-	-	2,923	-	-	2,923
2. Ruwa River S/B	48	34	15,076	247	30,274	45,679	-	-	1,054	-	-	1,054
3. Seke & Harava Dams S/B	236	-	1,091	26	-	1,353	-	-	344	-	-	344
4. Nyatsime River S/B	1,217	11,740	48,912	3,142	10,740	61,868	-	-	1,824	-	-	1,824
5. Mukuvisi River S/B	16,913	22,746	63,425	89,642	41,762	234,488	14,821	-	234	-	325	15,380
6. Manyame River (D.stream) S/B	-	116	15,130	-	41,557	56,803	-	-	438	-	-	438
7. Marimba River S/B	14,968	21,553	50,928	22,387	11,392	121,228	-	-	271	-	-	271
8. Lake Chivero S/B	-	-	-	-	-	-	-	-	832	-	-	832
9. Muzururu River S/B	-	-	-	-	-	-	-	-	1,416	-	-	1,416
10. Gwebi River S/B	5,329	-	-	-	-	5,329	37,139	-	3,339	-	-	40,479
11. Lake Manyame S/B	1,084	830	1,789	185	18,042	21,930	-	-	1,889	-	3,451	5,340
Grand Total	39,794	57,018	196,351	115,629	153,767	548,677	51,961	-	14,565	-	3,776	70,302

Note: 1. Estimated population and land use are based on Section 12.2.3., Chapter 2, Supporting Report

2. Population in rural districts is categorised to high-density area.

The pollution load collected from the sewered area is discharged at sewage treatment works. The discharged pollution load was calculated using planned treatment efficiency. Calculation results are presented in Tables 10.2.5 to 10.2.6. In the calculation, following conditions were assumed on the future arrangements of sewerage systems.

- Existing trickling filters of the Crowborough, Firle and Zengeza STWs will be maintained with its present planned capacity. Treated effluent will be discharged to irrigation farm.
- New BNR plants will be constructed to cope with increasing raw sewage inflow at the Crowborough, Firle and Zengeza STWs. Treated effluent will be discharged directly to nearby rivers.
- New STWs, namely the Harare East STW and the Harare South STW with BNR process, are planned to cope with increasing population in southern and eastern areas of Harare city.
- Wastewater Stabilisation Pond in the Marlborough, Donnybrook and Ruwa STWs will be maintained and expanded to cope with increasing sewage inflow.
- Augmentation of the Norton STW will be carried out adopting Trickling Filter method based on the existing plan.

Treatment efficiencies of STWs were assumed by respective treatment methods as follows:

Table 10.2.7 Treatment Efficiency by Treatment Method

Treatment Method	Treatment Efficiency (Pollution Load Reduction Ratio)			
	BOD_5	COD	T-N	T-P
Biological Nutrient Removal	95%	90%	80%	75%
Trickling Filter	90%	85%	30%	30%
Wastewater Stabilisation Pond	90%	85%	50%	30%

It was also assumed that 8% of the pollution load transferred for irrigation reuse reaches to the subject water bodies as concentrated load.

Calculation results are presented in Table 10.2.8 (refer to Section 10.2, Chapter 2, Supporting Report).

Table 10.2.5 Pollution Load from Sewage Treatment Works (Scenario 1)

YEAR 2005

Sub-basin	Sewage Treatment Works	Average Flow (m3/d)	Irrigation Reuse (%)	Influent Pollution Load (kg/day)				Discharged Pollution Load (kg/day)				Concentrated Pollution Load (kg/day)			
				BOD	COD	T-N	T-P	BOD	COD	T-N	T-P	BOD (dry)	COD	T-N	T-P
Marimba R.	Crowborough (TF)	36,000	100%	19,549	42,160	4,048	465	1,955	6,324	2,834	325	156	506	227	26
do	Crowborough (BNR)	82,347	0%	44,716	96,437	9,260	1,063	2,236	9,644	1,852	266	2,236	9,644	1,852	266
L. Chivero	Firle (TF)	36,000	100%	21,999	50,747	3,628	448	2,200	7,612	2,540	314	176	609	203	25
Mukuvisi R.	Firle (BNR)	142,829	0%	87,279	201,336	14,395	1,777	4,364	20,134	2,879	444	4,364	20,134	2,879	444
Gwebi R.	Marlborough (WSP)	3,961	100%	629	1,258	163	18	63	189	82	12	5	15	7	1
Ruwa R.	Donnybrook (WSP)	6,877	100%	4,655	9,310	1,164	127	466	1,397	582	89	37	112	47	7
do	Harare East (BNR)	5,732	0%	3,805	7,611	951	104	190	761	190	26	190	761	190	26
Manyame R. -D	Harare South (BNR)	55,314	0%	52,591	140,109	3,381	642	2,630	14,011	676	160	2,630	14,011	676	160
Nyatsime R.	Zengeza (TF)	20,400	100%	14,589	29,594	3,417	385	1,459	4,439	2,392	269	117	355	191	22
Nyatsime R.	Zengeza (BNR)	10,352	0%	7,403	15,017	1,734	195	370	1,502	347	49	370	1,502	347	49
L. Manyame	Norton (TF)	10,792	100%	8,843	29,843	932	112	884	4,477	652	78	71	358	52	6
Ruwa R.	Ruwa (WSP)	11,463	100%	5,880	15,752	1,291	147	588	2,363	645	103	47	189	52	8
Total		422,066		271,938	639,175	44,365	5,483	17,404	72,851	15,671	2,137	10,399	48,195	6,722	1,041

YEAR 2015

Sub-basin	Sewage Treatment Works	Average Flow (m3/d)	Irrigation Reuse (%)	Influent Pollution Load (kg/day)				Discharged Pollution Load (kg/day)				Concentrated Pollution Load (kg/day)			
				BOD	COD	T-N	T-P	BOD	COD	T-N	T-P	BOD (dry)	COD	T-N	T-P
Marimba R.	Crowborough (TF)	36,000	100%	18,594	39,759	3,947	450	1,859	5,964	2,763	315	149	477	221	25
do	Crowborough (BNR)	105,051	0%	54,260	116,019	11,517	1,313	2,713	11,602	2,303	328	2,713	11,602	2,303	328
L. Chivero	Firle (TF)	36,000	100%	21,318	48,788	3,623	443	2,132	7,318	2,536	310	171	585	203	25
Mukuvisi R.	Firle (BNR)	179,900	0%	106,530	243,805	18,105	2,213	5,327	24,380	3,621	553	5,327	24,380	3,621	553
Gwebi R.	Marlborough (WSP)	6,717	100%	1,066	2,132	277	30	107	320	139	21	9	26	11	2
Ruwa R.	Donnybrook (WSP)	10,710	100%	6,732	13,464	1,683	184	673	2,020	842	129	54	162	67	10
do	Harare East (BNR)	33,075	0%	30,471	89,609	2,029	399	1,524	8,961	406	100	1,524	8,961	406	100
Manyame R. -D	Harare South (BNR)	80,081	0%	67,665	170,258	7,149	1,053	3,383	17,026	1,430	263	3,383	17,026	1,430	263
Nyatsime R.	Zengeza (TF)	20,400	100%	27,575	58,929	4,776	627	2,758	8,839	3,343	439	221	707	267	35
do	Zengeza (BNR)	27,577	0%	13,993	29,903	2,423	318	700	2,990	485	79	700	2,990	485	79
L. Manyame	Norton (TF)	35,916	100%	41,028	158,515	2,309	299	4,103	23,777	1,617	209	328	1,902	129	17
Ruwa R.	Ruwa (WSP)	15,979	100%	7,626	20,466	1,673	192	763	3,070	837	134	61	246	67	11
Total		587,405		396,859	991,646	59,512	7,520	26,040	116,267	20,320	2,881	14,637	69,064	9,211	1,449

Note: 1) Concentration ratios of pollution loads are; Direct Discharge; 100% Irrigation reuse; 8% (for BOD during dry season ; 8%)

2) Intruded water to sewer (groundwater, etc.) is not included in sewage flow.

3) Concentrated BOD is calculated for dry season.

4) Pollution load reduction efficiency at STWs:

	BOD	COD	T-N	T-P
BNR	95%	90%	80%	75%
TF	90%	85%	30%	30%
WSP	90%	85%	50%	30%

5) Effluent from Zengeza (TF) is transferred to outside of the study basin.

Table 10.2.6 Pollution Load at Sewage Treatment Works (Scenario 2)

YEAR 2005

Sub-basin	Sewage Treatment Works	Average Flow (m3/d)	Irrigation Reuse (%)	Influent Pollution Load (kg/day)				Discharged Pollution Load (kg/day)				Concentrated Pollution Load (kg/day)			
				BOD	COD	T-N	T-P	BOD	COD	T-N	T-P	BOD (dry)	COD	T-N	T-P
Marimba R.	Crowborough (TF)	36,000	100%	19,093	42,244	3,657	430	1,909	6,337	2,560	301	153	507	205	24
do	Crowborough (BNR)	53,317	0%	28,277	62,565	5,416	637	1,414	6,256	1,083	159	1,414	6,256	1,083	159
L. Chivero	Firle (TF)	36,000	100%	21,106	49,615	3,222	409	2,111	7,442	2,256	286	169	595	180	23
Mukuvisi R.	Firle (BNR)	127,017	0%	74,466	175,055	11,370	1,442	3,723	17,506	2,274	361	3,723	17,506	2,274	361
Gwebi R.	Marlborough (WSP)	4,116	100%	653	1,307	170	18	65	196	85	13	5	16	7	1
Ruwa R.	Donnybrook (WSP)	7,327	100%	4,960	9,920	1,240	135	496	1,488	620	95	40	119	50	8
do	Harare East (BNR)	5,732	0%	3,805	7,611	951	104	190	761	190	26	190	761	190	26
Manyame R. -D	Harare South (BNR)	40,993	0%	45,265	125,458	1,543	441	2,263	12,546	309	110	2,263	12,546	309	110
Nyatsime R.	Zengeza (TF)	20,400	100%	14,285	28,845	3,420	381	1,428	4,327	2,394	267	114	346	192	21
Nyatsime R.	Zengeza (BNR)	26,146	0%	18,308	36,969	4,383	488	915	3,697	877	122	915	3,697	877	122
L. Manyame	Norton (TF)	5,978	100%	7,132	26,422	500	65	713	3,963	350	45	57	317	28	4
Ruwa R.	Ruwa (WSP)	3,720	100%	2,629	9,250	472	58	263	1,387	236	41	21	111	19	3
	Total	366,745		239,980	575,259	36,343	4,609	15,492	65,906	13,232	1,826	9,065	42,777	5,413	862

YEAR 2015

Sub-basin	Sewage Treatment Works	Average Flow (m3/d)	Irrigation Reuse (%)	Influent Pollution Load (kg/day)				Discharged Pollution Load (kg/day)				Concentrated Pollution Load (kg/day)			
				BOD	COD	T-N	T-P	BOD	COD	T-N	T-P	BOD (dry)	COD	T-N	T-P
Marimba R.	Crowborough (TF)	36,000	100%	17,796	38,583	3,632	419	1,780	5,787	2,542	293	142	463	203	23
do	Crowborough (BNR)	85,228	0%	42,131	91,342	8,597	991	2,107	9,134	1,719	248	2,107	9,134	1,719	248
L. Chivero	Firle (TF)	36,000	100%	19,361	44,435	3,260	400	1,936	6,665	2,282	280	155	533	183	22
Mukuvisi R.	Firle (BNR)	196,546	0%	105,706	242,596	17,797	2,182	5,285	24,260	3,559	546	5,285	24,260	3,559	546
Gwebi R.	Marlborough (WSP)	5,329	100%	846	1,692	220	24	85	254	110	17	7	20	9	1
Ruwa R.	Donnybrook (WSP)	10,215	100%	6,421	12,841	1,605	175	642	1,926	803	123	51	154	64	10
do	Harare East (BNR)	33,075	0%	30,471	89,609	2,029	399	1,524	8,961	406	100	1,524	8,961	406	100
Manyame R. -D	Harare South (BNR)	41,320	0%	45,481	125,891	1,597	447	2,274	12,589	319	112	2,274	12,589	319	112
Nyatsime R.	Zengeza (TF)	20,400	100%	25,956	54,408	5,092	625	2,596	8,161	3,564	438	208	653	285	35
do	Zengeza (BNR)	57,769	0%	33,267	69,732	6,526	801	1,663	6,973	1,305	200	1,663	6,973	1,305	200
L. Manyame	Norton (TF)	21,930	100%	36,847	150,155	1,249	184	3,685	22,523	875	129	295	1,802	70	10
Ruwa R.	Ruwa (WSP)	4,867	100%	3,426	12,067	614	77	343	1,810	307	54	27	145	25	4
	Total	548,677		367,710	933,349	52,217	6,725	23,918	109,044	17,792	2,538	13,738	65,687	8,148	1,312

Note: 1) Concentration ratios of pollution loads are; Direct Discharge; 100% Irrigation reuse; 8% (for BOD during dry season ; 8%)

2) Intruded water to sewer (groundwater, etc.) is not included in sewage flow.

