

CHAPTER 6

PROJECTION OF FRAME VALUES



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6.1 General

A projection of the various frame values from the present (1995) to the final target year (2015) was made for the identified water pollution sources. These frame values include population, industry, livestock and slaughterhouse, farming and others. The unit of each frame value was selected with reference to the data availability for the establishment of the unit pollution load both in quality and quantity.

6.2 Population Projection

6.2.1 Urban Population of Calculation Base Year 1992

The most recent population census was conducted in 1992 for the urban areas. The census figures could be used in principle as the projection base for the planning base year 1995, and for the medium and final target years. However, some studies present modified figures in their respective urban areas. In this connection, a comparative study was made of the five urban areas concerned, referring to the existing plans to come up with those to be used for planning purposes. Table 6.2.1 summarizes the comparison results.

Table 6.2.1 1992 Urban Population by Different Source

Name	1992 Census	Harare Combination M/P *1	Harare Water M/P *2	Adopted
Harare City	1,126,473	1,156,331	1,184,170	1,126,473
Chitungwiza Mun.	274,912	354,541	274,912	354,541
Norton Town	20,405	-	20,083	20,405
Ruwa Local Board	1,447	-	1,447	1,447
Epworth Local Board	62,630	-	62,701	62,630

Note: *1; Harare Combination Master Plan, Report of Study, 26 August 1992
*2; Master Plan for Water Distribution, Volume 3/Appendix A, 1995
(estimated figures based on field survey)

Harare City; excluding Epworth Local Board

The national census results in 1992 were, in principle, employed for the 1992 urban population, since there were no big differences between the census figures and the existing plans, except for that of Chitungwiza Municipality. The present population of Chitungwiza Municipality used in Harare Combination M/P was employed to meet the current population reported by the municipality. The following illustrates the outline of the past population trends by urban area.

- Harare City
Population investigations in Harare were conducted in 1904, 1962, 1982 and 1992. The annual average growth rate in the last decade between 1982 (658,364) and 1992 (1,189,103) was about 6.1%. The 1992 census population of the City, excluding Epworth Local Board, was 1,126,473 (City total was 1,189,103).
- Chitungwiza Municipality
The annual average growth rate in the census results between 1982 (171,559) and 1992 (274,912) was approximately 4.8%. However, the actual increase of the population in the status of municipality become considerable, as noted in the second urban development project (growth rate is analyzed to be 9% per annum).
- Norton Town Council
The population of Norton in 1982 and 1992 was 12,483 and 20,405, respectively, with an annual growth rate of approximately 5.04%.
- Ruwa Local Board
The population of Ruwa in 1992 was 1,447 as a result of the national census, which is used for any existing plans.
- Epworth Local Board
The 1992 census population was 62,630, which is the base figure for any planning purpose of the Local Board.

The distribution of population to the relevant river/lake sub-basins in Harare City was attempted covering the Gwebi, Marimba, Mukuvisi and Ruwa Rivers and Lake Chivero, as well as other rivers outside of the study basin. The population distribution within the suburban areas (see Figure 6.2.1) in Harare City was studied in 1993 by the City Authority (Master Plan for Water Distribution, 1995). Using the study results, the population in 1993 was distributed to the concerned sub-basins of river/lake in consideration of the area's composition of the suburban areas in the respective sub-basins. Table 6.2.2 and Table 6.2.3 show the suburban area composition by sub-basin of the river/lakes in Harare City (1993) and the population distribution by river/lake sub-basin in Harare City in 1993, respectively. The study basin encompasses 447.10 km² with 1,214,119 persons.

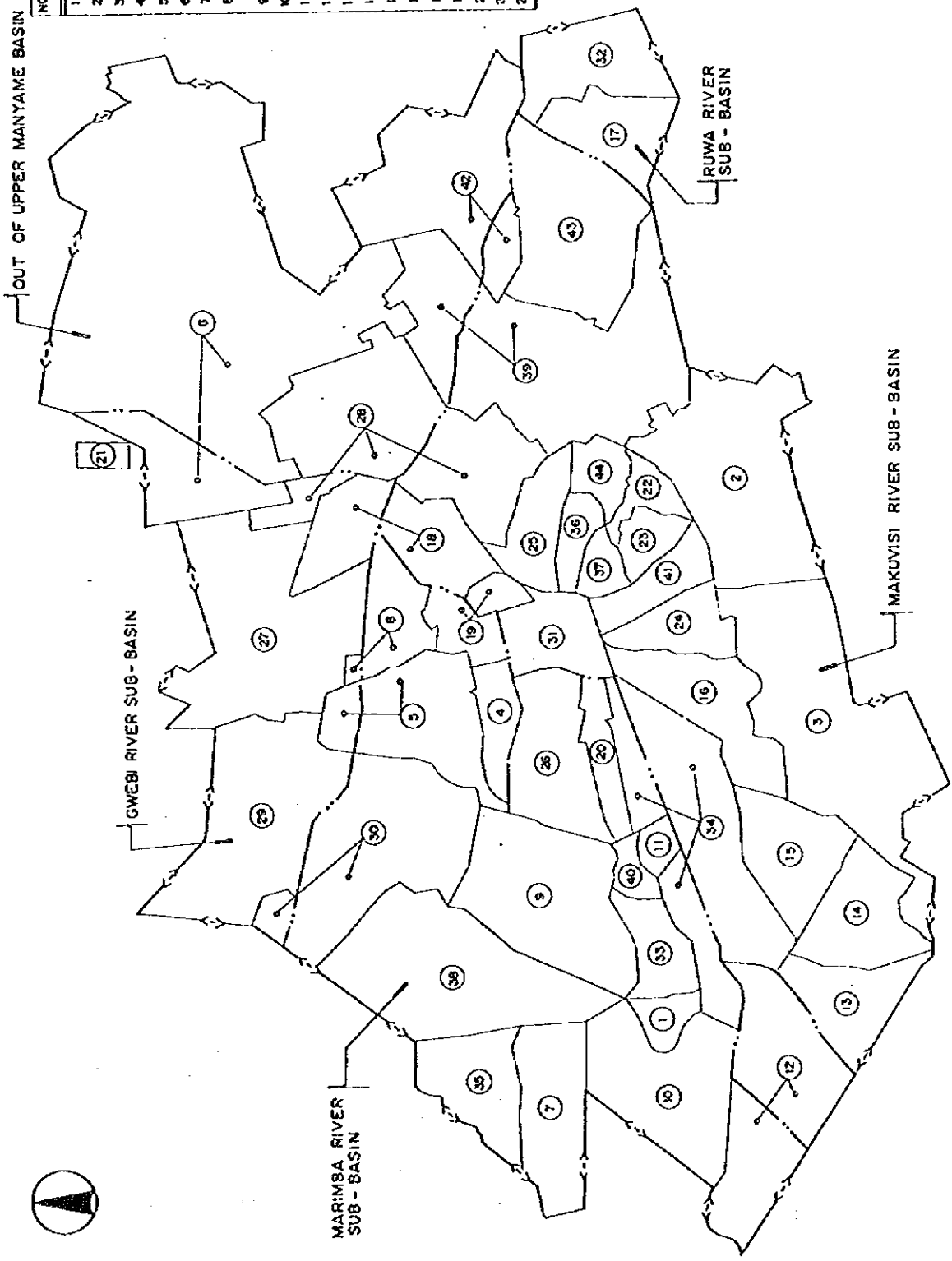
6.2.2 Rural District Population of Calculation Base Year 1992

There are seven Rural Districts (R.D.) in the study area: Harare, Goromonzi, Manyame and Marondera in Mashonaland East, Mazowe in Mashonaland Central, and Chegutu and Zvimba in Mashonaland West. The administrative area and population of the concerned R.D. in 1992 are referred to the 1992 census results as shown in Table 6.2.4. Meanwhile, the population in



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NO.	SUBURBAN	AREA Km ²	NO.	SUBURBAN	AREA Km ²
1	MARIMBA/PARK	2.35	23	CRANBORNE	2.72
2	HATFIELD	22.20	24	SUNNINGDALE	5.15
3	WATERFALLS	28.14	25	EAST-LEA	5.94
4	MILTON PARK	3.83	26	BELVEDERE	10.36
5	AVONDALE	13.09	27	MT. PLEASANT	24.37
6	BORROWDALE	78.53	28	HIGHLANDS	27.92
7	KUWADZANA	10.10	29	MARLBOROUGH	19.87
8	ALEXANDRA PARK	5.84	30	MABELREIGN	20.85
9	WARREN PARK	17.94	31	CITY CENTRE	6.37
10	MUFAKOSE	14.03	32	TAFARA	9.76
11	RUGARE	1.44	33	KAMBUZUMU	4.82
12	BUDIRIRO	18.65	34	SOUTHERTON	23.64
13	GLEN VIEW	7.45	35	DZIVARESEKWA	7.88
14	HIGHFIELDS	8.24	36	HILLSIDE	2.82
15	MBARE	10.09	37	BRAESIDE	2.08
16	MABVUKU	7.17	38	TYNWALD	21.45
17	GUNHILL	12.16	39	GREENDALE	33.41
18	BELGRAVIA	4.86	40	WESTWOOD	1.66
19	RIDGEVIEW	4.00	41	ARCADIA	4.44
20	HATCHLIFFE	1.17	42	CHIKURUBI	19.66
21	QUEENSDALE	2.67	43	CLEVELAND DAM	17.15
22			44	MUKUMSI W/LANDS	3.10

LEGEND :

- - - - - CITY BOUNDARY

- - - - - RIVER BASIN BOUNDARY

- - - - - SUB - URBAN BOUNDARY

Figure 6.2.1 Suburban Areas in Harare City

Table 6.2.2 (1) Suburban Area Composition by Sub-Basin of River/Lake

Unit: km²

Suburban	Sub-basin	Ruwa	Mukuvisi	Marimba	Lake Chivero	Gwebi	Outside	Total
1	Marimba Park			2.35				2.35
2	Maffield		22.20					22.20
3	Waterfalls		28.14					28.14
4	Milton Park			3.83				3.83
5	Avondale			10.90		2.19		13.09
6	Borrowdale					7.97	70.38	78.35
7	Kuwadzana			10.10				10.10
8	Alexandra Park			5.37		0.47		5.84
9	Warren Park			17.94				17.94
10	Mufakose			14.03				14.03
11	Rugare			1.44				1.44
12	Budiro			7.45	11.20			18.65
13	Glen View		7.45					7.45
14	Glen Norah		8.48					8.48
15	Highfields		8.24					8.24
16	Mbare		10.09					10.09
17	Mavuku	7.17						7.17
18	Gunhill		6.53			5.63		12.16
19	Belgravia		0.99	3.87				4.86
20	Ridgeview			4.00				4.00
21	Hacienda					1.17		1.17
22	Queensdale		2.67					2.67
23	Cranborne		2.72					2.72
24	Sunningdale		5.13					5.13
25	Eastlea		5.94					5.94
26	Belvedere			10.36				10.36
27	Mt. Pleasant					24.37		24.37
28	Highlands		9.69			3.08	15.15	27.92
29	Marlborough					19.87		19.87