3) Concentrated BOD is calculated for dry season.

4) Pollution load reduction efficiency at WTWs:

	BOD	COD	T-N	T-P
BNR	95%	90%	80%	75%
TF	90%	85%	30%	30%
WSP	90%	85%	50%	30%

5) Effluent from Zengeza (TF) is transferred to outside of the study basin.

Table 10.2.8 Concentrated Pollution Load by Pollution Source

(kg/day)

Pollution Indices Scenario, Year	Dom./Com./Ins. Sewage			Industrial	Livestock	Natural Pollution	Solid Waste Dumping	Water Treatment Works	Total
	Sewered	Unsewered	Total	Unsewered*					
BOD, Dry Season									
Scenario 1, 2005	10,282	608	10,890	657	589	248	-	113	12,497
Scenario 1, 2015	14,417	732	15,149	657	589	248	-	219	16,862
Scenario 2, 2005	8,951	380	9,331	657	589	248	-	113	10,938
Scenario 2, 2015	13,530	458	13,988	657	589	248	-	193	15,676
COD									
Scenario 1, 2005	47,840	1,216	49,056	2,765	14,725	45,946	149	1,261	113,903
Scenario 1, 2015	68,357	1,465	69,822	2,765	14,725	45,946	199	1,695	135,152
Scenario 2, 2005	42,431	760	43,191	2,765	14,725	45,946	113	998	107,738
Scenario 2, 2015	65,034	916	65,950	2,765	14,725	45,946	149	1,542	131,077
T-N									
Scenario 1, 2005	6,531	152	6,683	11	4,225	3,845	43	29	14,837
Scenario 1, 2015	8,943	183	9,126	11	4,225	3,845	57	36	17,302
Scenario 2, 2005	5,221	95	5,316	11	4,225	3,845	33	22	13,453
Scenario 2, 2015	7,863	114	7,977	11	4,225	3,845	43	27	16,130
T-P									
Scenario 1, 2005	1,019	17	1,036	1	661	320	-	14	2,031
Scenario 1, 2015	1,414	12	1,426	2	661	320	-	20	2,429
Scenario 2, 2005	841	10	851	1	661	320	-	10	1,843
Scenario 2, 2015	1,277	12	1,289	2	661	320	-	19	2,291

*: Pollution load of industries in sewered area is counted as a part of domestic pollution load of sewered area.

10.2.2 Industrial Wastewater

(1) Wastewater Quantity

Future industrial wastewater quantity was calculated by multiplying the unit industrial wastewater quantity per employee and the number of employees in the future as shown in Table 9.3.7.

(2) Pollution Load

Future pollution load was calculated by multiplying the unit pollution load of industrial wastewater per employee and the number of employees in the future as presented in Table 9.3.8.

(3) Sewered/Unsewered Wastewater

Future wastewater quantity and pollution load were calculated by sub-basin under the category of sewered and unsewered area based on the present sewerage service coverages. The results are shown in Table 9.3.9. Pollution load of industrial wastewater in the unsewered area is also presented in Table 10.2.8. Industrial wastewater in the sewered area is considered as a part of effluent discharged from STWs in the same table (refer to Section 10.2, Chapter 2, Supporting Report).

10.2.3 Other Pollution Load

In addition to aforementioned pollution loads, those caused by the following pollution sources were considered in the calculation as presented in Table 10.2.8 (refer to Section 10.2, Chapter 2, Supporting Report).

(1) Livestock

Number of major livestock presented in Table 9.3.10 was assumed to be constant through the future as discussed in sub-section 6.4. Therefore, generated and concentrated pollution load calculated for present analysis in Table 9.3.11 was also adopted for the future analysis.

(2) Farmland / Natural Land

The pollution loads calculated for each sub-basin as shown in Table 9.3.12 using the area of each sub-basin and unit pollution load presented in Tables 8.4.11 was assumed to be constant through the future. The pollution load may be defined as concentrated pollution loads.

(3) Solid Waste Dumping Sites

The leachate volume at dumping sites in the future was projected to increase in proportion to population of respective local authorities as discussed in sub-section 6.6. Adopting the concentration of leachate pollution load presented in Table 8.4.11, calculation was made as presented in Table 10.2.9 for the future analysis. Concentration ratio was assumed to be 80% (nil for BOD during dry season) taking into account of the location of dumping sites.

(4) Water Treatment Works

Wastewater generated through backwashing process at the Morton Jaffray WTW is presently discharged to nearby water way without any treatment. Introduction of backwashing wastewater treatment facilities were assumed for the purpose of the future pollution analysis. Water intake amount by the Morton Jaffray and Prince Edward WTWs was decided as discussed in sub-section 7.2. (refer to Section 10.2, Chapter 2, Supporting Report).

10.3 Pollution Load Run-off Model

10.3.1 Rivers

(1) River flow run-off model

The future pollution analysis of rivers was also conducted in terms of BOD_5 under the dry season condition. The river flows to be adopted in the analysis was those in dry season based on average figures in dry season of last 10 years as discussed in sub-section 7.2 (Table 7.2.25). Applying those flows, the river flow run-off model was illustrated with pollution load discharging points and water quality checking points as presented in Figure 7.2.19.

(2) Pollution load run-off model

Concentrated BOD load presented in Table 10.2.8 was allocated to each pollution load discharging point (refer to Section 10.3, Chapter 2, Supporting Report). Integrating these data, the pollution load run-off model for future pollution analysis of rivers was formulated as illustrated in Figures 10.3.1 and 10.3.2.

Table 10.2.9 Concentrated Pollution Load at Solid Waste Dumping Site (Future)

Quantity of Leachate (m3/year)

Local Authority		Harare	Harare	Chitungwiza	Norton	Ruwa/Epworth
Sub-basin		Marimba R.*	Gwebi R.	Nyatsime R.	L. Manayame	Ruwa R.**
Present Q.	on-going	13,200	3,300	6,600	3,300	1,650
	completed	12,000	2,000	0	0	0
Population Increase Rate						
Scenario 1	2005		1.93	1.09	1.93	1.87
	2015		2.45	1.49	3.66	2.34
Scenario 2	2005		1.34	1.59	1.23	1.23
	2015		1.73	2.29	1.48	1.48
Future Leachate Quantity						
Scenario 1	2005	-	58,892	7,201	6,362	3,093
	2015	-	74,758	9,839	12,068	3,858
Scenario 2	2005	-	40,850	10,507	4,047	2,023
	2015	-	52,881	15,132	4,873	2,436

*: Existing dumping site is assumed to be closed. Same load is assumed to be transferred to Gwebi R. Sub-basin.
**: Dumping site for Epworth is assumed to be developed in Ruwa R. Sub-basin.

Concentrated Pollution Load (kg/day)

Local Authority			Harare	Harare	Chitungwiza	Norton	Ruwa/Epworth
Sub-basin			Marimba R.*	Gwebi R.	Nyatsime R.	L. Manayame	Ruwa R.**
Present Concentrated Pollution Load		BOD***	28	6	7	4	2
		COD	50	10	13	7	3
		T-N	14	3	4	2	1
		T-P	-	-	-	-	-
Population Increase against 1995	Scenario1						
		2005		1.93	1.09	1.93	1.87
		2015		2.45	1.49	3.66	2.34
	Scenario2						
		2005		1.34	1.59	1.23	1.23
		2015		1.73	2.29	1.48	1.48
Future Concentrated Pollution Load							
Scenario1							
	2005	BOD***	-	66	8	8	4
		COD	-	116	14	13	6
		T-N	-	33	4	4	2
		T-P	-	-	-	-	-
	2015	BOD***	-	83	10	15	5
		COD	-	147	19	26	7
		T-N	-	42	6	7	2
		T-P	-	-	-	-	-
Scenario2							
	2005	BOD***	-	46	11	5	2
		COD	-	80	21	9	4
		T-N	-	23	6	2	1
		T-P	-	-	-	-	-
	2015	BOD***	-	59	16	6	3
		COD	-	104	30	10	4
		T-N	-	29	9	3	1
		T-P	-	-	-	-	-

*: Existing dumping site is assumed to be closed. Same load is assumed to be transferred to Gwebi R. Sub-basin.
**: Dumping site for Epworth is assumed to be developed in Ruwa R. Sub-basin.
***:Nil during dry season.

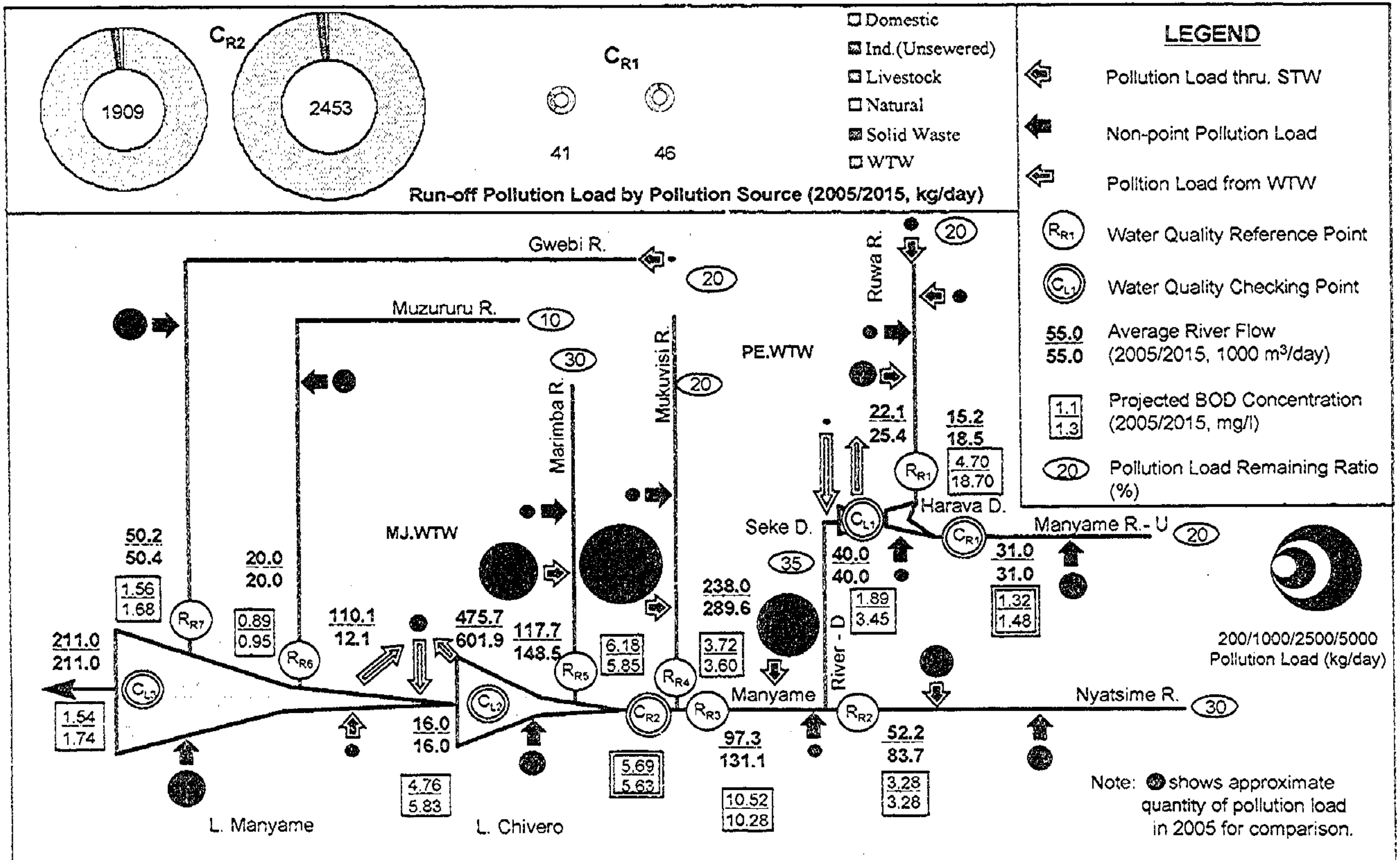

Figure 10.3.1 Pollution Load Run-off Model for Future Water Pollution Analysis (BOD . Scenario 1, 2005, Dry Season)