Source: City of Harare, Master Plan for Water Distribution, Appendix A, June 1995

Table 6.2.2 (2) Suburban Area Composition by Sub-Basin of River/Lake

Unit: km²

Suburban	Sub-basin	Ruwa	Mukuvisi	Marimba	Lake Chivero	Gwebi	Outside	Total
30	Mabelreign			19.60		1.25		20.85
31	City Centre		6.37					6.37
32	Tafara	9.73						9.73
33	Kambuzuma			4.82				4.82
34	Southerton		15.09	8.55				23.64
35	Dzivaresekwa			7.88				7.88
36	Hillside		2.62					2.62
37	Braeside		2.08					2.08
38	Tynwald			21.45				21.45
39	Greendale		25.75				7.66	33.41
40	Westwood			1.66				1.66
41	Arcadia		4.44					4.44
42	Chikurubi		2.50				17.16	19.66
43	Cleveland Dam		17.15					17.15
44	Mukuvisi W'lands		3.13					3.13
	Total	16.90	197.40	155.60	11.20	66.00	110.35	557.45

Source: City of Harare, Master Plan for Water Distribution, Appendix A, June 1995

Total Area of Study basin in Harare City (1993) : 447.10 km²

Total Area Out of Study basin in Harare City (1993): 110.35 km²

Table 6.2.3 (1) Population Distribution by River/Lake Sub-Basin in Harare City (1993)

Unit: Population; person

Population density: person/km²

Suburban	Sub-basin	Ruwa	Mukuvisi	Marimba	Lake Chivero	Gwebi	Outside	Total	Population Density
1	Marimba Park		7,667					7,667	3,263
2	Haffield		30,590					30,590	1,378
3	Waterfalls		34,412					34,412	1,223
4	Milton Park			3,824				3,824	998
5	Avondale			13,797		2,772		16,569	1,266
6	Borrowdale					3,630	32,058	35,688	455
7	Kuwadzana			75,200				75,200	7,446
8	Alexandra Park			2,344		205		2,549	436
9	Warren Park			68,827				68,827	3,837
10	Mufakose			95,593				95,593	6,813
11	Rugare			8,922				8,922	6,196
12	Budiriro			65,003	0			65,003	3,485
13	Glen View		137,654					137,654	18,477
14	Glen Norah		63,729					63,729	7,515
15	Higbfields		85,396					85,396	10,364
16	Mbare		107,064					107,064	10,611
17	Mavuku	47,159						47,159	6,577
18	Gunhill		2,054			1,770		3,824	314
19	Belgravia		519	2,030				2,549	524
20	Ridgeview			1,275				1,275	319
21	Hatcliffe					5,098		5,098	4,357
22	Queensdale		6,373					6,373	2,387
23	Cranborne		10,197					10,197	3,749
24	Sunningdale		7,647					7,647	1,491
25	Eastlea		8,923					8,923	1,502
26	Belvedere			11,471				11,471	1,107
27	Mt. Pleasant					33,139		33,139	1,360
28	Highbands		12,828			4,078	20,057	36,963	1,324
29	Marlborough					20,393		20,393	1,026

Source: City of Harare, Master Plan for Water Distribution, Appendix A, June 1995

Table 6.2.3 (2) Population Distribution by River/Lake Sub-Basin in Harare City (1993)

Unit: Population; person

Suburban	Sub-basin	Population density; person/km ²							
		Ruwa	Mukuvisi	Marimba	Lake Chivero	Gwebi	Outside	Total	Population Density
30	Mabelreign			27,558		1,757		29,315	1,406
31	City Centre		36,963					36,963	5,803
32	Tafara	31,684						31,684	3,256
33	Kambuzuma			34,413				34,413	7,140
34	Southern		4,881	2,766				7,647	323
35	Dzivareshkwa			44,599				44,599	5,660
36	Hillside		3,840					3,840	1,466
37	Braeside		5,098					5,098	2,451
38	Tynwald			7,647				7,647	357
39	Greendale		27,506					35,688	1,068
40	Westwood			1,275			8,182	1,275	768
41	Arcadia		2,549					2,549	574
42	Chikurubi		0				0	0	0
43	Cleveland Dam		0					0	0
44	Mukuvisi Wlands		0					0	0
	Total	78,843	588,223	474,211	0	72,842	60,297	1,274,416	2,286

Source: City of Harare, Master Plan for Water Distribution, Appendix A, June 1995

Total Population of Study basin in Harare City (1993) : 1,214,119

Total Population Out of Study basin in Harare City (1993) : 60,297

the study area by R.D. were estimated in proportion to the area's composition and presented in the same table.

Table 6.2.4 Rural District Population in 1992

Province	Rural District Council	Administrative Area		Study Area	
		Area (km ²)	Population	Area (km ²)	Population
Mashonaland East	Harare R.D.	258.9	21,600	258.9	21,600
	Goromonzi R.D.	2,487.0	147,159	495.6	29,325
	Manyame R.D.	2,587.0	75,178	534.1	15,521
	Marondera R.D.	3,489.0	105,138	226.6	6,828
Mashonaland Central	Mazowe R.D.	4,416.0	197,508	254.0	11,360
Mashonaland West	Chegutu R.D.	5,409.5	140,378	261.1	6,776
	Zvimba R.D.	6,200.0	230,161	1,318.6	48,950
Total		24,847.4	917,122.0	3,348.9	140,360

Note: R.D.; Rural District

Since there was no data available on the 1992 population by river/lake sub-basin, the distribution of the population by R. D. to the concerned sub-basins was done in proportion to the area's measured composition. Table 6.2.5 presents composition of the sub-basin areas by urban area/rural district and the population is summarized in Table 6.2.6.

6.2.3 Alternative Population Projection of the Study Area

The population of the Study Area by local authority was projected for the base year 1995, the medium target years 2000 and 2005, and the final target year 2015. The base figures for the projection are either those of the year 1992 or 1993. The 1993 population projected by the City Authority, based on 1992 census results, is used for Harare City for the convenience of planning.

The factors for the population projection are referred to in the previous study results, which include (1) the Harare Combination Master Plan, 1992, (2) the Master Plan for Water Distribution for the City of Harare, 1995, and the future land use plans for the four cases as shown below.

Case 1: Application of population growth rates used in the "Master Plan for Water Distribution, the City of Harare, 1995, Appendix A." The projected future growth rates are as follows:

Harare City	:	6.04%
Chitungwiza Municipality	:	4.80%
Other urban area	:	6.40%
Rural District	:	2.65%

Table 6.2.5 River/Lake Area Composition by Urban Area/Rural District

Unit: km²

Province/City	Local Authority	Manyame *4	Ruwa	Seke & Harava	Nyaisime	Mukuvisi	Manyame *3	Marimba	Lake Chivero	Muzururu	Gwebi	Lake Manyame	Total
Harare	Chitungwiza		16.9			197.4		155.6	11.2		66.0		447.1
	Ruwa		31.4		33.1		8.9						42.0
	Epworth		7.4	0.8		2.9							31.4
	Harare R. D.	1.3	44.6	24.6		20.2	30.4						121.1
	Harare R.D.*5			57.2			80.6						137.8
Mashonaland East	Goromonzi R. D.	399.1	94.7	1.8									495.6
	Manyame R. D.	73.6		30.6	320.3		46.1		63.5				534.1
	Marondera R. D.				226.6						254.0		226.6
	Mazowe R. D.											19.5	19.5
	Norton											212.3	212.3
Mashonaland West	Chegutu R. D.								48.8				48.8
	Zvimba R. D.					9.5		59.4	131.5 *2	310.0	450.0	358.2 *1	1,318.6
Total		474.0	195.0	115.0	580.0	230.0	166.0	215.0	255.0	310.0	770.0	590.0	3,900.0

Note : R. D. ; Rural District

*1 : Include Lake Manyame Area (81.0 km²)

*2 : Include Lake Chivero Area (26.3 km²)

*3 : Manyame River Sub-Basin (Section between The confluences of Mukuvisi river and Seke Dam)

*4 : Manyame River Sub-Basin (Upstream)

*5 : The area of the City of Harare expansion area

Table 6.2.6 Population Distribution to River/Lake Sub-basins by Urban Area /Rural District(1992/1993)

Unit: person

Province/City	Local Authority	Manyame *3	Ruwa	Seke & Harava	Nyatsime	Mukuvisi	Manyame *2	Marimba	Lake Chivero	Muzuruu	Gwebi	Lake Manyame	Total
Harare	Chitungwiza		78,843			588,223	75,129	474,211	0		72,842		1,214,119
	Ruwa		1,447		279,412								354,541
	Epworth		41,753	4,514		16,363							1,447
	Harare R. D.	108	3,721	2,050		1,685	2,538						62,630
Mashonaland East	Harare R.D.*4			4,775			6,723						10,102
	Goromonzi R. D.	23,615	5,603	107									11,498
	Manyame R. D.	2,139		889	9,308		1,340		1,845				29,325
	Marondera R. D.				6,828								15,521
Mashonaland Central	Mazowe R. D.										11,360		6,828
	Norton											20,405	11,360
Mashonaland West	Chegutu R. D.								1,266			5,510	20,405
	Zvimba R. D. *1					385		2,400	4,251	12,527	18,185	11,202	6,776
Total		25,862	131,367	12,335	295,548	606,656	85,730	476,611	7,362	12,527	102,387	37,117	1,793,502

Note : R. D. ; Rural District

Base Year ; 1993 on the Harare City and 1992 on the other authorities

*1 : Include Lake Manyame Area (81.0 km²) and Lake Chivero Area (26.3 km²)

*2 : Manyame River Sub-Basin (Section between the confluences of Mukuvisi River to Seke Dam)

*3 : Manyame River Sub-Basin (Upstream)

*4 : The area of the City of Harare expansion area

Case 2: Application of the population growth rates for Harare City in the "Crowborough Sewage Treatment Works, City of Harare, Volume 1 Catchment Study, 1995" and Case 1 assumption for other areas.

Harare City	:	5.59%
Chitungwiza Municipality	:	4.80%
Other urban area	:	6.40%
Rural District	:	2.65%

Case 3: Application of the population growth rates used in "Harare Combination Master Plan, Report of Study, 1992"

Local Authority	1993	1994	1995	2000	2005	2010	2015
Harare City	3.45	3.36	3.28	3.08	2.85	2.69	2.54
Chitungwiza Mun.	5.98	5.83	5.57	5.08	4.44	3.93	3.50
Other Authorities	4.68	2.23	2.19	2.11	2.01	1.93	1.82

Case 4: Application of the factors used in "Master Plan for Water Distribution, Harare City, Volume 3, 1995".