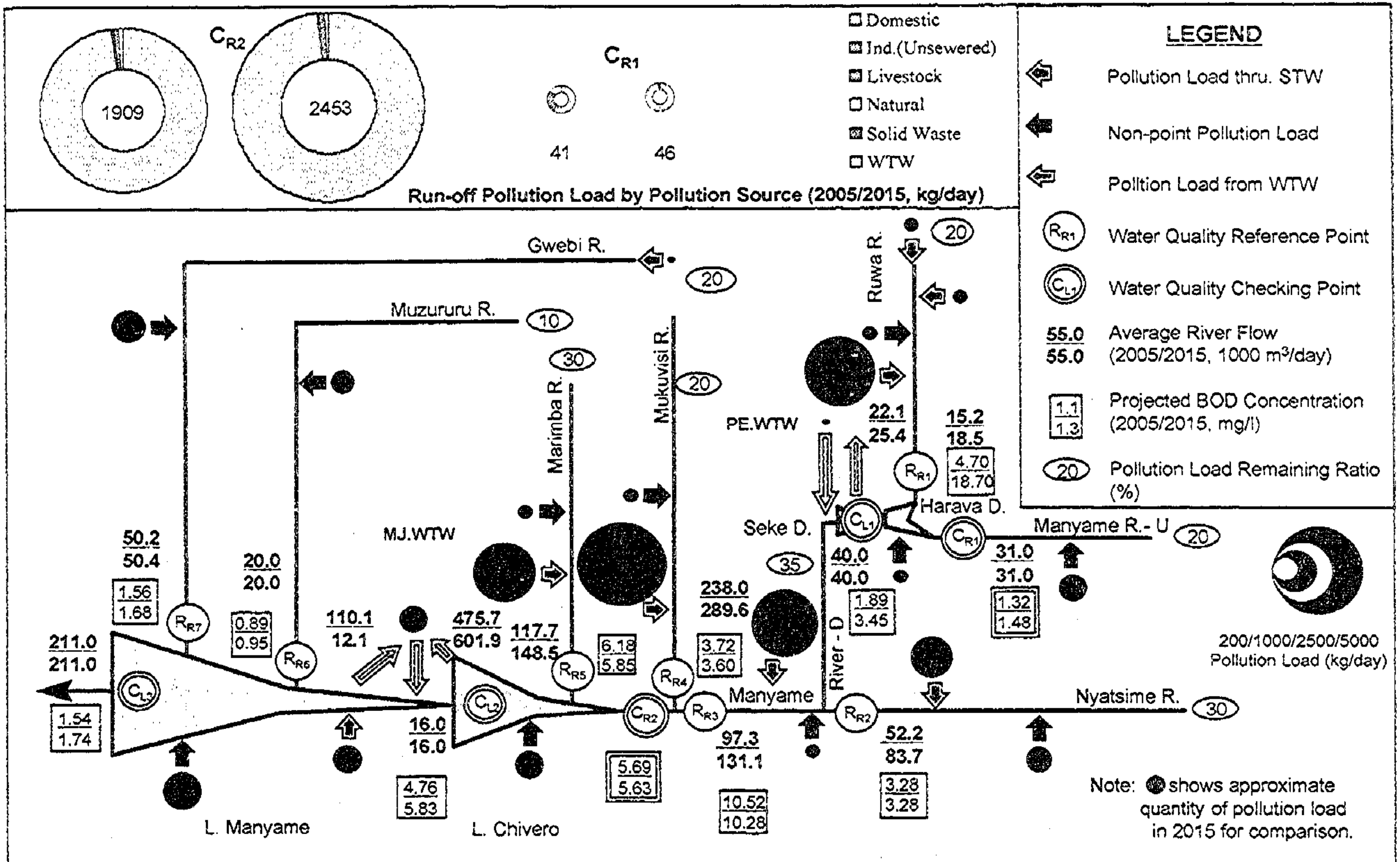

Figure 10.3.2 Pollution Load Run-off Model for Future Water Pollution Analysis (BOD , Scenario 1, 2015, Dry Season)

10.3.2 Lakes/Dams

(1) Water balance of lakes/dams

The pollution analysis of lakes was conducted under the annual average condition. The water balance of lakes to be adopted in the analysis is those based on annual average figures in the last 10 years as discussed in sub-section 7.2 (refer to Table 7.2.26). Applying the water balance, the run-off model was illustrated with pollution load discharging points and water quality checking points as presented in Figure 7.2.20.

(2) Pollution load run-off model

The concentrated pollution load was calculated in the previous section by each scenario for COD, T-N and T-P, respectively. Integrating the flow run-off model and the calculated concentrated pollution load, the pollution load run-off models in terms of COD, T-N and T-P was formulated by each scenario as shown in Figures 10.3.3 to 10.3.8. These pollution loads were assumed to reach to the subject lakes without reduction (purification) in the main river because of the reason stipulated in sub-section 9.4.2 (2).

10.4 Future Water Pollution Analysis

10.4.1 General

The pollution load remaining ratios of respective rivers in terms of BOD_5 identified in the present pollution analysis were adopted for the future pollution analysis. While, self-purification coefficients of respective lakes in terms of T-N, T-P and COD computed in the present analysis were also adopted for the future pollution analysis of lakes.

10.4.2 Rivers

Based on the BOD load run-off model established in sub-section 10.3, projection of BOD concentration at water quality checking points of rivers was conducted for each scenario as summarised in Table 10.4.1 (refer to Section 10.4, Chapter 2, Supporting Report).

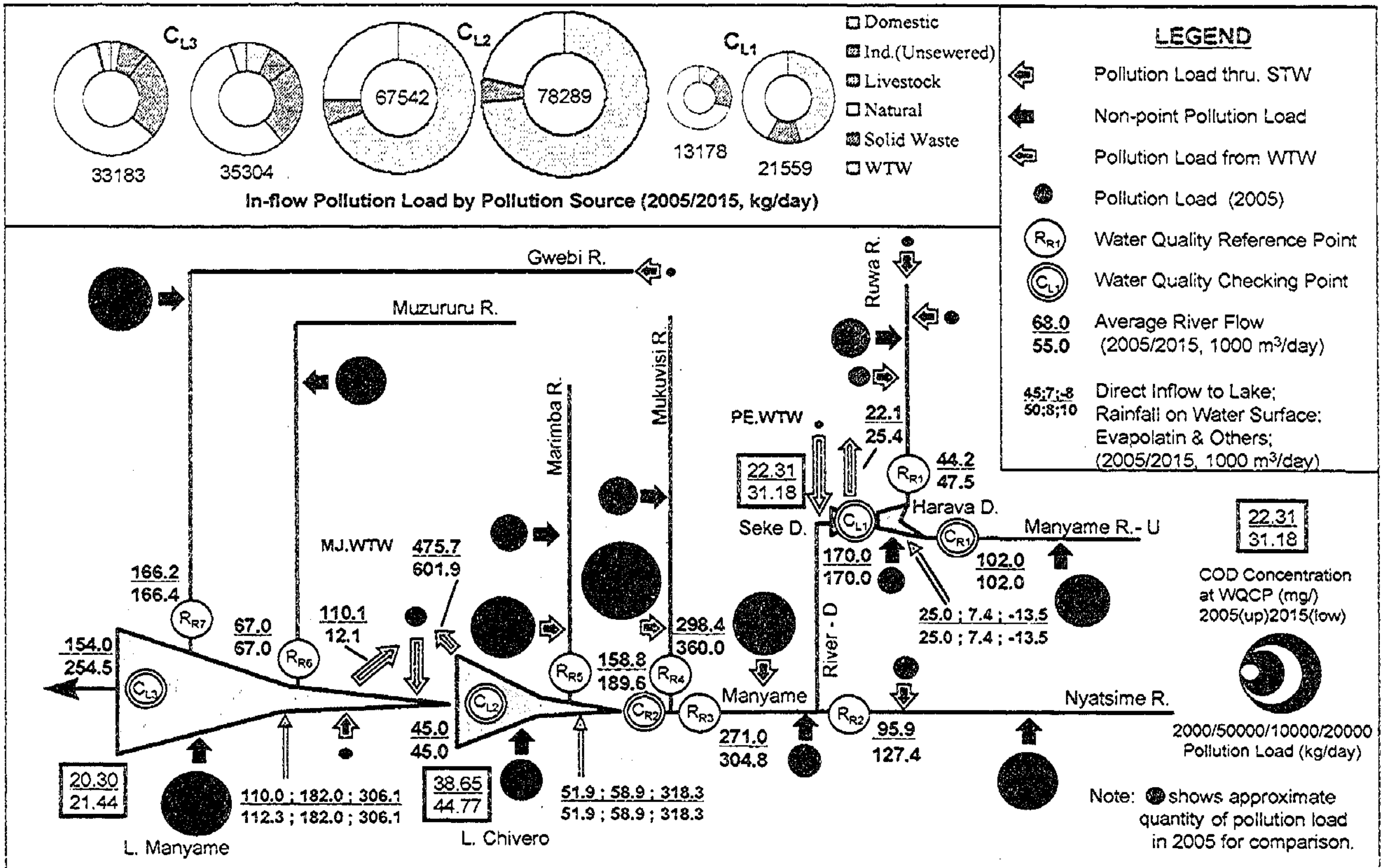

Figure 10.3.3 Pollution Load Run-off Model for Future Water Pollution Analysis (COD , Scenario 1, 2005)

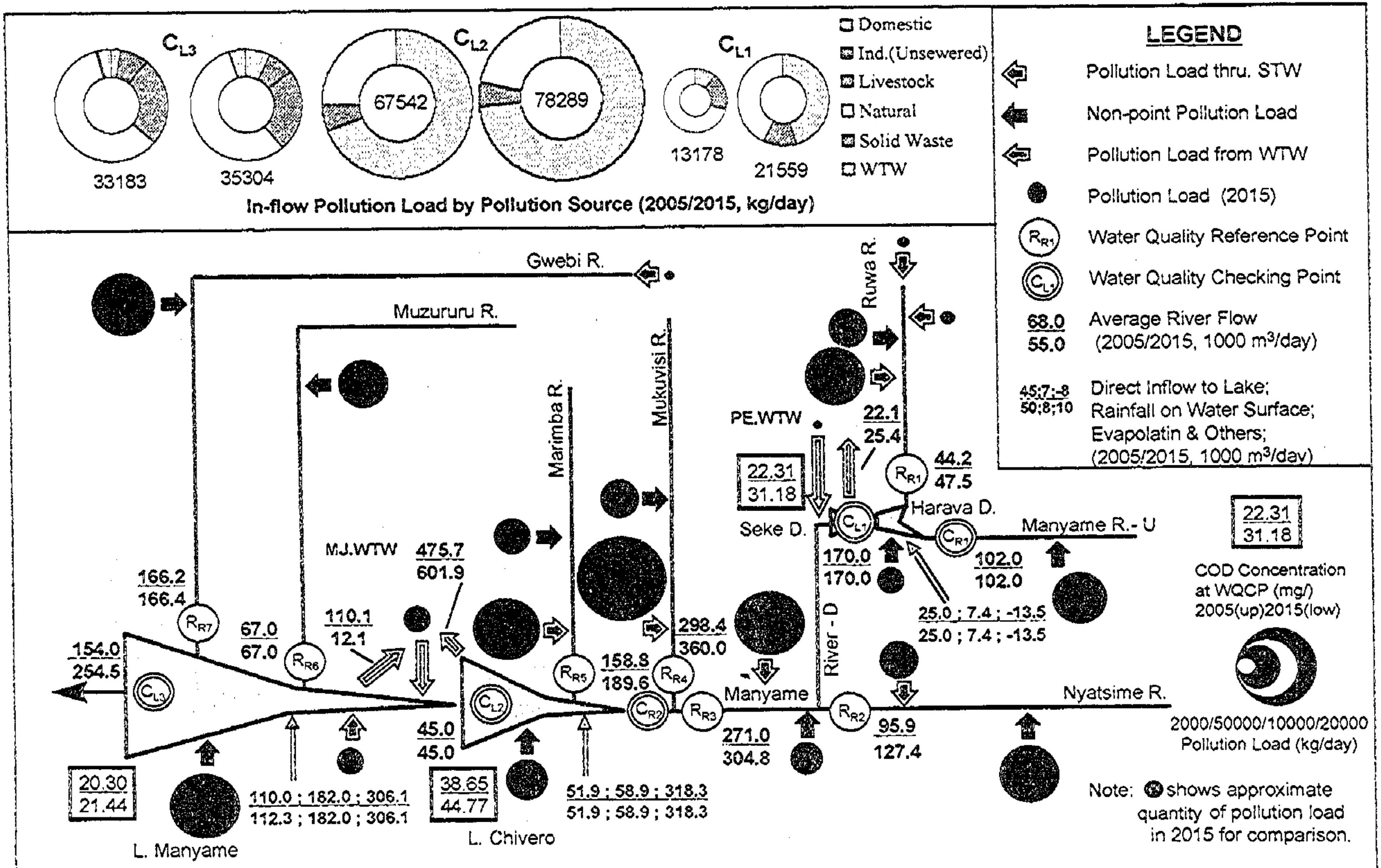

Figure 10.3.4 Pollution Load Run-off Model for Future Water Pollution Analysis (COD , Scenario 1, 2015)

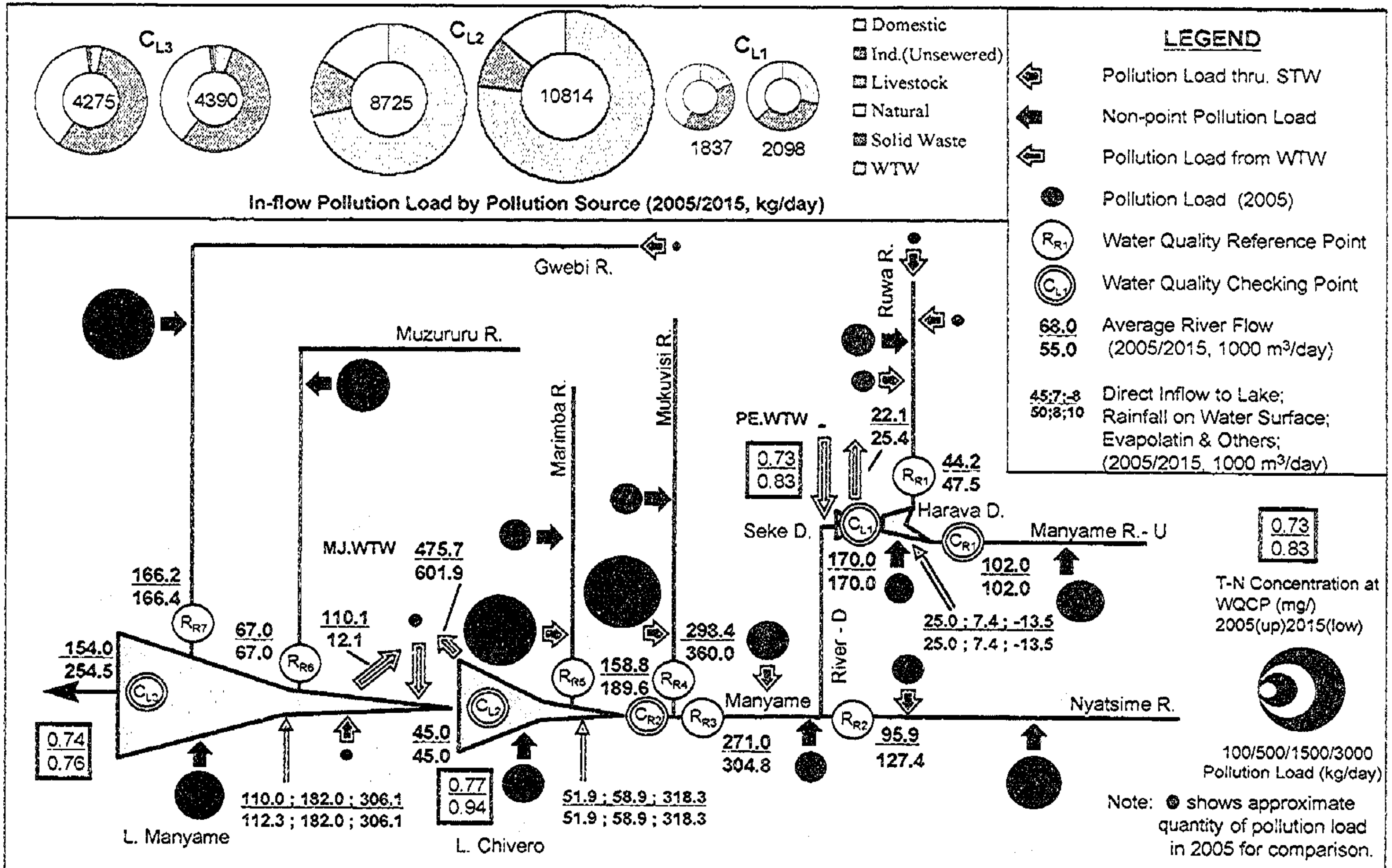

Figure 10.3.5 Pollution Load Run-off Model for Future Water Pollution Analysis (T-N , Scenario 1, 2005)

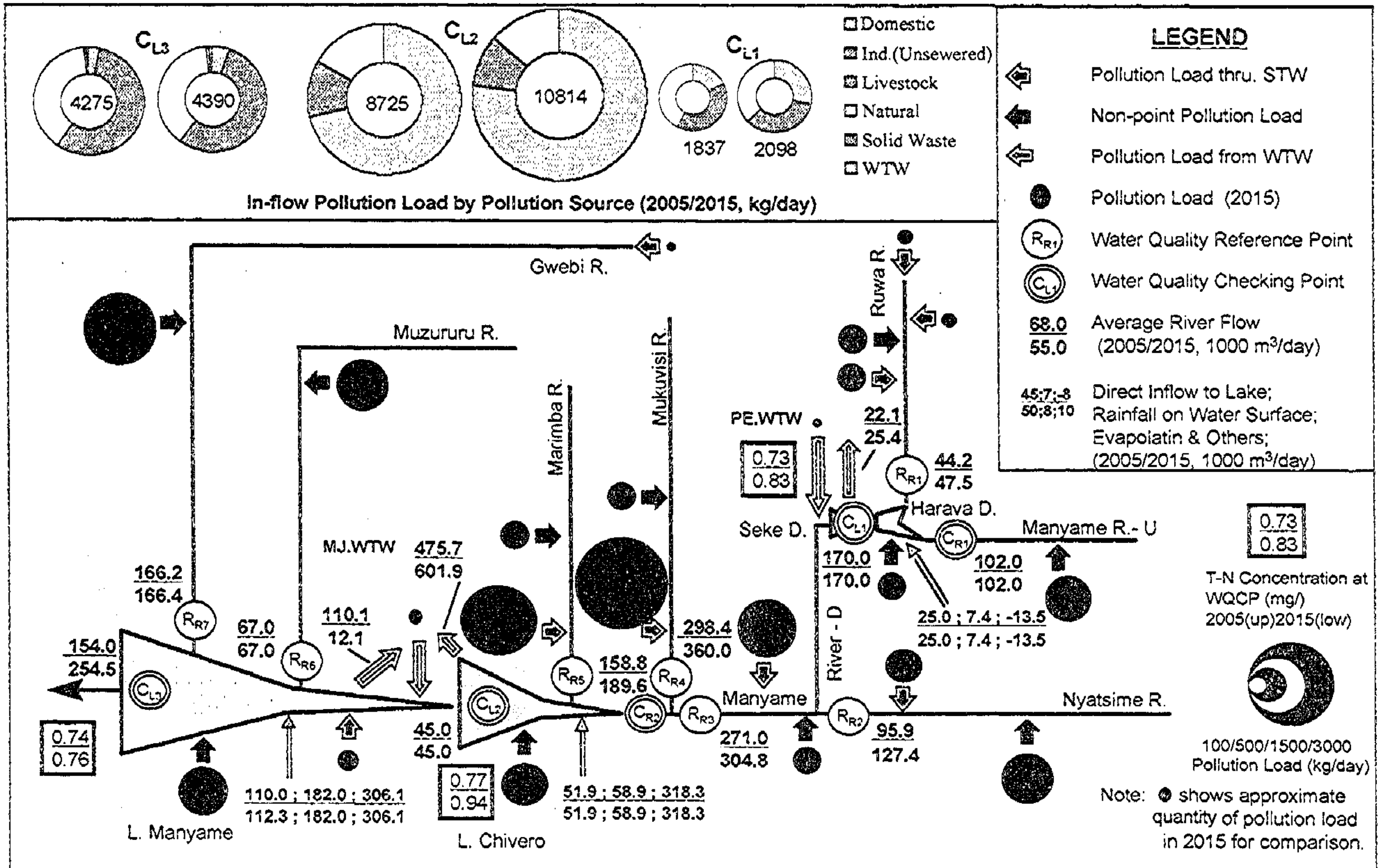

Figure 10.3.6 Pollution Load Run-off Model for Future Water Pollution Analysis (T-N , Scenario 1, 2015)

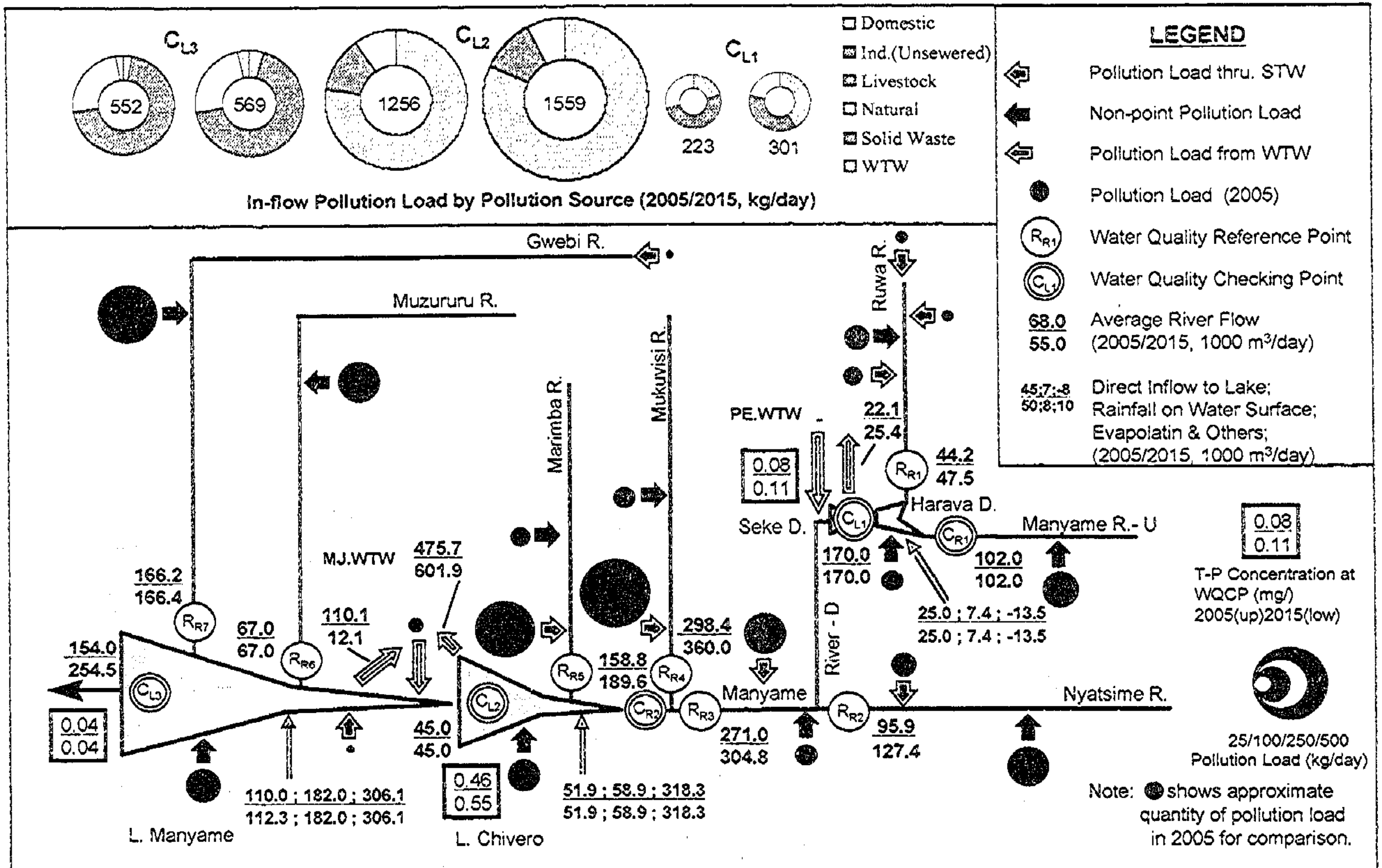

Figure 10.3.7 Pollution Load Run-off Model for Future Water Pollution Analysis (T-P , Scenario 1, 2005)