Low Density:

60% of land available for housing, 2,000 m² housing size, 4 persons/house

Medium Density:

60% of land available for housing, 800 m² housing size, 6 persons/house

High Density: Harare City, Chitungwiza Municipality

60% of land available for housing, 300 m² housing size, 10 persons/house

High Density*: Norton Town, Ruwa Local Board

60% of land available for housing, 400 m² housing size, 6 persons/house

Low/Medium Density*:

60% of land available for housing, 1,400 m² housing size, 5 persons/house

Medium/High Density*:

60% of land available for housing, 550 m² housing size, 8 persons/house

High Density & High Income*:

60% of land available for housing, 800 m² housing size, 6 persons/house

Note: *Assumed in this Study referring to other standards in the "Master Plan for Water Distribution."

Tables 6.2.7 (1) to (4) show the projected population of the Study Area by urban/rural district area covering four cases. Table 6.2.8 and Figure 6.2.2 summarize the projection results and Table 6.2.9 presents the projected population by the concerned authority together with those projected for the four cases as mentioned above. The figures range widely, requiring the establishment of scenarios.

Table 6.2.7 (1) Population Projection of the Study Area (Case-1)

Local Authority	1992	1993	1994	1995	2000	2005	2010	2015
Harare City	1,126,473	1,214,119	1,287,452	1,365,214	1,830,414	2,454,132	3,290,383	4,411,589
Chitungwiza Municipality	354,541	371,559	389,394	408,085	515,890	652,173	824,460	1,042,260
Norton Town	20,405	21,711	23,100	24,579	33,517	45,706	62,328	84,995
Ruwa	1,447	1,540	1,638	1,743	2,377	3,241	4,420	6,027
Epworth	62,630	66,638	70,903	75,441	102,876	140,289	191,307	260,879
Total	1,965,496	1,675,567	1,772,487	1,875,061	2,485,074	3,295,542	4,372,899	5,805,751
Harare Rural District	10,102	10,370	10,645	10,927	12,453	14,193	16,176	18,436
Harare Rural District *1	11,498	11,803	12,115	12,437	16,674	22,356	29,974	40,188
Goromonzi Rural District	29,325	30,102	30,900	31,719	36,150	41,201	46,957	53,517
Manyame Rural District	15,521	15,932	16,355	16,788	19,133	21,807	24,853	28,325
Marondera Rural District	6,828	7,009	7,195	7,385	8,417	9,593	10,933	12,461
Mazowe Rural District	11,360	11,661	11,970	12,287	14,004	15,960	18,190	20,732
Chegutu Rural District	6,776	6,956	7,140	7,329	8,353	9,520	10,850	12,366
Zvumba Rural District	48,950	50,247	51,579	52,946	60,343	68,773	78,382	89,332
Total	140,360	144,080	147,898	151,817	175,528	203,403	236,315	275,357
Grand Total	1,705,856	1,819,646	1,920,385	2,026,878	2,660,602	3,498,945	4,609,214	6,081,108

Note : Calculation base year ; 1993 for Harare and 1992 for the other authorities

*1: The population of the City of Harare Expansion area (1992 to 1995 = 2.65%, 2000 to 2015 = 6.04%)

Annual growth rate; Harare City ; 6.04 %

Chitungwiza Municipality ; 4.80 %

Other urban authorities ; 6.40 %

Local authorities ; 2.65 % (natural increase)

Table 6.2.7 (2) Population Projection of the Study Area (Case-2)

Local Authority	1992	1993	1994	1995	2000	2005	2010	2015
Harare City	1,126,473	1,214,119	1,281,988	1,353,651	1,776,727	2,332,033	3,060,897	4,017,562
Chitungwiza Municipality	354,541	371,559	389,394	408,085	515,890	652,173	824,460	1,042,260
Norton Town	20,405	21,711	23,100	24,579	33,517	45,706	62,328	84,995
Ruwa	1,447	1,540	1,638	1,743	2,377	3,241	4,420	6,027
Epworth	62,630	66,638	70,903	75,441	102,876	140,289	191,307	260,879
Total	1,565,496	1,675,567	1,767,024	1,863,499	2,431,387	3,173,443	4,143,412	5,411,724
Harare Rural District	10,102	10,370	10,645	10,927	12,453	14,193	16,176	18,436
Harare Rural District *1	11,498	11,803	12,115	12,437	16,323	21,425	28,122	36,911
Goromonzi Rural District	29,325	30,102	30,900	31,719	36,150	41,201	46,957	53,517
Manyame Rural District	15,521	15,932	16,355	16,788	19,133	21,807	24,853	28,325
Marondera Rural District	6,828	7,009	7,195	7,385	8,417	9,593	10,933	12,461
Mazowe Rural District	11,360	11,661	11,970	12,287	14,004	15,960	18,190	20,732
Chegutu Rural District	6,776	6,956	7,140	7,329	8,353	9,520	10,850	12,366
Zvumba Rural District	48,950	50,247	51,579	52,946	60,343	68,773	78,382	89,332
Total	140,360	144,080	147,898	151,817	175,177	202,472	234,463	272,080
Grand Total	1,705,856	1,819,646	1,914,921	2,015,316	2,606,564	3,375,916	4,377,875	5,683,804

Note : Calculation base year ; 1993 for of Harare and 1992 for other authorities

*1; The population of the City of Harare Expansion area (1992 to 1995 = 2.65%, 2000 to 2015 = 5.59%)

Annual growth rate: Harare City ; 5.59 % (source ; Central Statistical Office)

Chitungwiza Municipality ; 4.80 %

Other urban authorities ; 6.40 %

Local authorities ; 2.65 % (natural increase)

Table 6.2.7 (3) Population Projection of the Study Area (Case-3)

Local Authority	1992	1993	1994	1995	2000	2005	2010	2015
Harare City	1,126,473	1,214,119	1,254,913	1,296,075	1,508,350	1,735,895	1,982,277	2,247,144
Chitungwiza Municipality	354,541	375,743	397,648	419,797	537,824	668,304	810,362	962,456
Norton Town	20,405	21,360	21,836	22,314	24,770	27,362	30,106	32,947
Ruwa	1,447	1,515	1,548	1,582	1,757	1,940	2,135	2,336
Epworth	62,630	65,561	67,023	68,491	76,028	83,982	92,406	101,126
Total	1,565,496	1,678,297	1,742,970	1,808,260	2,148,728	2,517,484	2,917,285	3,346,009
Harare Rural District	10,102	10,575	10,811	11,047	12,263	13,546	14,905	16,311
Harare Rural District *1	11,498	12,036	12,305	12,574	14,633	16,841	19,231	21,801
Gorimonzai Rural District	29,325	30,697	31,382	32,069	35,598	39,323	43,267	47,350
Manyame Rural District	15,521	16,247	16,610	16,973	18,841	20,813	22,900	25,061
Marondera Rural District	6,828	7,148	7,307	7,467	8,289	9,156	10,074	11,025
Mazowe Rural District	11,360	11,892	12,157	12,423	13,790	15,233	16,761	18,343
Chegutu Rural District	6,776	7,093	7,251	7,410	8,226	9,086	9,997	10,941
Zvimba Rural District	48,950	51,241	52,384	53,531	59,422	65,638	72,222	79,038
Total	140,360	146,929	150,205	153,495	171,062	189,636	209,357	229,869
Grand Total	1,705,856	1,825,226	1,893,175	1,961,755	2,319,790	2,707,120	3,126,642	3,575,878

Note : Calculation base year ; 1993 for Harare and 1992 for other authorities

*1: The population of the City of Harare Expansion area (1992 to 1995 = 2.65%, 2000 to 2015 = Refer to able below)

Local Authority	Population Growth Rate (%)							
	1992	1993	1994	1995	2000	2005	2010	2015
Harare City		3.45	3.36	3.28	3.08	2.85	2.69	2.54
Chitungwiza Municipality		5.98	5.83	5.57	5.08	4.44	3.93	3.50
Norton Town		4.68	2.23	2.19	2.11	2.01	1.93	1.82

Source: Harare Combination Master Plan, Report of Study, 26 August 1992

Table 6.2.7 (4) Population Projection of the Study Area (Case-4)

Local Authority	Land Use (population density)	Land Use Area (km ²)			Population Projection		
		2000	2005	2015	2000	2005	2015
Harare City	Low Density	149.82	152.55	165.30	179,784	183,060	198,360
	Medium Density	24.26	37.02	37.02	109,170	166,590	166,590
	High Density	57.97	94.27	123.60	1,159,400	1,885,400	2,472,000
	Low/Medium Density	2.00	7.83	13.67	4,286	16,779	29,293
	Medium/High Density	6.01	6.01	7.47	52,451	52,451	65,193
	High Density High Income	2.72	2.72	2.72	12,240	12,240	12,240
Chitungwiza Municipality	Low Density	0.00	0.00	2.14	0	0	2,568
	Medium Density	3.35	3.35	8.26	15,075	15,075	37,170
	High Density	21.22	21.22	26.67	424,400	424,400	533,400
	Low Density	2.92	5.39	17.95	3,504	6,468	21,540
	Medium Density	0.20	2.12	5.50	900	9,540	24,750
	High Density	5.15	5.15	8.00	46,350	46,350	72,000
Norton Town	Low Density	3.89	9.44	9.44	4,668	11,328	11,328
	Medium Density	0.18	0.18	2.66	810	810	11,970
	High Density	4.89	6.50	7.50	44,910	58,500	67,500
Epworth	(same as Case-3)	-	-	-	76,028	83,982	101,126
	Total	284.58	353.75	437.90	2,133,076	2,972,972	3,827,028
Harare Rural District	(same as Case-3)	-	-	-	12,263	13,546	16,311
	Total	-	-	-	35,598	39,323	47,350
Goromonzi Rural District	(same as Case-3)	-	-	-	18,841	20,813	25,061
	Total	-	-	-	8,289	9,156	11,025
Manyame Rural District	(same as Case-3)	-	-	-	13,790	15,233	18,343
	Total	-	-	-	8,226	9,086	10,941
Marondera Rural District	(same as Case-3)	-	-	-	59,422	65,638	79,038
	Total	-	-	-	156,429	172,795	208,069
Mazowe Rural District	(same as Case-3)	-	-	-	-	-	-
	Total	-	-	-	-	-	-
Chegutu Rural District	(same as Case-3)	-	-	-	-	-	-
	Total	-	-	-	-	-	-
Zvimba Rural District	(same as Case-3)	-	-	-	-	-	-
	Total	-	-	-	-	-	-
Grand Total		-	-	-	2,289,505	3,145,767	4,035,097

Note : Low Density ; 60 % land available for housing, 2,000m² housing size, 4 persons/house

Medium Density ; 60 % land available for housing, 800m² housing size, 6 persons/house

High Density ; 60 % land available for housing, 300m² housing size, 10 persons/house for Harare and Chitungwiza

High Density ; 60 % land available for housing, 400m² housing size, 6 persons/house for Norton and Ruwa

Low/Medium Density ; 60 % land available for housing, 1,400m² housing size, 5 persons/house

Medium/High Density ; 60 % land available for housing, 550m² housing size, 8 persons/house