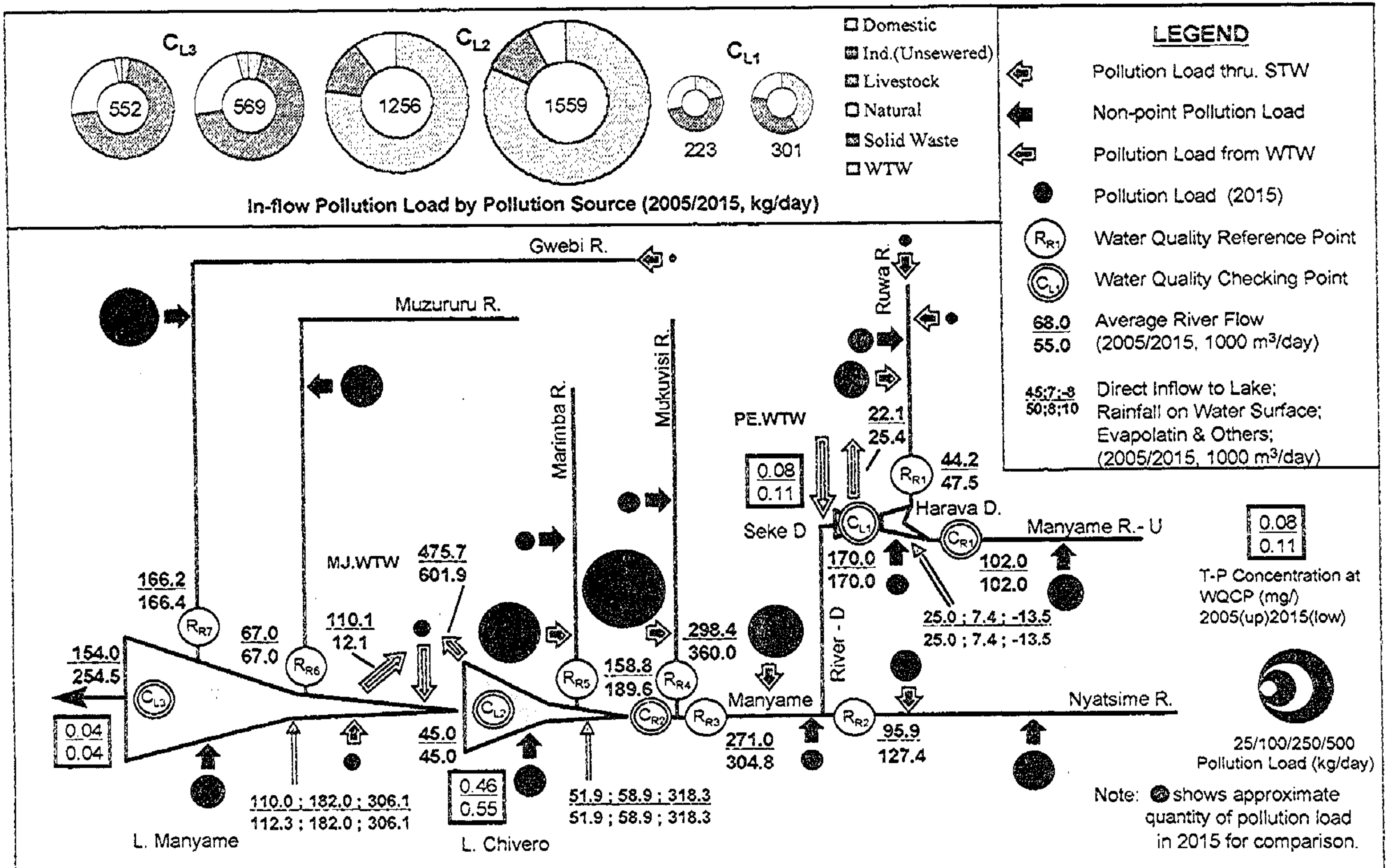

Figure 10.3.8 Pollution Load Run-off Model for Future Water Pollution Analysis (T-P , Scenario 1, 2015)

Table 10.4.1 Projected Future BOD Concentration at WQCPs

River	WQ CP	Stan-dard	Present	Scenario 1		Scenario 2	
				2005	2015	2005	2015
Manyame (u/s)	**C_{R1}**	**<3**	**1.1**	**1.32**	**1.48**	**1.03**	**1.13**
Ruwa	R_{R1}	-	3.8	4.70	18.70	4.38	19.24
Nyatsime	R_{R2}	-	2.1	3.28	3.28	4.56	4.57
Manyame (d/s)	R_{R3}	-	1.0	10.52	10.28	8.20	6.38
Mukuvisi	R_{R4}	-	2.0	3.72	3.60	3.87	3.99
Manyame (d/s)	**C_{R2}**	**<5**	**1.4**	**5.69**	**5.63**	**5.48**	**4.90**
Marimba	R_{R5}	-	8.7	6.18	5.85	7.68	7.29
Muzururu	R_{R6}	-	0.5	0.89	0.95	0.78	0.82
Gwebi	R_{R7}	-	1.6	1.56	1.68	1.35	1.43

(unit: mg/l)

Table 10.4.1 shows serious calculation results at some reference points; Ruwa (R_{R1}), Manyame (R_{R3}) and Marimba (R_{R5}) rivers, i.e. more than 5 mg/l of BOD concentration, all of which are affected by the discharge of effluent from the STWs in the sub-basin. However, BOD concentration at other points are within allowable level of water quality.

With regard to the checking point, BOD concentration at C_{R1} will be kept below the value of the environmental water quality standard. However, the value at the point C_{R2} is projected to be roughly water quality standard level.

10.4.3 Lakes/Dams

Based on the pollution load run-off models, projection of water quality of lakes and dams in the future was conducted as summarised in Table 10.4.2 (refer to Section 10.4, Chapter 2, Supporting Report).

Table 10.4.2 Projected Future Pollution Load Concentration at WQCPs of Lakes

River	WQ CP	Quality Standard		Present	Scenario 1		Scenario 2	
		2005	2015		2005	2015	2005	2015
T-N (mg/l)								
Seke & Harava	C_{L1}	<0.4	<0.2	0.65	0.73	0.83	0.71	0.80
L. Chivero	C_{L2}	<0.4	<0.2	0.51	0.77	0.94	0.66	0.86
L. Manyame	C_{L3}	<0.4	<0.2	0.75	0.74	0.76	0.73	0.74
T-P (mg/l)								
Seke & Harava	C_{L1}	<0.05	<0.01	0.07	0.08	0.11	0.08	0.11
L. Chivero	C_{L2}	<0.10	<0.01	0.27	0.46	0.55	0.41	0.51
L. Manyame	C_{L3}	<0.03	<0.01	0.04	0.04	0.04	0.04	0.04
COD* (mg/l)								
Seke & Harava	C_{L1}	<10	<6	20.63	22.31	31.18	21.86	30.57
L. Chivero	C_{L2}	<16	<6	25.30	38.65	44.77	35.51	42.69
L. Manyame	C_{L3}	<16	<6	22.70	20.30	21.44	19.92	21.02

*: Standard value of COD presented in Table 7.1.14 is indicated as COD_{Mn}. COD in this table is presented as COD_{Cr} assuming as two times of COD_{Mn}.

The improvement of water quality of lakes/dams from the present status seems to be difficult through the future as presented in Table 10.4.2, even though utmost possible sewage treatment including development of new two STWs and augmentation of the existing STWs was assumed in the calculation for projection. Generally, projected values in the scenario 2 (lower development) is better than those in the scenario 1. However, water quality of the Lake Manyame and the Seke & Harava dams show comparatively stable water quality. Nevertheless, this projection implies that assumed sewage treatment, which is recognised as practical, is indispensable and even if depression of development in the basin may be considered.

The projected water quality of the Lake Chivero is serious among others. The future water quality level may be regarded to be on the same level or some deterioration comparing with the present water quality level under the available data base.

CHAPTER 11

STUDY ON POLLUTION LOAD REDUCITON

CHAPTER 11 STUDY ON POLLUTION LOAD REDUCTION

11.1 General

The pollution load (PL) to be reduced by target year at each water quality checking point (WQCP) was calculated by comparing the run-off load calculated in sub-section 10.4 with the allowable PL calculated based on the environmental water quality standard at each WQCP discussed in sub-section 7.1. The allowable PL by different pollution source at each WQCP may be determined in proportion to the composition of their present run-off load. The allocation of PL to be reduced by the relevant pollution source shall be made considering different countermeasures against the respective pollution sources; these countermeasures include the expansion and upgrading of sewerage systems for domestic/commercial/ institutional sewage, effluent control to industrial wastewater, effluent control/ improvement of wastewater treatment for livestock, wastewater treatment at WTWs, and leachate treatment at solid waste dumping site. Figure 11.1.1 shows the manner of calculation for allowable PL by pollution source.

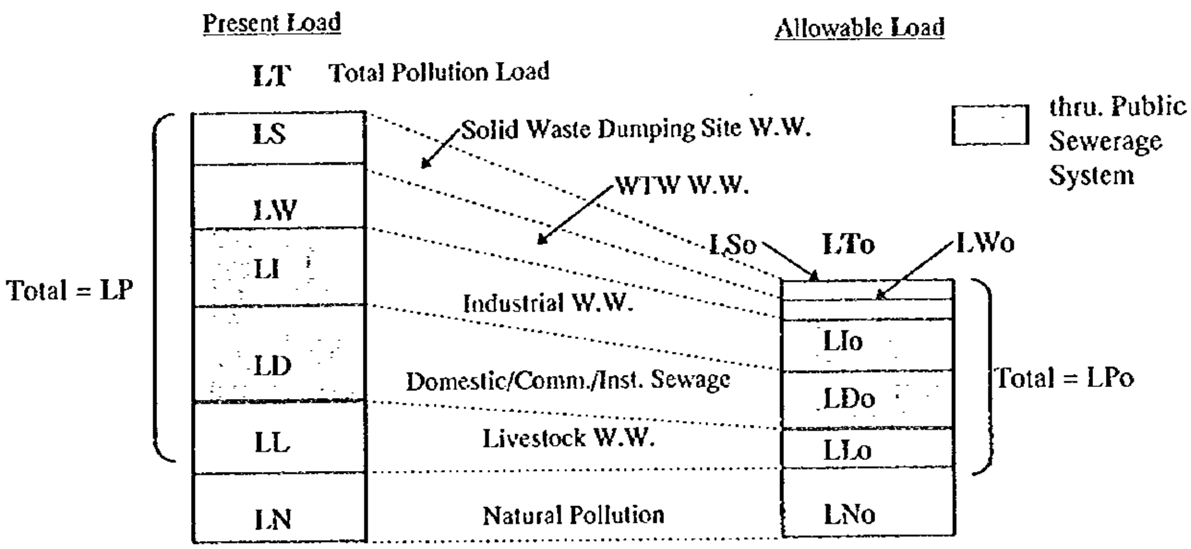

Figure 11.1.1 Manner of Calculation for Allowable Pollution Load by Pollution Source

In Figure 11.1.1, the allowable PL by pollution source is expressed as follows:

$LSo = LPo \times LS/LP$
$LWo = LPo \times LW/LP$
$LIo = LPo \times LI/LP$
$LDo = LPo \times LD/LP$
$LLo = LPo \times LL/LP$
$LNo = LN$

11.2 Composition of Present Pollution Load by Pollution Source at Respective WQCPs

The composition of the present PL by pollution source at each WQCP was studied to come up with the percentages for allocation of total allowable load discussed in sub-section 11.3.

11.2.1 Rivers (BOD)

The WQCPs to be studied for the composition of run-off load caused by different pollution sources are C_{R1} and C_{R2}. The point C_{R1} covers only the Manyame river (upstream) sub-basin while the point C_{R2} covers 6 sub-basins, namely, the Manyame River (upstream), the Ruwa River, the Seke and Harava Dams, the Nyatsime River, the Manyame River (downstream), and the Mukuvisi River. The concentrated BOD load of the respective sub-basin flows down being affected by the purification of the rivers. Therefore, the rivers' self-purification effect was considered in the calculation of the run-off BOD load by pollution source. The result of the calculation is summarised in Table 11.2.1 (refer to Table 11.2.1, Section 11.2, Chapter 2, Supporting Report).

Table 11.2.1 Composition of Present Run-off BOD Load by Pollution Source

WQCP	Sub-basin	PL Source Category	Run-off BOD Load at WQCP (kg/day)				Composition	
			Direct Inflow	Inflow from Direct Upstream	Inflow from C_{R1}	Total	Total	excl. Natural
C_{R1}	Manyame - Upstream	Domestic	18.6	N.A.	N.A.	18.6	55%	65%
		Industrial (Unsewered)	0.0			0.0	0%	0%
		Livestock	9.8			9.8	29%	35%
		Natural	5.6			5.6	16%	-
		Solid Waste	0.0			0.0	0%	0%
		WTW	0.0			0.0	0%	0%
		Total	34.1			34.1	100%	100%
C_{R2}	Manyame - Downstream	Domestic	0.0	132.8	2.6	135.4	74%	80%
		Industrial (Unsewered)	0.0	11.4	0.0	11.4	6%	7%
		Livestock	0.0	20.3	1.4	21.6	12%	12%
		Natural	0.0	11.7	0.8	12.5	7%	-
		Solid Waste	0.0	0.0	0.0	0.0	0%	0%
		WTW	0.0	0.9	0.0	0.9	1%	1%
		Total	0.0	177.1	4.8	181.9	100%	100%

Note: Composition of Run-off Load
Total; Share in Total Run-off Load (including upstream WCP)
excl. Natural; Share in Run-off Load of Direct Inflow and Upstream Inflow (excl. natural load)
N.A.; Not Applicable

The following were found form calculation results shown in Table 11.2.1:

- At the point C_{R1}, where there is no STW in the catchment area, the run-off BOD load consists of Domestic PL (55%), Livestock PL (29%) and Natural PL (16%). This domestic PL is discharged from unsewered sewage (refer to Table 9.4.1).
- At the point C_{R2}, where five STWs exist including the Zengeza and Firle STWs, the run-off BOD load consists of Domestic PL (74%), Unsewered-Industrial PL (6%), Livestock PL (12%), Natural PL (7%) and WTW PL (1%).
- At the point C_{R2}, the share of run-off load from C_{R1} is minimal at less than 3% because of the purification effect of the Seke and Harava Dams and the Manyame River (down stream section).