High Density High Income ; 60 % land available for housing, 800m² housing size, 6 persons/house

Table 6.2.8 Comparison of Population Projection of the Study Area

Case	1993	1994	1995	2000	2005	2010	2015
Case-1	1,819,646	1,920,385	2,026,878	2,660,602	3,498,945	4,609,214	6,081,108
Case-2	1,819,646	1,914,921	2,015,316	2,606,564	3,375,916	4,377,875	5,683,804
Case-3	1,825,226	1,893,175	1,961,755	2,319,790	2,707,120	3,126,642	3,575,878
Case-4	1,825,226	1,891,552	1,957,877	2,289,505	3,145,767	3,590,432	4,035,097

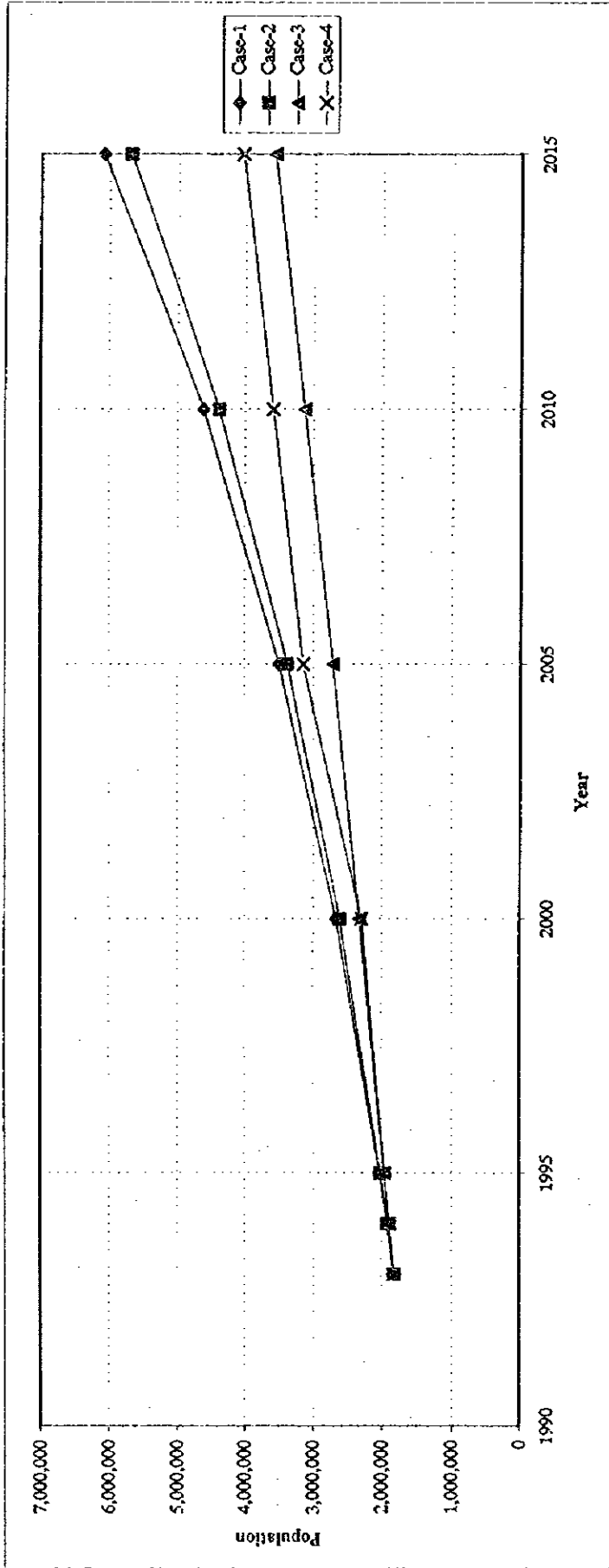


Figure 6.2.2 Population Projection by Case

Table 6.2.9 Comparison of Population Projection between Urban Authorities

Authority/Case/Source Document		2000	2005	2015	
Projected Four Cases in this Study	Harare	Case-1	1,847,088	2,476,488	4,451,777
		Case-2	1,793,050	2,353,458	4,054,473
		Case-3	1,522,983	1,752,736	2,268,945
		Case-4	1,517,331	2,316,520	2,943,676
	Chitungwiza	Case-1	515,890	652,173	1,042,260
		Case-2	515,890	652,173	1,042,260
		Case-3	537,824	668,304	962,456
		Case-4	439,475	439,475	573,138
	Norton	Case-1	33,517	45,706	84,995
		Case-2	33,517	45,706	84,995
		Case-3	24,770	27,362	32,947
		Case-4	50,754	62,358	118,290
	Ruwa	Case-1	2,377	3,241	6,027
		Case-2	2,377	3,241	6,027
		Case-3	1,757	1,940	2,336
		Case-4	49,488	70,638	90,798
	Total	Case-1	2,398,872	3,177,608	5,585,059
		Case-2	2,344,834	3,054,578	5,187,755
		Case-3	2,087,334	2,450,342	3,266,684
		Case-4	2,057,048	2,888,991	3,725,902
Projected by Concerned Authorities	M. P. W. D. *1	Harare	2,354,399 (2002)	-	4,775,831 (2012)
		Chitungwiza	426,930 (2002)	-	663,010 (2012)
		Norton	37,346 (2002)	-	69,448 (2012)
		Ruwa	2,691 (2002)	-	5,004 (2012)
	H. C. M. P. *2	Harare	1,486,055	1,710,076	2,213,474
		Chitungwiza	553,094	687,375	990,299
	N. M. P. *3	Norton	-	-	62,428 (2010)
	R. L. D. P. *4	Ruwa	-	-	53,000 (2011) *5

- Note : *1 ; The City of Harare, Master Plan for Water Distribution, Volume 3, October 1995, p.29
 *2 ; Harare Combination Master Plan, Report of Study, August 1992, Table-4
 *3 ; Norton Master Plan, The Study Report and Written Statement Final, October 1995, p.18
 *4 ; Ruwa Local Development Plan, March 1996, p.8
 *5 ; 90,000 persons (In case of full development)

6.2.4 Future Population Scenarios

The two scenarios on future population were constructed for the purpose of water pollution control planning on a practical basis in consideration of the range of the 2015 population under the four study cases as shown below.

<u>Case</u>	<u>2015 Population</u>	<u>Range</u>
1	6,081,108	1.70
2	5,683,804	1.59
3	3,575,878	1.00
4	4,035,097	1.13

Note: Range is estimated in case that Case 3 is a base (1.0).

Scenarios are preliminary established as follows:

- Scenario 1: Case 4 (Maximum)
- Scenario 2: Case 3 (Minimum)

Table 6.2.10 shows projected population by urban area by river/lake sub-basin for the two scenarios and Table 6.2.11 summarizes the projection results by river/lake sub-basin.

6.3. Industrial Development

6.3.1 General

The projection of wastewater discharged from factories both in quality and quantity is imperative for water pollution analysis. In this connection, the frame values are projected with reference to the common parameter to be used for unit pollution quality and quantity.

The present industrial development and its features were analyzed in addition to previous studies/plans and socio-economic aspects. The methodology of the projection was established on a practical basis utilizing the National Development Plan and other available data.

6.3.2 Situation of Industries

There are some industrial areas in respective urban areas: Harare City, Chitungwiza Municipality, Norton Town Council and Ruwa Local Board, with a total area of approximately 3,151 ha. The composition of industrial area as well as major types of industry and number of employees are shown in Table 6.3.1.

Table 6.2.10 (1) Population Projection by Urban Area by River/Lake Sub-Basin (Scenario-1)

Sub-Basin and Local Authority	Land Use	Land Use Area (km ²)			Population Projection		
		2000	2005	2015	2000	2005	2015
(1) Manyame River Upstream Sub-Basin							
Goromonzi Rural District	(same as scenario-2)	-	-	-	28,667	31,666	38,130
Harare Rural District	(same as scenario-2)	-	-	-	131	145	174
Manyame Rural District	(same as scenario-2)	-	-	-	2,597	2,868	3,454
Total		-	-	-	31,395	34,679	41,758
(2) Ruwa River Sub-Basin							
Harare City	High Density	5.29	5.29	7.65	105,800	105,800	153,000
	Low Density	3.89	9.44	9.44	4,668	11,328	11,328
Ruwa	Medium Density	0.18	0.18	2.66	810	810	11,970
	High Density	4.89	6.50	7.50	44,010	58,500	67,500
Epworth	(same as scenario-2)	-	-	-	50,685	55,988	67,417
Goromonzi Rural District	(same as scenario-2)	-	-	-	6,802	7,513	9,047
Harare Rural District	(same as scenario-2)	-	-	-	4,517	4,990	6,008
Total		-	-	-	217,292	244,929	326,270
(3) Seke & Harava Dam Sub-Basin							
Harare City	Low Density	3.30	3.30	3.30	3,960	3,960	3,960
	High Density	2.19	2.19	2.19	43,800	43,800	43,800
Epworth	(same as scenario-2)	-	-	-	5,480	6,053	7,289
Goromonzi Rural District	(same as scenario-2)	-	-	-	130	143	173
Harare Rural District	(same as scenario-2)	-	-	-	2,489	2,749	3,310
Manyame Rural District	(same as scenario-2)	-	-	-	1,079	1,192	1,435
Total		-	-	-	56,938	57,897	59,967
(4) Nyatsime River Sub-Basin							
Chitungwiza Municipality	Low Density	0.00	0.00	2.14	0	0	2,568
	Medium Density	3.35	3.35	8.26	15,075	15,075	37,170
	High Density	17.78	17.78	23.23	355,600	355,600	464,600
Manyame Rural District	(same as scenario-2)	-	-	-	11,299	12,481	15,029
Marondera Rural District	(same as scenario-2)	-	-	-	8,289	9,156	11,025
Total		-	-	-	390,263	392,312	530,392

Table 6.2.10 (1) Population Projection by Urban Area by River/Lake Sub-Basin (Scenario-1) (cont'd)

Sub-Basin and Local Authority	Land Use	Land Use Area (km ²)			Population Projection			
		2000	2005	2015	2000	2005	2015	
(5) Mukuvisi River Sub-Basin	Low Density	73.81	74.72	76.35	88,572	89,664	91,620	
	Medium Density	11.84	13.12	13.12	53,280	59,040	59,040	
	High Density	25.51	29.88	32.60	510,200	597,600	652,000	
	Low/Medium Mixed Density	2.00	2.00	2.00	4,286	4,286	4,286	
	Medium/High Mixed Density	6.01	6.01	6.01	52,451	52,451	52,451	
	High Density High Income	2.36	2.36	2.36	10,620	10,620	10,620	
	(same as scenario-2)	-	-	-	19,863	21,942	26,421	
	(same as scenario-2)	-	-	-	2,045	2,259	2,721	
	(same as scenario-2)	-	-	-	467	516	622	
	Total		-	-	-	741,784	838,378	899,781
(6) Manyame River Downstream Sub-Basin (Mukuvisi Rver to Seke Dam)	Medium Density	4.58	4.58	4.58	20,610	20,610	20,610	
	High Density	1.28	5.66	22.79	25,600	113,200	455,800	
	High Density	3.44	3.44	3.44	68,800	68,800	68,800	
	(same as scenario-2)	-	-	-	3,081	3,403	4,098	
	(same as scenario-2)	-	-	-	1,627	1,797	2,164	
	Total	-	-	-	119,718	207,810	551,472	
	(7) Marimba River Sub-Basin	Low Density	39.73	39.73	39.73	47,676	47,676	47,676
		Medium Density	7.84	19.32	19.32	35,280	86,940	86,940
		High Density	21.15	35.65	41.13	423,000	713,000	822,600
		Low/Medium Mixed Density	0.00	5.83	11.67	0	12,493	25,007
Medium/High Mixed Density		0.00	0.00	1.46	0	0	12,742	
High Density High Income		0.36	0.36	0.36	1,620	1,620	1,620	
(same as scenario-2)		-	-	-	2,913	3,218	3,875	
Total		-	-	-	510,489	864,947	1,000,460	

Table 6.2.10 (1) Population Projection by Urban Area by River/Lake Sub-Basin (Scenario-1) (cont'd)

Sub-Basin and Local Authority	Land Use	Land Use Area (km ²)			Population Projection		
		2000	2005	2015	2000	2005	2015
(8) Lake Chivero Sub-Basin							
Harare City	High Density	2.55	8.10	9.74	51,000	162,000	194,800
Chegutu Rural District	(same as scenario-2)	-	-	-	1,537	1,698	2,044
Manyame Rural District	(same as scenario-2)	-	-	-	2,240	2,474	2,979
Zvimba Rural District	(same as scenario-2)	-	-	-	5,160	5,700	6,864
Total		-	-	-	59,937	171,872	206,687
(9) Muzuru River Sub-Basin							
Harare City	High Density	0.00	7.50	7.50	0	150,000	150,000
Zvimba Rural District	(same as scenario-2)	-	-	-	15,207	16,798	20,227
Total		-	-	-	15,207	166,798	170,227
(10) Gwebi River Sub-Basin							
Harare City	Low Density	32.98	34.80	45.92	39,576	41,760	55,104
Mazowe Rural District	(same as scenario-2)	-	-	-	13,790	15,233	18,343
Zvimba Rural District	(same as scenario-2)	-	-	-	22,075	24,385	29,363
Total		-	-	-	75,441	81,378	102,810
(11) Lake Manyame Sub-Basin							
Norton Town	Low Density	2.92	5.39	17.95	3,504	6,468	21,540
	Medium Density	0.20	2.12	5.50	900	9,540	24,750
	High Density	5.15	5.15	8.00	46,350	46,350	72,000
Chegutu Rural District	(same as scenario-2)	-	-	-	6,689	7,389	8,897
Zvimba Rural District	(same as scenario-2)	-	-	-	13,598	15,021	18,087
Total		-	-	-	71,041	84,768	145,274
Grand Total		-	-	-	2,289,505	3,145,767	4,035,098

Note : Low Density ; 60 % land available for housing, 2,000m² housing size, 4 persons/house

Medium Density ; 60 % land available for housing, 800m² housing size, 6 persons/house

High Density ; 60 % land available for housing, 300m² housing size, 10 persons/house for Harare and Chitungwiza

High Density ; 60 % land available for housing, 400m² housing size, 6 persons/house for Norton and Ruwa

Low/Medium Density ; 60 % land available for housing, 1,400m² housing size, 5 persons/house

Medium/High Density ; 60 % land available for housing, 550m² housing size, 8 persons/house

High Density High Income ; 60 % land available for housing, 800m² housing size, 6 persons/house

Table 6.2.10 (2) Population Projection by Urban Area by River/Lake Sub-Basin (Scenario-2)

Sub-Basin Name	Population Projection									
	1992	1993	1994	1995	2000	2005	2010	2015		
(1) Manvame River Upstream Sub-Basin										
Goromonzi Rural District	23,615	24,720	25,271	25,825	28,667	31,666	34,842	38,130		
Harare Rural District	108	113	116	118	131	145	159	174		
Manvame Rural District	2,139	2,239	2,289	2,339	2,597	2,868	3,156	3,454		
Total	25,862	27,072	27,676	28,282	31,395	34,679	38,157	41,758		
(2) Ruwa River Sub-Basin										
Harare City	-	78,843	81,492	84,165	97,950	112,726	128,726	145,926		
Ruwa	1,447	1,515	1,548	1,582	1,757	1,940	2,135	2,336		
Epworth	41,733	43,707	44,682	45,660	50,685	55,988	61,603	67,417		
Goromonzi Rural District	5,603	5,865	5,996	6,127	6,802	7,513	8,267	9,047		
Harare Rural District	3,721	3,895	3,982	4,069	4,517	4,990	5,490	6,008		
Total	52,524	133,825	137,700	141,604	161,710	183,157	206,221	230,734		
(3) Seke & Harava Dam Sub-Basin										
Epworth	4,514	4,725	4,831	4,936	5,480	6,033	6,660	7,289		
Goromonzi Rural District	107	112	115	117	130	143	158	173		
Harare Rural District	2,050	2,146	2,194	2,242	2,489	2,749	3,025	3,310		
Harare Rural District *1	4,775	4,998	5,110	5,222	6,077	6,994	7,987	9,054		
Manvame Rural District	889	931	951	972	1,079	1,192	1,312	1,435		
Total	12,335	12,912	13,200	13,489	15,254	17,131	19,141	21,261		
(4) Nyaisime River Sub-Basin										
Chitungwiza Municipality	279,412	296,121	313,385	330,840	423,856	526,687	638,642	758,507		
Manvame Rural District	9,308	9,744	9,961	10,179	11,299	12,481	13,733	15,029		
Marondera Rural District	6,828	7,148	7,307	7,467	8,289	9,156	10,074	11,025		
Total	295,548	313,012	330,653	348,486	443,444	548,325	662,450	784,561		
(5) Mukuvisi River Sub-Basin										
Harare City	-	588,223	607,987	627,929	730,773	841,016	960,384	1,088,708		
Epworth	16,363	17,129	17,511	17,894	19,863	21,942	24,142	26,421		
Harare Rural District	1,685	1,764	1,803	1,843	2,045	2,259	2,486	2,721		
Zvimba Rural District	385	403	412	421	467	516	568	622		
Total	18,433	607,519	627,713	648,087	753,150	865,733	987,581	1,118,471		

Note : Refer to Table 6.2.10 on population growth rate in Table 6.2.10

: Base year ; 1993 for Harare and 1992 for the other authorities

: *1 The population of the City of Harare expansion area (increase rate 1992 to 1995 = other authorities, 2000 to 2015 = Harare City)

Table 6.2.10 (2) Population Projection by Urban Area by River/Lake Sub-Basin (Scenario-2) (cont'd)

Sub-Basin	Population Projection									
	1992	1993	1994	1995	2000	2005	2010	2015		
(6) Manyame River Downstream Sub-Basin (Mukuvisi River to Seke Dam)										
Chitungwiza Municipality	75,129	79,622	84,264	88,957	113,968	141,617	171,720	203,949		
Harare Rural District	2,538	2,657	2,716	2,776	3,081	3,403	3,745	4,098		
Harare Rural District *1	6,723	7,038	7,195	7,352	8,556	9,847	11,245	12,747		
Manyame Rural District	1,340	1,403	1,434	1,465	1,627	1,797	1,977	2,164		
Total	85,730	90,719	95,608	100,550	127,231	156,664	188,686	222,958		
(7) Marimba River Sub-Basin										
Harare City	-	474,211	490,144	506,221	589,132	678,007	774,238	877,690		
Zvimba Rural District	2,400	2,512	2,568	2,625	2,913	3,218	3,541	3,875		
Total	2,400	476,723	492,713	508,846	592,045	681,225	777,779	881,565		
(8) Lake Chivero Sub-Basin										
Harare City	-	0	0	0	0	0	0	0		
Chegutu Rural District	1,266	1,325	1,355	1,384	1,537	1,698	1,868	2,044		
Manyame Rural District	1,845	1,931	1,974	2,018	2,240	2,474	2,722	2,979		
Zvimba Rural District	4,251	4,450	4,549	4,649	5,160	5,700	6,272	6,864		
Total	7,362	7,707	7,878	8,051	8,937	9,872	10,862	11,887		
(9) Muzuru River Sub-Basin										
Zvimba Rural District	12,527	13,113	13,406	13,699	15,207	16,798	18,483	20,227		
Total	12,527	13,113	13,406	13,699	15,207	16,798	18,483	20,227		
(10) Gwebi River Sub-Basin										
Harare City	-	72,842	75,289	77,759	90,495	104,146	118,928	134,819		
Mazowe Rural District	11,360	11,892	12,157	12,423	13,790	15,233	16,761	18,343		
Zvimba Rural District	18,185	19,036	19,461	19,887	22,075	24,385	26,831	29,363		
Total	29,545	103,770	106,907	110,069	126,360	143,764	162,520	182,524		
(11) Lake Manyame Sub-Basin										
Norton Town	20,405	21,360	21,836	22,314	24,770	27,362	30,106	32,947		
Chegutu Rural District	5,510	5,768	5,896	6,026	6,689	7,389	8,130	8,897		
Zvimba Rural District	11,202	11,726	11,988	12,250	13,598	15,021	16,528	18,087		
Total	37,117	38,854	39,721	40,590	45,057	49,771	54,763	59,931		
Grand Total	-	1,825,226	1,893,175	1,961,755	2,319,790	2,707,120	3,126,642	3,575,878		

Note : Refer to Table 6.2.10 on population growth rate in Table 6.2.10

: Base year ; 1993 for Harare and 1992 for the other authorities

: *1 The population of the City of Harare expansion area (increase rate 1992 to 1995 = other authorities, 2000 to 2015 = Harare City)

Table 6.2.11 Summary of Population Projection by River/Lake Sub-Basin for Two Scenarios