11.2.2 Lakes/Dams (T-N, T-P and COD)

The water quality checking points to be studied are C_{L1}, C_{L2} and C_{L3}. The following are the composition of covered water bodies by each WQCP:

- C_{L1} (Seke & Harava Dams); Manyame River (upstream)
Ruwa River
Seke and Harava Dams
- C_{L2} (Lake Chivero); C_{L1}
Manyame River (downstream)
Nyatsime River
Mukuvisi River
Marimba River
Lake Chivero
- C_{L3} (Lake Manyame); C_{L2}
Muzururu River
Gwebi River

The results of the calculation are summarised in Table 11.2.2 (refer to Tables 11.2.2 to 11.2.4, Section 11.2, Chapter 2, Supporting Report). The following are found form the table:

- At the point C_{L1}, where no STW exists in the sub-basin, the inflow PL mainly consists of livestock PL and natural PL. The total of these two pollution load exceeds 90% of total

Table 11.2.2 Composition of Present Inflow Pollution Load by Pollution Source at WQCPs (T-N, T-P and COD)

WQCP	Sub-basin	PL Source Category	T-N Inflow PL (kg/day)	T-N Composition* Total	T-N Composition* excluding Natural	T-P Inflow PL (kg/day)	T-P Composition* Total	T-P Composition* excluding Natural	COD Inflow PL (kg/day)	COD Composition* Total	COD Composition* excluding Natural
C_{L1}	Seke & Harava Dams	Domestic	125.0	7.7%	14.6%	15.0	7.8%	11.8%	873.0	6.9%	25.8%
		Ind.(Unsewered)	0.0	0.0%	0.0%	0.0	0.0%	0.0%	0.0	0.0%	0.0%
		Livestock	728.3	44.8%	85.3%	112.3	58.6%	88.2%	2,513.4	19.9%	74.1%
		Natural	773.0	47.5%	-	64.3	33.6%	-	9,236.3	73.2%	-
		Solid Waste	0.9	0.1%	0.1%	0.0	0.0%	0.0%	3.3	0.0%	0.1%
		WTW	0.0	0.0%	0.0%	0.0	0.0%	0.0%	0.0	0.0%	0.0%
		Total	1,627.2	100.0%	100.0%	191.6	100.0%	100.0%	12,626.0	100.0%	100.0%
C_{L2}	Lake Chivero	Domestic	3,117.0	54.3%	74.0%	372.0	55.8%	69.4%	17,189.0	41.2%	81.2%
		Ind.(Unsewered)	2.9	0.1%	0.1%	1.2	0.2%	0.2%	217.6	0.5%	1.0%
		Livestock	1,071.4	18.6%	25.5%	162.8	24.4%	30.4%	3,665.7	8.8%	17.3%
		Natural	1,425.8	24.8%	-	118.6	17.8%	-	17,035.3	40.8%	-
		Solid Waste	17.4	0.3%	0.4%	0.0	0.0%	0.0%	62.7	0.2%	0.3%
		WTW	1.1	0.0%	0.0%	0.1	0.0%	0.0%	33.8	0.1%	0.2%
		C_{L1}	109.7	1.9%	-	11.9	1.8%	-	3,507.1	8.4%	-
		Total	5,745.2	100.0%	100.0%	666.6	100.0%	100.0%	41,711.3	100.0%	100.0%
C_{L3}	Lake Manyame	Domestic	76.0	1.7%	2.7%	10.0	1.7%	2.2%	735.0	1.7%	3.5%
		Ind.(Unsewered)	10.5	0.2%	0.4%	1.7	0.3%	0.4%	2,668.7	6.3%	12.6%
		Livestock	2,425.7	54.6%	87.6%	385.9	64.2%	85.4%	8,546.3	20.3%	40.2%
		Natural	1,646.6	37.1%	-	136.9	22.8%	-	19,674.3	46.8%	-
		Solid Waste	4.7	0.1%	0.2%	0.0	0.0%	0.0%	17.0	0.0%	0.1%
		WTW	253.5	5.7%	9.2%	54.3	9.0%	12.0%	9,284.7	22.1%	43.7%
		C_{L2}	23.0	0.5%	-	12.2	2.0%	-	1,138.5	2.7%	-
		Total	4,440.1	100.0%	100.0%	601.0	100.0%	100.0%	42,064.5	100.0%	100.0%

Note: Composition of Inflow Pollution Load

Total; Share inTotal Inflow Pollution Load (including PL from upstream WQCP)

excl. Natural; Share in Inflow Pollution Load (excluding PL from upstream WQCP and natural load) inflow PL in terms of T-N, T-P and COD. The share of livestock PL increases to 85%, 88% and 74% of the controllable PL (PL excluding natural PL and the influence of the inflow PL from upstream WQCP) in terms of T-N, T-P and COD, respectively. These figures imply the difficulty of PL reduction.

- At the point C_{L2}, to which effluent is discharged from five STWs including the Zengeza, Firle, and Crowborough STWs, the main inflow PLs are domestic PL, livestock PL and natural PL. Because of high sewerage service coverage for many population, domestic PL dominates around a half of total PL for all pollution indices. The domestic shares are 74%, 69% and 81% of the respective controllable PLs in terms of T-N, T-P and COD.
- At the point C_{L3}, where two small STWs exist, i.e. the Marlborough and Norton STWs, main inflow PL are livestock PL and natural PL. The shares of livestock PL are 88%, 85% and 40% of the respective controllable PL in terms of T-N, T-P and COD.
- At the points of C_{L2} and C_{L3}, the influence of inflow PL from upstream WQCP is minimal.
- Influence of leachate from solid waste dumping site is negligible at all WQCPs.
- Share of PL discharged from the Morton Jaffray WTW is 9%, 12% and 44% of the respective controllable PL in terms of T-N, T-P and COD.

11.3 Allowable Pollution Load and Required Pollution Load Reduction

11.3.1 Rivers (BOD)

The allowable PL at each checking point was calculated using the environmental water quality standard and the established flow rates. The following are the conditions/assumptions adopted to calculate allowable PL and PL to be reduced.

- PL run-off model: models established in Chapter 10
- Natural PL: the load is fixed as a non-controllable load at the respective checking point.
- PL from upstream WQCP: allowable PL calculated based on the environmental water quality standard.

The calculation results for the two scenarios are presented in Table 11.3.1 which indicates that the reduction of PL is not necessary for C_{R1} because of the projected BOD concentration is lower than assumed water quality standard. Projected water quality at C_{R2} seems to be critical, however the level meets almost the requirement.

Table 11.3.1 Allowable Polllution Load and Required Pollution Load Reduction (BOD)

Scenario 1

Water Quality Checking Point	Planned Flow Rate (m3/day)	Water Quality Standard (mg/l)	Allowable Run-off Load (kg/d)	BOD Load Source Category	Projected Run-off Pollution Load (kg/day)	Required Pollution Load Reduction (kg/d)
2005						
C_{R1}	31,000	5.0	149	Others	35	-114
			6	Natural	6	0
			155	Total	41	-114
C_{R2}	335,300	5.0	1,638	Others	1,870	232
			12	Natural	12	0
			26	C_{R1}	26	0
			1,677	Total	1,909	232
2015						
C_{R1}	31,000	3.0	87	Others	40	-47
			6	Natural	6	0
			93	Total	46	-47
C_{R2}	430,700	5.0	2,131	Others	2,403	273
			12	Natural	12	0
			10	C_{R1}	10	0
			2,154	Total	2,426	273

Scenario 2

Water Quality Checking Point	Planned Flow Rate (m3/day)	Water Quality Standard (mg/l)	Allowable Run-off Load (kg/d)	BOD Load Source Category	Projected Run-off Pollution Load (kg/day)	Required Pollution Load Reduction (kg/d)
2005						
C_{R1}	31,000	5.0	149	Others	26	-123
			6	Natural	6	0
			155	Total	32	-123
C_{R2}	310,600	5.0	1,511	Others	1,660	150
			12	Natural	12	0
			30	C_{R1}	30	0
			1,553	Total	1,703	150
2015						
C_{R1}	31,000	3.0	87	Others	29	-58
			6	Natural	6	0
			93	Total	35	-58
C_{R2}	432,800	5.0	2,141	Others	2,099	-42
			12	Natural	12	0
			11	C_{R1}	11	0
			2,164	Total	2,122	-42

11.3.2 Lakes/Dams (T-N, T-P and COD)

The allowable PL at each WQCP of the lakes/dams was calculated using the environmental water quality standards and the water balances established in sub-section 7.2. The conditions/ assumptions adopted to calculate allowable PL and PL to be reduced are as follows:

- PL run-off model: models established in Chapter 10
- Natural PL: the load is fixed as a non-controllable load at the respective checking point.
- PL from upstream WQCP: allowable PL calculated based on the environmental water quality standard.

The calculation results are presented in Tables 11.3.2 to 11.3.4; they indicate that pollution road to be reduced is quite large at all WQCPs for all pollution indices, especially for the year 2015. The implementation of practical countermeasures, i.e. sewage treatment projects in the future and the introduction of WTW wastewater treatment facilities, were already assumed in the calculation. Other countermeasures, regarded as impractical or hard to implement, are not considered in the calculation.

11.4 Allowable Pollution Load and Required Pollution Load Reduction by Pollution Source

Based on the composition of the present PL by pollution source at the WQCPs presented in Table 11.2.2 and the allowable PL presented in Tables 11.3.2 to 11.3.4, the allowable PL by pollution source in terms of T-N, T-P and COD was calculated respectively for each scenario as shown in Tables 11.4.1 to 11.4.2.

In these Tables, the PL discharged from land and upstream WQCPs were fixed at the present level or calculated with the water quality standard concentration, respectively. In the year 2015, most of the allowable PL becomes less than the natural PL because of the assumed strict water quality standards.

Tables 11.4.3 to 11.4.5 present the PL to be reduced by pollution source, applying the allowable PL presented in Tables 11.4.1 and 11.4.2. These tables indicate the large requirement of PL reduction, especially by the domestic and livestock pollution sources. As stated previously, the implementation of practical countermeasures was already counted in

Table 11.3.2 Required Pollution Load Reduction (T-N)

Scenario 1

Water Quality Checking Point	Inflow T-N Load (kg/day)	T-N Load from Upstream WQCP (kg/day)	Total Inflow T-N Load (kg/day)	Allowable Inflow Pollution Load (kg/day)	Required Pollution Load Reduction (kg/day)	Percentage of PL Reduction against Inflow T-N
2005						
C_{L1}	1,837	-	1,837	1,010	827	45%
C_{L2}	8,725	68	8,793	4,601	4,192	48%
C_{L3}	4,275	18	4,293	2,317	1,976	46%
2015						
C_{L1}	2,098	-	2,098	505	1,592	76%
C_{L2}	10,814	34	10,848	2,326	8,522	79%
C_{L3}	4,390	9	4,399	1,159	3,240	74%

Scenario 2

Water Quality Checking Point	Inflow T-N Load (kg/day)	T-N Load from Upstream WQCP (kg/day)	Total Inflow T-N Load (kg/day)	Allowable Inflow Pollution Load (kg/day)	Required Pollution Load Reduction (kg/day)	Percentage of PL Reduction against Inflow T-N
2005						
C_{L1}	1,789	-	1,789	1,009	780	44%
C_{L2}	7,457	68	7,525	4,569	2,956	40%
C_{L3}	4,207	18	4,225	2,317	1,908	45%
2015						
C_{L1}	2,031	-	2,031	505	1,526	75%
C_{L2}	9,826	34	9,860	2,315	7,545	77%
C_{L3}	4,272	9	4,281	1,159	3,122	73%

Table 11.3.3 Required Pollution Load Reduction (T-P)

Scenario 1

Water Quality Checking Point	Inflow T-P Load (kg/day)	T-P Load from Upstream WQCP (kg/day)	Total Inflow T-P Load (kg/day)	Allowable Inflow Pollution Load (kg/day)	Required Pollution Load Reduction (kg/day)	Percentage of PL Reduction against Inflow T-P
2005						
C_{L1}	222.8	-	223	137	86	38%
C_{L2}	1,256.3	8.5	1,265	275	990	79%
C_{L3}	552.2	4.5	557	407	150	27%
2015						
C_{L1}	301.1	-	301	27	274	91%
C_{L2}	1,559.1	1.7	1,561	29	1,532	98%
C_{L3}	568.7	0.5	569	136	433	76%

Scenario 2

Water Quality Checking Point	Inflow T-P Load (kg/day)	T-P Load from Upstream WQCP (kg/day)	Total Inflow T-P Load (kg/day)	Allowable Inflow Pollution Load (kg/day)	Required Pollution Load Reduction (kg/day)	Percentage of PL Reduction against Inflow T-P
2005						
C_{L1}	216.4	-	216	137	79	37%
C_{L2}	1,083.4	8.5	1,092	267	825	76%
C_{L3}	543.3	4.5	548	407	141	26%
2015						
C_{L1}	294.2	-	294	27	267	91%
C_{L2}	1,436.2	1.7	1,438	28	1,410	98%
C_{L3}	560.2	0.5	561	136	425	76%

Table 11.3.4 Required Pollution Load Reduction (COD)

Scenario 1

Water Quality Checking Point	Inflow COD Load (kg/day)	COD Load from Upstream WQCP (kg/day)	Total Inflow COD Load (kg/day)	Allowable Inflow Pollution Load (kg/day)	Required Pollution Load Reduction (kg/day)	Percentage of PL Reduction against Inflow COD
2005						
C_{L1}	13,178	-	13,178	4,687	8,491	64%
C_{L2}	67,542	1,700	69,242	25,393	43,849	65%
C_{L3}	33,183	720	33,903	30,813	3,090	9%
2015						
C_{L1}	21,559	-	21,559	3,483	18,077	84%
C_{L2}	78,288	1,020	79,308	7,293	72,016	92%
C_{L3}	35,304	270	35,574	10,663	24,912	71%

Scenario 2

Water Quality Checking Point	Inflow COD Load (kg/day)	COD Load from Upstream WQCP (kg/day)	Total Inflow COD Load (kg/day)	Allowable Inflow Pollution Load (kg/day)	Required Pollution Load Reduction (kg/day)	Percentage of PL Reduction against Inflow COD
2005						
C_{L1}	12,970	-	12,970	4,684	8,286	64%
C_{L2}	62,136	1,700	63,836	24,681	39,155	63%
C_{L3}	32,633	720	33,353	30,808	2,545	8%
2015						
C_{L1}	21,286	-	21,286	3,479	17,806	84%
C_{L2}	75,050	1,020	76,070	7,164	68,906	92%
C_{L3}	34,741	270	35,011	10,656	24,354	70%

Table 11.4.1 Allowable Pollution Load by Pollution Source at WQCPs (Scenario 1)

WQCP	Sub-basin	PL Source Category	T-N				T-P				COD			
			Present Composition*1		Allowable PL by PS*2 (kg/day)		Present Composition*1		Allowable PL by PS*2 (kg/day)		Present Composition*1		Allowable PL by PS*2 (kg/day)	
			Total	excl. Natural	2005	2015	Total	excl. Natural	2005	2015	Total	excl. Natural	2005	2015
C_{L1}	Seke & Harava Dams	Domestic	7.7%	14.6%	34.6	-39.2	7.8%	11.8%	8.6	-4.3	6.9%	25.8%	-1,171.6	-1,481.8
		Ind.(Unsewered)	0.0%	0.0%	0.0	0.0	0.0%	0.0%	0.0	0.0	0.0%	0.0%	0.0	0.0
		Livestock	44.8%	85.3%	201.7	-228.1	58.6%	88.2%	64.3	-32.5	19.9%	74.1%	-3,373.1	-4,266.3
		Natural*3	47.5%	-	773.0	773.0	33.6%	-	64.3	64.3	73.2%	-	9,236.3	9,236.3
		Solid Waste	0.1%	0.1%	0.3	-0.3	0.0%	0.0%	0.0	0.0	0.0%	0.1%	-4.4	-5.5
		WTW	0.0%	0.0%	0.0	0.0	0.0%	0.0%	0.0	0.0	0.0%	0.0%	0.0	0.0
		U/S WQCP*4	-	-	0.0	0.0	-	-	0.0	0.0	-	-	0.0	0.0
		Total	100.0%	100.0%	1,009.6	505.5	100.0%	100.0%	137.2	27.5	100.0%	100.0%	4,687.2	3,482.7
C_{L2}	Lake Chivero	Domestic	55.3%	74.0%	2,300.5	641.1	56.8%	69.4%	102.8	-63.5	45.0%	81.2%	5,406.0	-8,739.1
		Ind.(Unsewered)	0.1%	0.1%	2.1	0.6	0.2%	0.2%	0.3	-0.2	0.6%	1.0%	68.4	-110.6
		Livestock	19.0%	25.5%	790.8	220.4	24.9%	30.4%	45.0	-27.8	9.6%	17.3%	1,152.9	-1,863.7
		Natural*3	25.3%	-	1,425.8	1,425.8	18.1%	-	118.6	118.6	44.6%	-	17,035.3	17,035.3
		Solid Waste	0.3%	0.4%	12.9	3.6	0.0%	0.0%	0.0	0.0	0.2%	0.3%	19.7	-31.9
		WTW	0.0%	0.0%	0.8	0.2	0.0%	0.0%	0.0	0.0	0.1%	0.2%	10.6	-17.2
		U/S WQCP*4	-	-	68.0	34.0	-	-	8.5	1.7	-	-	1,700.0	1,020.0
		Total	100.0%	100.0%	4,600.8	2,325.7	0.0%	100.0%	275.2	28.8	0.0%	100.0%	25,393.0	7,292.8
C_{L3}	Lake Manyame	Domestic	1.7%	2.7%	17.9	-13.6	1.7%	2.2%	5.9	0.0	1.8%	3.5%	360.3	-321.0
		Ind.(Unsewered)	0.2%	0.4%	2.5	-1.9	0.3%	0.4%	1.0	0.0	6.5%	12.6%	1,308.4	-1,165.6
		Livestock	54.9%	87.6%	571.2	-434.8	65.5%	85.4%	226.7	-1.5	20.9%	40.2%	4,189.9	-3,732.6
		Natural*3	37.3%	-	1,646.6	1,646.6	23.3%	-	136.9	136.9	48.1%	-	19,674.3	19,674.3
		Solid Waste	0.1%	0.2%	1.1	-0.8	0.0%	0.0%	0.0	0.0	0.0%	0.1%	8.3	-7.4
		WTW	5.7%	9.2%	59.7	-45.4	9.2%	12.0%	31.9	-0.2	22.7%	43.7%	4,551.9	-4,055.1
		U/S WQCP*4	-	-	18.0	9.0	-	-	4.5	0.5	-	-	720.0	270.0
		Total	100.0%	100.0%	2,317.0	1,159.0	0.0%	100.0%	406.9	135.6	0.0%	100.0%	30,813.1	10,662.6

Note: *1; Composition of Present Inflow Pollution Load
Total; Share in Total Inflow Pollution Load (excluding upstream WQCP)
excl. Natural; Share in Inflow Pollution Load (excluding upstream WQCP and natural load)
*2; Allowable Pollution Load by Pollution Source for Environmental Water Quality Standard
*3; Fixed Pollution Load
*4; Fixed Pollution Load at Water Quality Standard.

Table 11.4.2 Allowable Pollution Load by Pollution Source at WQCPs (Scenario 2)

WQCP	Sub-basin	PL Source Category	T-N				T-P				COD			
			Present Composition*1		Allowable PL by PS*2 (kg/day)		Present Composition*1		Allowable PL by PS*2 (kg/day)		Present Composition*1		Allowable PL by PS*2 (kg/day)	
			Total	excl. Natural	2005	2015	Total	excl. Natural	2005	2015	Total	excl. Natural	2005	2015
C_{L1}	Seke & Harava Dams	Domestic	7.7%	14.6%	34.6	-39.2	7.8%	11.8%	8.6	-4.3	6.9%	25.8%	-1,172.3	-1,482.7
		Ind.(Unsewered)	0.0%	0.0%	0.0	0.0	0.0%	0.0%	0.0	0.0	0.0%	0.0%	0.0	0.0
		Livestock	44.8%	85.3%	201.5	-228.3	58.6%	88.2%	64.3	-32.5	19.9%	74.1%	-3,375.3	-4,268.8
		Natural*3	47.5%	-	773.0	773.0	33.6%	-	64.3	64.3	73.2%	-	9,236.3	9,236.3
		Solid Waste	0.1%	0.1%	0.3	-0.3	0.0%	0.0%	0.0	0.0	0.0%	0.1%	-4.4	-5.5
		WTW	0.0%	0.0%	0.0	0.0	0.0%	0.0%	0.0	0.0	0.0%	0.0%	0.0	0.0
		U/S WQCP*4	-	-	0.0	0.0	-	-	0.0	0.0	-	-	0.0	0.0
		Total	100.0%	100.0%	1,009.4	505.3	100.0%	100.0%	137.2	27.5	100.0%	100.0%	4,684.3	3,479.3
C_{L2}	Lake Chivero	Domestic	55.3%	74.0%	2,276.8	633.3	56.8%	69.4%	97.2	-63.8	45.0%	81.2%	4,827.7	-8,843.5
		Ind.(Unsewered)	0.1%	0.1%	2.1	0.6	0.2%	0.2%	0.3	-0.2	0.6%	1.0%	61.1	-112.0
		Livestock	19.0%	25.5%	782.6	217.7	24.9%	30.4%	42.5	-27.9	9.6%	17.3%	1,029.6	-1,886.0
		Natural*3	25.3%	-	1,425.8	1,425.8	18.1%	-	118.6	118.6	44.6%	-	17,035.3	17,035.3
		Solid Waste	0.3%	0.4%	12.7	3.5	0.0%	0.0%	0.0	0.0	0.2%	0.3%	17.6	-32.3
		WTW	0.0%	0.0%	0.8	0.2	0.0%	0.0%	0.0	0.0	0.1%	0.2%	9.5	-17.4
		U/S WQCP*4	-	-	68.0	34.0	-	-	8.5	1.7	-	-	1,700.0	1,020.0
		Total	100.0%	100.0%	4,568.8	2,315.1	0.0%	100.0%	267.2	28.3	0.0%	100.0%	24,680.8	7,164.2
C_{L3}	Lake Manyame	Domestic	1.7%	2.7%	17.9	-13.6	1.7%	2.2%	5.9	0.0	1.8%	3.5%	360.2	-321.2
		Ind.(Unsewered)	0.2%	0.4%	2.5	-1.9	0.3%	0.4%	1.0	0.0	6.5%	12.6%	1,307.7	-1,166.3
		Livestock	54.9%	87.6%	571.1	-435.1	65.5%	85.4%	226.7	-1.5	20.9%	40.2%	4,187.8	-3,735.1
		Natural*3	37.3%	-	1,646.6	1,646.6	23.3%	-	136.9	136.9	48.1%	-	19,674.3	19,674.3
		Solid Waste	0.1%	0.2%	1.1	-0.8	0.0%	0.0%	0.0	0.0	0.0%	0.1%	8.3	-7.4
		WTW	5.7%	9.2%	59.7	-45.5	9.2%	12.0%	31.9	-0.2	22.7%	43.7%	4,549.6	-4,057.8
		U/S WQCP*4	-	-	18.0	9.0	-	-	4.5	0.5	-	-	720.0	270.0
		Total	100.0%	100.0%	2,316.9	1,158.7	0.0%	100.0%	406.9	135.6	0.0%	100.0%	30,807.9	10,656.4

Note: *1; Composition of Present Inflow Pollution Load
Total; Share in Total Inflow Pollution Load (excluding upstream WQCP)
excl. Natural; Share in Inflow Pollution Load (excluding upstream WQCP and natural load)
*2; Allowable Pollution Load by Pollution Source for Environmental Water Quality Standard
*3; Fixed Pollution Load
*4; Fixed Pollution Load at Water Quality Standard.

Table 11.4.3 Required Pollution Load Reduction by Pollution Source at WQCPs (T-N)

WQCP	Sub-basin	PL Source Category	Scenario 1								Scenario 2							
			2005				2015				2005				2015			
			Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL	Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL	Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL	Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL
C_{L1}	Seke & Harava Dams	Domestic	333.6	34.6	298.9	90%	594.3	-39.2	633.4	107%	286.9	34.6	252.3	88%	528.4	-39.2	567.6	107%
		Ind.(Unsewered)	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-
		Livestock	728.3	201.7	526.6	72%	728.3	-228.1	956.4	131%	728.3	201.5	526.8	72%	728.3	-228.3	956.6	131%
		Natural	773.0	773.0	0.0	0%	773.0	773.0	0.0	0%	773.0	773.0	0.0	0%	773.0	773.0	0.0	0%
		Solid Waste	1.9	0.3	1.6	87%	2.3	-0.3	2.6	112%	1.2	0.3	1.0	80%	1.5	-0.3	1.8	119%
		WTW	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-
		Total	1,836.8	1,009.6	827.1	45%	2,097.9	505.5	1,592.5	76%	1,789.5	1,009.4	780.1	44%	2,031.2	505.3	1,526.0	75%
C_{L2}	Lake Chivero	Domestic	6,221.5	2,300.5	3,921.0	63%	8,308.2	641.1	7,667.1	92%	4,951.1	2,276.8	2,674.2	54%	7,317.6	633.3	6,684.3	91%
		Ind.(Unsewered)	0.9	2.1	-1.2	-142%	0.9	0.6	0.3	33%	0.9	2.1	-1.2	-139%	0.9	0.6	0.3	34%
		Livestock	1,071.4	790.8	280.7	26%	1,071.4	220.4	851.1	79%	1,071.4	782.6	288.8	27%	1,071.4	217.7	853.7	80%
		Natural	1,425.8	1,425.8	0.0	0%	1,425.8	1,425.8	0.0	0%	1,425.8	1,425.8	0.0	0%	1,425.8	1,425.8	0.0	0%
		Solid Waste	4.4	12.9	-8.5	-195%	6.0	3.6	2.4	40%	6.4	12.7	-6.4	-100%	9.2	3.5	5.6	61%
		WTW	1.3	0.8	0.5	39%	1.7	0.2	1.5	87%	1.2	0.8	0.4	36%	1.4	0.2	1.2	84%
		Total	8,725.2	4,532.8	4,192.4	48%	10,813.9	2,291.7	8,522.3	79%	7,456.7	4,500.8	2,955.9	40%	9,826.2	2,281.1	7,545.1	77%
C_{L3}	Lake Manyame	Domestic	128.1	17.9	110.2	86%	223.9	-13.6	237.6	106%	78.1	17.9	60.2	77%	131.0	-13.6	144.6	110%
		Ind.(Unsewered)	10.5	2.5	8.0	76%	10.5	-1.9	12.4	118%	10.5	2.5	8.0	76%	10.5	-1.9	12.4	118%
		Livestock	2,425.7	571.2	1,854.5	76%	2,425.7	-434.8	2,860.5	118%	2,425.7	571.1	1,854.6	76%	2,425.7	-435.1	2,860.8	118%
		Natural	1,646.6	1,646.6	0.0	0%	1,646.6	1,646.6	0.0	0%	1,646.6	1,646.6	0.0	0%	1,646.6	1,646.6	0.0	0%
		Solid Waste	36.7	1.1	35.6	97%	49.0	-0.8	49.8	102%	25.2	1.1	24.1	96%	32.4	-0.8	33.3	103%
		WTW	27.3	59.7	-32.4	-119%	34.6	-45.4	80.1	231%	21.1	59.7	-38.6	-183%	26.0	-45.5	71.5	275%
		Total	4,274.9	2,299.0	1,975.9	46%	4,390.4	1,150.0	3,240.4	74%	4,207.2	2,298.9	1,908.4	45%	4,272.2	1,149.7	3,122.5	73%