Sub-Basin	Scenario	2000	2005	2015
(1) Manyame River Upstream Sub-Basin	Scenario-1	31,395	34,679	41,758
	Scenario-2	31,395	34,679	41,758
(2) Ruwa River Sub-Basin	Scenario-1	217,292	244,929	326,270
	Scenario-2	161,710	183,157	230,734
(3) Seke & Harava Dam Sub-Basin	Scenario-1	56,938	57,897	59,967
	Scenario-2	15,254	17,131	21,261
(4) Nyatsime River Sub-Basin	Scenario-1	390,263	392,312	530,392
	Scenario-2	443,444	548,325	784,561
(5) Mukuvisi River Sub-Basin	Scenario-1	741,784	838,378	899,781
	Scenario-2	753,150	865,733	1,118,471
(6) Manyame River Downstream (Muzururu River to Seke Dam)	Scenario-1	119,718	207,810	551,472
	Scenario-2	127,231	156,664	222,958
(7) Marimba River Sub-Basin	Scenario-1	510,489	864,947	1,000,460
	Scenario-2	592,045	681,225	881,565
(8) Lake Chivero Sub-Basin	Scenario-1	59,937	171,872	206,687
	Scenario-2	8,937	9,872	11,887
(9) Muzururu River Sub-Basin	Scenario-1	15,207	166,798	170,227
	Scenario-2	15,207	16,798	20,227
(10) Gwebi River Sub-Basin	Scenario-1	75,441	81,378	102,810
	Scenario-2	126,360	143,764	182,524
(11) Lake Manyame Sub-Basin	Scenario-1	71,041	84,768	145,274
	Scenario-2	45,057	49,771	59,931
Total	Scenario-1	2,289,505	3,145,768	4,035,098
	Scenario-2	2,319,790	2,707,119	3,575,877

Table 6.3.1 Features in Each Industrial Area (1995)

Local Authority	Industrial Area	Main Type of Industry	No. of Employees
Harare City	2,532 ha	Processed Foodstuff Textile Products Metal Products	85,845
Chitungwiza Municipality	135 ha	Processed Foodstuff Transportation Equipment	2,089
Norton Town Council	273 ha	Pulp & Paper Metal Products	2,960
Ruwa Local Board	211 ha	Plastic Products Metal Products	2,321
Total	3,151 ha		93,215

Detailed information on the industry is shown in Table 6.3.2. The outstanding industries in the study area are life-related manufactures, namely food and textiles. Although the required land arrangements have been mostly completed and the basic infrastructures, i.e. water supply and sewerage, have also been provided in each industrial area, their occupation rates are still low except for Harare City. Nevertheless, they are preparing/implementing the industrial area expansion plan in accordance with the "Second Five-Year National Development Plan".

6.3.3. Methodology of the Projection

(1) Frame Value

Unit wastewater quantity is generally determined by means of the following unit parameters; industrial production, factory's site area, employee number and product.

Unit industrial product is commonly adopted as a frame value, however, industrial production data is only available for Harare City at Central Statistical Office (CSO), while area size of each factory in Harare City is not available. The common available data for the study area is number of employees, thus, it was adopted as a frame value.

Table 6.3.2 Present Number of Employees and Composition Ratio by Industrial Type

Type No.	Type of Industry	Harare City			Chitungwiza			Norton			Ruwa		
		Number of Factories	Number of Employees	Ratio of Employees (%)	Number of Factories	Number of Employees	Ratio of Employees (%)	Number of Factories	Number of Employees	Ratio of Employees (%)	Number of Factories	Number of Employees	Ratio of Employees (%)
1	Processed Foodstuffs	-	23,676	27.6	5	836	40.0	3	245	8.3	1	125	5.4
2	Textile Products	-	15,354	17.9	2	53	2.5	1	13	0.4	1	90	3.9
3	Lumber & Wooden Products	-	4,763	5.5	1	26	1.2	2	246	8.3	1	45	1.9
4	Pulp, Paper & Related Products	-	753	0.9	-	-	0.0	1	650	22.0	-	-	-
5	Publising & Printing	-	4,282	5.0	1	20	1.0	-	-	-	-	-	-
6	Chemicals	-	7,668	8.9	-	-	0.0	1	30	1.0	1	60	2.6
7	Plastic Products	-	2,839	3.3	1	25	1.2	-	-	-	5	448	19.3
9	Leather & Related Products	-	-	-	-	-	-	1	119	4.0	-	-	-
10	Rubber Products	-	-	-	-	-	-	-	-	-	1	30	1.3
11	Ceramics, Stone & Clay Products	-	4,692	5.5	1	30	1.4	1	61	2.1	1	35	1.5
14	Metal Products	-	11,425	13.3	2	93	4.5	3	545	18.4	4	267	11.5
15	General Machinery	-	-	-	-	-	-	1	32	1.1	1	10	0.4
16	Electrical Machinery	-	4,401	5.1	-	-	-	2	118	4.0	-	-	-
17	Transportation Equipment	-	4,652	5.4	3	875	41.9	2	178	6.0	-	-	-
19	Other Industry Products	-	1,340	1.6	1	131	6.3	3	723	24.4	5	1,211	52.2
	Total	-	85,845	100.0	17	2,089	100.0	21	2,960	100.0	21	2,321	100.0

(2) Methodology

Projection of the frame value was made according to the following procedure.

1) Data Collection

- Harare City : Number of employees is obtained from "Census of Industrial Projection 1992/93 Report-Mining, Manufacturing Construction, Electricity and Water Supply" (CSO)
- Chitungwiza, Norton and Ruwa : Occupied area and floor area, types of products, number of employees and supplied water amount to each factory were investigated through field survey.

2) Calculation of the number of employees by type of industry

Industry was classified into 19 types. Then the number of employees and their ratio by type of industry were calculated.

3) Projection of future number of employees

The future number of employees was calculated for each sub-basin in assumption that the number will increase in proportion to the area expansion in the future.

6.3.4 Estimation of Number of Employees

(1) Present number of employees by type of industry.

The present number of employees in Harare was quoted from the "Census of Industrial Projection 1992/93 Report - Mining, Manufacturing, Construction, Electricity and Water Supply." The number of employees in 25 industrial types was adopted as the present value. Regarding the remaining three municipalities, field survey results, to wit factory's area, floor area, number of employees, supplied water amount, were utilized.

All types of industry were classified into 19 types of middle classifications shown in Table 6.3.3 and number of employees and their ratio for 19 types were calculated. The result is shown in Table 6.3.2.

Table 6.3.3 Classification of Industrial Type

1.	Processed Foodstuffs	11.	Ceramics, Stone & Clay Products
2.	Textile Products	12.	Iron & Steel
3.	Lumber & Wooden Products	13.	Nonferrous Metals
4.	Pulp, Paper & Related Products	14.	Metal Products
5.	Publishing & Printing	15.	General Machinery
6.	Chemicals	16.	Electrical Machinery
7.	Plastic Products	17.	Transportation Equipment
8.	Petroleum & Coal Products	18.	Precision Instruments
9.	Leather & Related Products	19.	Other Manufacturing Industry Products
10.	Rubber Products		

(2) Estimation of number of employees

The future number of employees were estimated for each sub-basin in assumption that the number will increase in accordance with the increasing rate of industrial area in future land use plan. The result is shown in Table 6.3.4. The estimation was conducted based on the following conditions:

1) Harare

The future number of employees was calculated by the increasing rate of industrial area in future land use plan and distributed into each sub-basin by their area ratio.

2) Chitungwiza, Norton and Ruwa

The intermediate industrial occupation rate was estimated on the assumption that the rate will be 100% in the year 2015.

Each factory's site area was calculated assumptioning that the ratio between the site area and the whole industrial area was 80%.

3) Chitungwiza and Norton

The number of employees per unit site area of factory was assumed to be constant from present to the future.

4) Ruwa

The number of employees per unit site area of factory was assumed to decrease to 40 person/ha which is equal to the existing number in Harare and Chitungwiza, since the present number in Ruwa is extremely high compared with the others.

Table 6.3.4 Present and Future Number of Employees

Local Authority	Sub-Basin	Item	Present	Year 2000	Year 2005	Year 2015	
Harare City	Marimba River Sub-Basin	Industrial Area (km ²)	6.56	6.56	6.56	6.56	
		Number of Employees	22,300	22,300	22,300	22,300	
	Mukuvisi River Sub-Basin	Industrial Area (km ²)	18.76	22.04	22.04	24.23	
		Number of Employees	63,700	74,900	74,900	82,400	
	Ruwa River Sub-Basin	Industrial Area (km ²)	0.00	0.00	0.00	14.76	
		Number of Employees	0	0	0	50,200	
	Manyame River Sub-Basin	Industrial Area (km ²)	0.00	0.88	22.76	22.76	
		Number of Employees	0	3,000	77,400	77,400	
	Total	Industrial Area (km ²)	25.32	29.48	51.36	68.31	
		Number of Employees	86,000	100,200	174,600	232,300	
Chitungwiza Municipality	Nyatsime River Sub-Basin	Industrial Area (km ²)	1.35	1.35	1.35	7.93	
		Total Site Area (ha)	108.0	108.0	108.0	634.4	
		Occupied Area (ha)	57.5	70.1	82.7	634.4	
		Occupation Rate (%)	53.2	64.9	76.6	100.0	
		Employees per hectare	43.48	43.48	43.48	43.48	
		Number of Employees	2,500	3,100	3,600	27,600	
	Manyame River Sub-Basin	Industrial Area (km ²)	0.00	0.00	0.00	1.48	
		Total Site Area (ha)	0.0	0.0	0.0	118.4	
		Occupied Area (ha)	0.0	0.0	0.0	118.4	
		Occupation Rate (%)	0.0	0.0	0.0	100.0	
		Employees per hectare	0.00	0.00	0.00	43.48	
		Number of Employees	0	0	0	5,200	
	Total	Industrial Area (km ²)	1.35	1.35	1.35	9.41	
		Number of Employees	2,500	3,100	3,600	32,800	
	Norton Town Council	Lake Manyame Sub-Basin	Industrial Area (km ²)	2.73	2.73	3.86	10.83
			Total Site Area (ha)	218.4	218.4	308.8	866.4
Occupied Area (ha)			169.2	181.5	274.2	866.4	
Occupation Rate (%)			77.5	83.1	88.8	100.0	
Employees per hectare			17.73	17.73	17.73	17.73	
Number of Employees			3,000	3,300	4,900	15,400	
Ruwa Local Board	Ruwa River Sub-Basin	Industrial Area (km ²)	2.11	5.06	5.06	5.06	
		Total Site Area (ha)	168.8	404.8	404.8	404.8	
		Occupied Area (ha)	12.3	61.7	108.7	404.8	
		Occupation Rate (%)	7.3	30.5	53.7	100.0	
		Employees per hectare	186.99	150.24	113.50	40.00	
		Number of Employees	2,300	9,300	12,400	16,200	

5) Chitungwiza

The present number of employees and the site area of the factories were estimated multiplying by 1.2 the survey results, since some of factory's data were not available.

6.4 Livestock

The present number of major livestock in the Study Area surveyed by the Department of Veterinary Services of Ministry of Agriculture is presented in Table 6.4.1. Besides the listed species, a large number of poultry is raised in the Study Area. However, it is usually considered that pollution load from poultry breeding does not flow into public water bodies. Therefore, it is disregarded in the water pollution analysis. In sub-section 9.3.3, the number of livestock shown Table 6.4.1 was divided into sub-basins in proportion to each area size in respective sub-basin presented in Table 6.4.2.

The Second Five-Year National Development Plan (1991-1995) reported increase ratio of livestock in Zimbabwe from 1980 to 1988 as follows;

- Cattle: 0.38% increase for total period
- Goats: 275% increase for total period
- Sheep: 167% increase for total period
- Pigs: 197% increase for total period

The plan also stated expectation during the plan period (1991-1995) as follows;

- Cattle slaughtering: increase from 600,000 to 690,000
- Goats : promotion of production
- Sheep : encouragement of production
- Pigs : pork meat consumption increase by average rate of 5% per annum

Actual accomplishment, however, showed constant or rather decreasing figures from 1989 to 1993 as presented in Table 6.4.3.

The number of livestock in the Study area to be applied in the future water pollution analysis is assumed to be unchanged because of following reason:

- 1) Farmland in the study area has been developed considerably.
- 2) The horticulture sector is expected to increase in the future. The study area may be regarded as suitable horticultural area.

Table 6.4.1 Number of Major Livestock in the Study Area

Province	Veterinary Area	Cattle	Goats	Sheep	Pigs	Horses
Mash. Central	Nyabira	65,191	1,122	3,020	15,400	785
Mash. East	Marondera	13,720	4,708	720	1,054	48
do	Melfort/Ruwa	6,490	440	820	1,360	120
do	Harare Central	21,890	2,000	1,500	2,500	1,200
do	Manyame	20,250	2,613	38	420	-
Mash. West	Chegutu	7,267	67	140	142	37
	Total	134,808	10,950	6,238	20,876	2,190

Source: Department of Veterinary Services, Ministry of Agriculture, 1996

Table 6.4.2 Breakdown of Veterinary Areas by Sub-basin

Sub-Basin	Total Area	Nyabira	Marondera	Melfort/Ruwa	Harare C.	Manyame	Chegutu
Manyame R. (U/S)	474.0	-	143.8	240.7	-	89.5	-
Ruwa River	195.0	-	-	147.0	48.0	-	-
Sekle & Harava Dams	115.0	-	-	-	23.6	88.6	2.8
Nyatsime River	580.0	-	270.0	-	-	310.0	-
Mukuvisi River	230.0	-	-	-	230.0	-	-
Manyame R. (D/S)	166.0	-	-	-	15.8	54.1	96.1
Marimba River	215.0	-	-	-	215.0	-	-
Lake Chivero	255.0	-	-	-	67.3	-	187.7
Muzuruu River	310.0	226.0	-	-	65.3	-	18.7
Gwebi River	770.0	557.3	-	-	182.8	-	29.9
Lake Manyame	590.0	59.0	-	-	17.9	-	513.1
Study Area Total	3,900.0	842.3	413.8	387.7	865.7	542.2	848.3

(unit: km²)

Table 6.4.3 Number of Major Livestock in Zimbabwe

Large Scale Commercial Farms						
Year	Cattle		Working Bulls	Sheep	Pigs	Goats
	Beef	Dairy				
1987	1,667,547	120,839	27,542	101,317	92,180	24,632
1988	1,655,886	121,393	26,962	101,868	90,996	28,449
1989	1,653,543	122,964	27,488	107,163	93,880	34,682
1990	1,703,994	127,146	27,969	116,466	105,433	37,475
1991	1,714,210	126,039	28,476	111,934	106,482	34,534
1992	1,641,608	124,190	27,698	113,255	109,718	35,565
1993	1,451,450	114,858	25,490	105,387	95,338	36,898

Source: Livestock on Large Scale Commercial Farms - 1993, CSO

Small Scale Commercial Farms				
Year	Cattle	Sheep	Goats	Pigs
1989	217,160	20,676	65,640	7,120
1990	214,892	19,678	62,994	7,611
1991	219,699	19,341	65,931	7,766
1992	182,175	16,621	60,512	4,098
1993	181,612	16,001	61,582	3,348

Source: Agricultural Production on Small Scale Commercial Farms - 1993, CSO

Communal Land				
Year	Cattle	Sheep	Goats	Pigs
1989	46,687	3,603	67,806	1,272
1990	44,234	3,075	59,249	1,340
1991	49,737	3,528	70,804	1,351
1992	17,567	1,730	39,912	235
1993*	17,567	1,730	39,912	235

Source: Agricultural Production on Communal Land Irrigation Schemes - 1993, CS

*: assumed to be the same to 1992 figures

Resettlement Schemes				
Year	Cattle	Sheep	Goats	Pigs
1989	318,704	14,850	154,436	8,724
1990	349,909	15,888	170,656	9,205
1991	364,413	15,384	172,646	8,593
1992	346,070	14,789	180,159	5,047
1993	307,776	13,132	162,932	4,967

Source: Agricultural Production on Resettlement Schemes - 1993, CSO

Total				
Year	Cattle	Sheep	Goats	Pigs
1989	2,386,546	146,292	322,564	110,996
1990	2,468,144	155,107	330,374	123,589
1991	2,502,574	150,187	343,915	124,192
1992	2,339,308	146,395	316,148	119,098
1993	2,098,753	136,250	301,324	103,888

- 3) Past records shows a stable increase trend line.
- 4) Urbanisation will be extended in the study area, especially around Harare City.

6.5 Farmland / Natural Land

The data on the area of farmland and natural land at present was not available. The calculation of the pollution load from both areas is done for total study area regardless of land use.

6.6 Solid Waste Dumping Sites

The location and area of the existing dumping sites in the related local authorities are presented in Table 9.3.17. Since the data on the future solid waste disposal system was not available, the quantity of leachate at the landfill site is assumed to increase in proportion to the population increase in the respective local board as presented in Table 10.2.35.

CHAPTER 7

**WATER USE AND HYDROLOGICAL CONDITIONS OF THE
WATER BODY THROUGH THE FUTURE**

CHAPTER 7 WATER USE AND HYDROLOGICAL CONDITIONS OF THE WATER BODY THROUGH THE FUTURE

7.1 Water Use in the Study Area

7.1.1 Water Use in the Entire Study Basin

In the upper Manyame river basin, the major impoundments are Lake Manyame, Lake Chivero, Seke Dam and Harava Dam. Several rivers flow into these water bodies. Their general dimensions and water use are shown in Table 7.1.1.

Table 7.1.1 Water Use in the Entire Study Basin

Water Body	Catchment Area (km ²)	Rated Capacity (x1000m ³)	Flow Rate (x 1000 m ³ /day)	Water Use
1. L. Manyame	590	480,236		Water Supply, Recreation and Fishery
Gwebi R.	770		166	Irrigation (Private Dam)
Muzururu R.	310		67	Irrigation (Private Dam)
2. L. Chivero	421	247,181		Water Supply, Recreation and Fishery
Marimba R.	215		63	Irrigation
Mukuvisi R.	230		114	Irrigation
Nyatsime R.	280		125	Irrigation
3. Seke & Harava Dam	115	12,406		Water Supply
Ruwa R.	195		42	Irrigation
Manyame R.	474		102	Irrigation

The direct use of river water is minimal due to limited flow available during dry season. As for irrigation, about 200 private dams are scattered in the Gwebi and Muzururu catchment area, while the reuse of treated effluent is dominant in the entire Study Area.

On the other hand, lakes and dams are utilised for water supply, recreation and commercial fishery purposes. Especially, the four impoundments are the most valuable water sources for water supply of metropolitan Harare and presently 477,000 m³/day is availed.

As for the recreational usage, Lake Manyame and Lake Chivero are designated as the national recreational park with a variety of interests including fishing, boating, swimming and game viewing. Commercial fishery is also allowed in both lakes.

Since these impoundments are situated in the lower elevation than the urban area and farm land, generated wastewater finally reaches to the lakes.

At the present time, there is no plan on future water use in the study basin. In other words, present water use will be practised through the future.

7.1.2 Domestic and Industrial Water Supply

(1) Existing Water Supply System

The Harare water supply system covers Harare City (350 km²) and its adjoining urban areas; Chitungwiza, Norton, Epworth, and Ruwa. The water supply service for the satellite areas of the city is provided by means of bulk water supply. The present water demand is reported at 360,000 m³/day. The industrial water consumption is about 70% of the domestic consumption.

1) Raw Water Sources

The raw water sources of the Harare water supply system depend on (four) 4 impounding dams as shown in Figure 7.1.1. The yield of these four impoundments is 477,000 m³/day and the total intake amount at present is approximately 440,000 m³/day. Water quality of the lakes/dams has deteriorated due to grey water and industrial wastewater discharge from urban areas into the Manyame river basin.

2) Water Treatment Plant

Two existing WTWs, Prince Edward and Morton Jaffray, adopt conventional water treatment system provided with sludge blanket clarifiers and rapid sand filters. The design capacity of the Morton Jaffray WTW and Prince Edward WTW are 614,000 m³/day and 90,000 m³/day, respectively (refer to Table 7.1.2). However, the Prince Edward WTW is operated intermittently to supplement peak demand, since its "safe yield" is limited to 23,000 m³/day.

Table 7.1.2 Outline of Water Treatment Works

Intake Source	Morton Jaffray WTW		Prince Edward WTW	
	Lake Manyame	Lake Chivero	Seke Dam	Harava Dam
Design Capacity	614,000m ³ /day		90,000m ³ /day	
Actual Production Capacity	350,000m ³ /day		23,000m ³ /day	