Table 11.4.4 Required Pollution Load Reduction by Pollution Source at WQCPs (T-P)

WQCP	Sub-basin	PL Source Category	Scenario 1								Scenario 2							
			2005				2015				2005				2015			
			Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL	Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL	Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL	Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL
C_{L1}	Seke & Harava Dams	Domestic	46.2	8.6	37.6	81%	124.6	-4.3	128.9	103%	39.9	8.6	31.3	78%	117.6	-4.3	122.0	104%
		Ind.(Unsewered)	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-
		Livestock	112.3	64.3	48.0	43%	112.3	-32.5	144.8	129%	112.3	64.3	48.0	43%	112.3	-32.5	144.8	129%
		Natural	64.3	64.3	0.0	0%	64.3	64.3	0.0	0%	64.3	64.3	0.0	0%	64.3	64.3	0.0	0%
		Solid Waste	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-
		WTW	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-
		Total	222.8	137.2	85.6	38%	301.1	27.5	273.7	91%	216.4	137.2	79.3	37%	294.2	27.5	266.8	91%
C_{L2}	Lake Chivero	Domestic	974.7	102.8	871.9	89%	1,277.3	-63.5	1,340.8	105%	801.8	97.2	704.6	88%	1,154.5	-63.8	1,218.3	106%
		Ind.(Unsewered)	0.2	0.3	-0.2	-128%	0.2	-0.2	0.5	188%	0.2	0.3	-0.2	-116%	0.2	-0.2	0.5	189%
		Livestock	162.8	45.0	117.8	72%	162.8	-27.8	190.5	117%	162.8	42.5	120.2	74%	162.8	-27.9	190.7	117%
		Natural	118.6	118.6	0.0	0%	118.6	118.6	0.0	0%	118.6	118.6	0.0	0%	118.6	118.6	0.0	0%
		Solid Waste	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-
		WTW	0.1	0.0	0.1	78%	0.2	0.0	0.2	109%	0.1	0.0	0.1	78%	0.2	0.0	0.2	109%
		Total	1,256.3	266.7	989.6	79%	1,559.1	27.1	1,532.0	98%	1,083.4	258.7	824.7	76%	1,436.2	26.6	1,409.7	98%
C_{L3}	Lake Manyame	Domestic	14.8	5.9	8.9	60%	24.1	0.0	24.2	100%	9.4	5.9	3.5	37%	17.3	0.0	17.4	100%
		Ind.(Unsewered)	1.1	1.0	0.1	6%	1.7	0.0	1.7	100%	1.1	1.0	0.1	6%	1.7	0.0	1.7	100%
		Livestock	385.9	226.7	159.2	41%	385.9	-1.5	387.4	100%	385.9	226.7	159.2	41%	385.9	-1.5	387.4	100%
		Natural	136.9	136.9	0.0	0%	136.9	136.9	0.0	0%	136.9	136.9	0.0	0%	136.9	136.9	0.0	0%
		Solid Waste	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-
		WTW	13.5	31.9	-18.4	-136%	20.1	-0.2	20.3	101%	10.1	31.9	-21.8	-217%	18.3	-0.2	18.5	101%
		Total	552.2	402.4	149.8	27%	568.7	135.2	433.5	76%	543.3	402.4	141.0	26%	560.2	135.2	425.0	76%

Table 11.4.5 Required Pollution Load Reduction by Pollution Source at WQCPs (COD)

WQCP	Sub-basin	PL Source Category	Scenario 1								Scenario 2							
			2005				2015				2005				2015			
			Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL	Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL	Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL	Projected Inflow Pollution Load (kg/day)	Allowable PL by PS (kg/day)	Required Pollution Load Reduction (kg/day)	% against Projected Inflow PL
C_{L1}	Seke & Harava Dams	Domestic	1,422.7	-1,171.6	2,594.3	182%	9,802.6	-1,481.8	11,284.4	115%	1,216.7	-1,172.3	2,389.0	196%	9,531.4	-1,482.7	11,014.1	116%
		Ind.(Unsewered)	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-
		Livestock	2,513.4	-3,373.1	5,886.6	234%	2,513.4	-4,266.3	6,779.7	270%	2,513.4	-3,375.3	5,888.7	234%	2,513.4	-4,268.8	6,782.2	270%
		Natural	9,236.3	9,236.3	0.0	0%	9,236.3	9,236.3	0.0	0%	9,236.3	9,236.3	0.0	0%	9,236.3	9,236.3	0.0	0%
		Solid Waste	5.6	-4.4	10.0	-	7.0	-5.5	12.5	179%	3.7	-4.4	8.0	-	4.4	-5.5	10.0	225%
		WTW	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-	0.0	0.0	0.0	-
		Total	13,178.1	4,687.2	8,490.9	64%	21,559.4	3,482.7	18,076.7	84%	12,970.1	4,684.3	8,285.8	64%	21,285.5	3,479.3	17,806.2	84%
C_{L2}	Lake Chivero	Domestic	46,705.5	5,406.0	41,299.5	88%	57,423.1	-8,739.1	66,162.2	115%	41,294.9	4,827.7	36,467.1	88%	54,178.6	-8,843.5	63,022.1	116%
		Ind.(Unsewered)	81.6	68.4	13.2	16%	81.6	-110.6	192.2	236%	81.6	61.1	20.5	25%	81.6	-112.0	193.6	237%
		Livestock	3,665.7	1,152.9	2,512.9	69%	3,665.7	-1,863.7	5,529.5	151%	3,665.7	1,029.6	2,636.2	72%	3,665.7	-1,886.0	5,551.7	151%
		Natural	17,035.3	17,035.3	0.0	0%	17,035.3	17,035.3	0.0	0%	17,035.3	17,035.3	0.0	0%	17,035.3	17,035.3	0.0	0%
		Solid Waste	14.2	19.7	-5.5	-	19.4	-31.9	51.3	265%	20.7	17.6	3.1	-	29.8	-32.3	62.1	208%
		WTW	39.5	10.6	28.8	73%	63.4	-17.2	80.6	127%	37.4	9.5	27.9	75%	59.4	-17.4	76.8	129%
		Total	67,541.8	23,693.0	43,848.8	65%	78,288.5	6,272.8	72,015.7	92%	62,135.7	22,980.8	39,154.8	63%	75,050.5	6,144.2	68,906.3	92%
C_{L3}	Lake Manyame	Domestic	928.1	360.3	567.8	61%	2,596.0	-321.0	2,917.0	112%	679.6	360.2	319.4	47%	2,239.8	-321.2	2,561.0	114%
		Ind.(Unsewered)	2,683.1	1,308.4	1,374.8	51%	2,683.1	-1,165.6	3,848.7	143%	2,683.1	1,307.7	1,375.4	51%	2,683.1	-1,166.3	3,849.5	143%
		Livestock	8,546.3	4,189.9	4,356.4	51%	8,546.3	-3,732.6	12,278.9	144%	8,546.3	4,187.8	4,358.5	51%	8,546.3	-3,735.1	12,281.4	144%
		Natural	19,674.3	19,674.3	0.0	0%	19,674.3	19,674.3	0.0	0%	19,674.3	19,674.3	0.0	0%	19,674.3	19,674.3	0.0	0%
		Solid Waste	129.3	8.3	121.0	-	172.7	-7.4	180.1	104%	88.9	8.3	80.6	-	114.4	-7.4	121.8	106%
		WTW	1,221.8	4,551.9	-3,330.1	-273%	1,631.8	-4,055.1	5,686.9	348%	960.3	4,549.6	-3,589.3	-374%	1,482.8	-4,057.8	5,540.6	374%
		Total	33,182.9	30,093.1	3,089.9	9%	35,304.2	10,392.6	24,911.5	71%	32,632.5	30,087.9	2,544.6	8%	34,740.6	10,386.4	24,354.2	70%

the calculation of discharged pollution loads for the domestic (sewerage system) and WTW (wastewater treatment facility). The reduction of PL shall be accomplished by the introduction of advanced sewage treatment processes and by adequate countermeasures to other pollution sources. However, it may be difficult to fulfil the requirement for the livestock PL.

The calculation results of Scenario-1 and Scenario-2 show the same tendency in general, though the individual figures are different. The achievement of assumed environmental water quality standards in the year 2015 seems to be difficult at all WQCPs in application of present practices and investment level.

The following are findings by water quality checking point.

- At the point C_{L1}, subject pollution sources to be reduced are population and livestock. Since the possible countermeasures have been assumed for the projection of domestic discharged PL the effort for PL reduction shall be concentrated on the livestock (about 80% of the requirement is allotted).
- At the point C_{L2}, domestic PL (about 90% of the PL to be reduced) shall be controlled. Since practical countermeasures were already counted on this source, drastic countermeasures may be introduced even for the year 2005.
- At the point C_{L3}, more than 90% of the PL to be reduced is accounted for the livestock PL. Therefore, the PL reduction shall be attained mainly by the livestock PL. The PL allocation to the solid waste is negligible comparing with the total PL to be reduced.
- The reduction of PL at the WTW is expected to be achieved before the year 2005 introducing wastewater treatment facilities at the Morton Jaffray WTW.

11.5 Countermeasures for Reduction of Pollution Load

As discussed in Chapter 10, it may be possible to maintain roughly the future water quality at the present level in provision of the countermeasures assumed in the projection. In other words, the water quality will seriously worsen if sewerage countermeasures, i.e. the augmentation of the sewerage systems and the provision of WTW wastewater treatment facilities, are not implemented. These countermeasures were adopted for the water quality projection as practical and possible bases to be implemented. The effluent quality of the STWs meets current regulations and discharge of treated effluent into rivers is in line with the policy of the Ministry of Lands and Water Resources.

Though further improvement of the water quality of the lakes/dams is desirable for the low cost operation of water treatment works, it seems to be difficult to introduce more sophisticated countermeasures and to provide measures to livestock PL because of economic and technical reasons. The operation cost between the WTWs and the STWs is a trade-off relationship, and it is economical to treat the necessary water only for the water supply purpose if the raw water quality is acceptable.

The following are alternative countermeasures without concerning cost requirements and technological level to achieve assumed water quality standard.

- Domestic PL: Advanced treatment (by physical and chemical processes)
  Control of phosphate-containing detergent
  Discharge of treated effluent outside the basin
  Relocation of population and industries to affordable different basins and compression of future frame values
- Livestock PL: On-site wastewater treatment (for pen feeding)
  Treatment pond system at the downstream of livestock feeding field
  Relocation of livestock to the outside of the basin and compression of frame values
- Natural PL: Stormwater treatment before discharging to rivers (on-site or by STW)
  Cleaning of roads and public spaces to remove nutrients
  Control in provision of fertiliser
- Solid Waste PL: On-site leachate treatment
  Relocation of dumping sites to the outside of the basin
- WTW PL: Wastewater treatment
- Direct countermeasures to lakes/dams:
  Removal of sedimentation on the bottom of lakes/dams
  Purification of lake water by cultivation and removal of water hyacinth
  Purification of river water with reed field
  Forced circulation of lake water (by air lift tube)
  Introduction of clean water (groundwater, surface water from the outside of the basin)

The required countermeasures by pollution source were discussed to meet water quality standard established. However, the water pollution analyses were conducted adopting macrocosmic approach with limited data available and various assumption. In this regard, it is strongly recommended that continuous water quality and flow monitoring at selective sampling points shall be conducted to obtain reliable data and to establish a reliable pollution analysis model. The periodical review and updating of the water pollution analysis shall be implemented to come up with appropriate countermeasures to suit for the actual needs through the future.