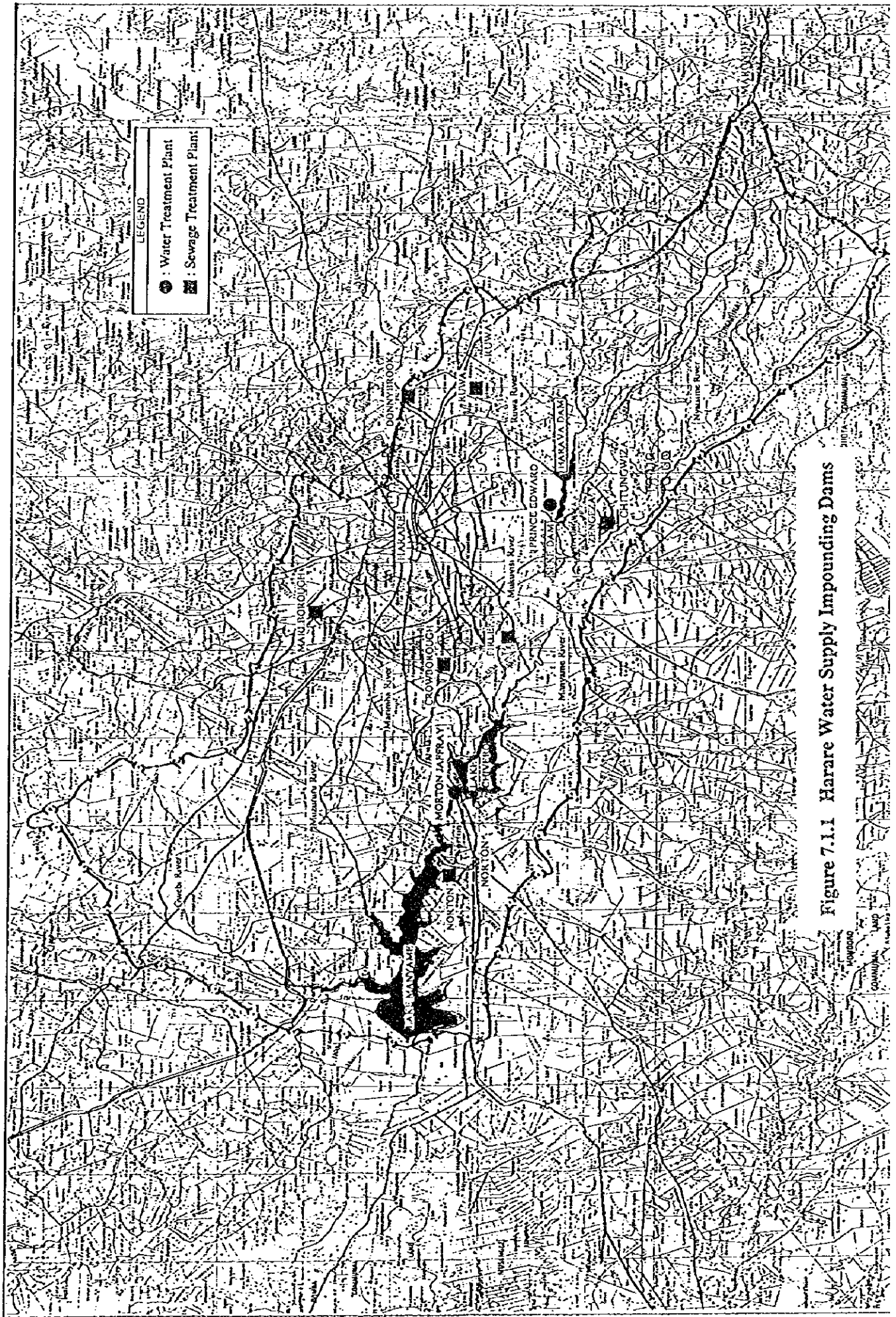


Figure 7.1.1 Harare Water Supply Impounding Dams

The deterioration of raw water quality has affected the operation of water treatment plants. The Morton Jaffray WTW, for instance, requires high chemical dosage which is beyond its full capacity of chemical handling and dosing equipment. As a result, the actual production is restricted up to only some 350,000m³/day in order to comply with required water quality standards.

3) Transmission and Distribution

Treated water is pumped from Morton Jaffray WTW to Warren Pump Station, and is again pumped to service reservoirs through four transmission mains. Water is then distributed through the respective network systems from the concerned service reservoirs to end users. Figure 7.1.2 shows schematic water supply system at present.

(2) Water Demand

1) Present daily water consumption

The previous water consumption experience by category (1986-1991) is shown in Table 7.1.3, and the water consumption of past 3 years (1992-1994) in Table 7.1.4.

Table 7.1.3 Water Consumption by Category(1986-1991)

Unit: m³/day

Year	Residential			Chitungwiza	Minor Supplies	Total of Sales	Total of Pumped
	High	Low/Mid	Ind./Com m./Inst.				
1986/87	35,000	66,000	72,000	27,000	3,000	203,000	250,000
1987/88	53,000	71,000	87,000	28,000	4,000	243,000	279,000
1988/89	44,000	73,000	88,000	27,000	5,000	237,000	274,000
1989/90	50,000	83,000	99,000	28,000	5,000	265,000	319,000
1990/91	53,000	97,000	115,000	28,000	9,000	302,000	352,000
Increase(%)	8.7	8	9.8	Neg.	N/A	8.3	

(Master Plan for Water Distribution, Vol. 3, Oct., 1995)

Table 7.1.4 Water Consumption (1992-94)

Unit: m³/day

	1992	1993	1994	Average	Remarks
Water Consumption	332,000	338,000	313,000	328,000	

2) Future water consumption projection

In the water supply master plan, three options of the future water consumption are studied as follows;

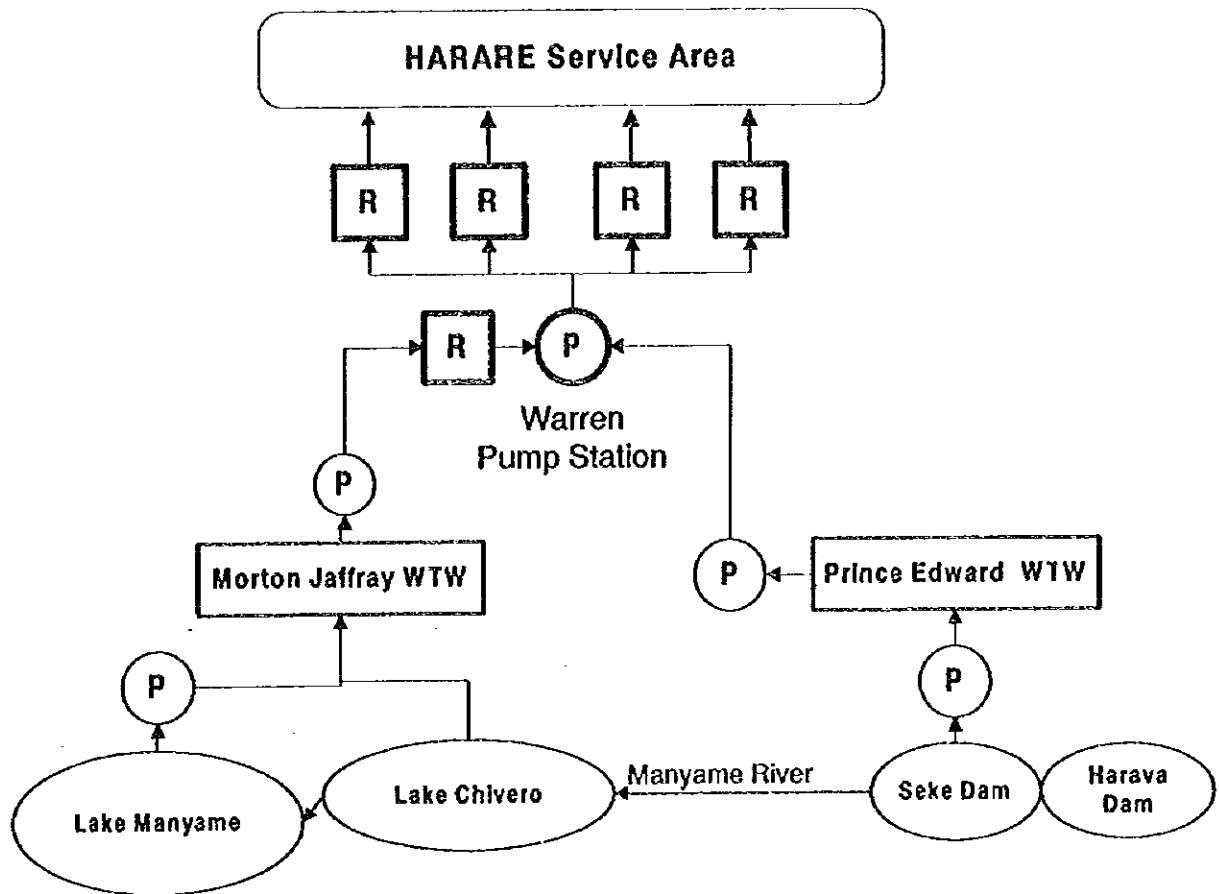


Figure 7.1.2 Schematic Water Supply System

Case-1: Application of historical increase rates of water consumption

Applying past increase rate (up to 1992), 2012 water demand is estimated at 1,868,000 m³/day.

Case-2: Applying population growth rate projected in the plan

Applying the projected population and unit consumption amount by different land use, 2012 demand is estimated at 1,388,800 m³/day.

Case-3: Application of modified consumption rates

In consideration of non-essential requirements in Case-2, 2012 water demand is estimated at 1,230,200 m³/day.

Table 7.1.5 summarises these three projections of future demand, of which, Case 2 was employed for preparation of water supply plan.

Table 7.1.5 Alternative Future Demand Projection

Year	2012					
	Population	case1	case2		case3	
		Daily demand (m ³ /day)	Per capita (l/p/day)	Daily demand (m ³ /day)	Per capita (l/p/day)	Daily demand (m ³ /day)
Harare High-density	3,787,911		80	303,000	80	303,000
Medium-density	501,375		300	150,400	250	125,300
Low-density	486,545		625	303,800	350	170,300
Sub-total				757,200		598,600
Inst/Comm/Ind				530,000*		530,000*
Chitungwiza	663,010			70,500**		70,500**
Norton&Ruwa	74,452			31,100***		31,100***
Total	5,513,292	1,868,000		1,388,800		1,230,200

* 70% of domestic use **4.5% annual increase ***6.4% annual increase

(Master Plan for Water Distribution, Vol. 3, Oct., 1995)

(3) Proposed Water Supply System

1) Raw water sources

If the treated effluent discharged from STWs could be fully used, the yield would be 592,000 m³/day. Even if under such a assumption, a shortfall is of 798,000 m³/day to meet 2012 demand of 1,390,000 m³/day.

At present, water source development program has been studied under the Department of Water Resources. In the Harare Water Supply Study(July, 1994), the Department has proposed a phased development of water sources in the Nyagui catchment and Shavanhowe catchment, 50-60 km to the east of Harare. It is planned that the construction of Kunzwi Dam on the Nyagui River would be undertaken in order to provide the bulk water to the City of Harare on and before 2005.

The proposed development and the present situation regarding water supply are summarised in Table 7.1.6 and Figure 7.1.3.

Table 7.1.6 Water Demand and Water Source

		1990/1994	2005	2012
1. Water source	Catchment	Rated Capacity(Million m³)		
Harava Dam	Manyame River	9.0	9.0	9.0
Seke Dam	Manyame River	3.4	3.4	3.4
Lake Manyame	Manyame River	247.2	247.2	247.2
Lake Chivero	Manyame River	480.2	480.2	480.2
Kunzwi Dam	Nyagui River	-	160	160
Musami Dam	Shavanhowe Rive	-	-	310
Total		740	900	1,210
2. Available for Water supply(m³/day)				
Manyame Basin		477,000	477,000	477,000
Supplment with ST ¹ (existing)		49,000	49,000	49,000
(future)		0	0/66,000	66,000
Manyame Subtotal		526,000	526/592,000	592,000
Nyagui Basin		-	192,000	192,000
Shavanhowe Basin		-	-	274,000
Total		592,000	784,000	1,058,000
3. WTW Design Capacity (m³/day)				
Prince Edward		90,000	90,000	90,000
Morton Jaffray		614,000	614,000	614,000
New WTW(1)		-	288,000	288,000
New WTW(2)		-	-	(411,000)
Total		704,000	992,000	(1,403,000)
4. Water demand(m³/day)		330,000	*810,000	1,390,000
5. Balance(2-4)		262,000	-260,000	-322,000

Note: * estimated from Figure (refer to Figure 7.1.3)

411,000 is estimated by 274,000x1.5

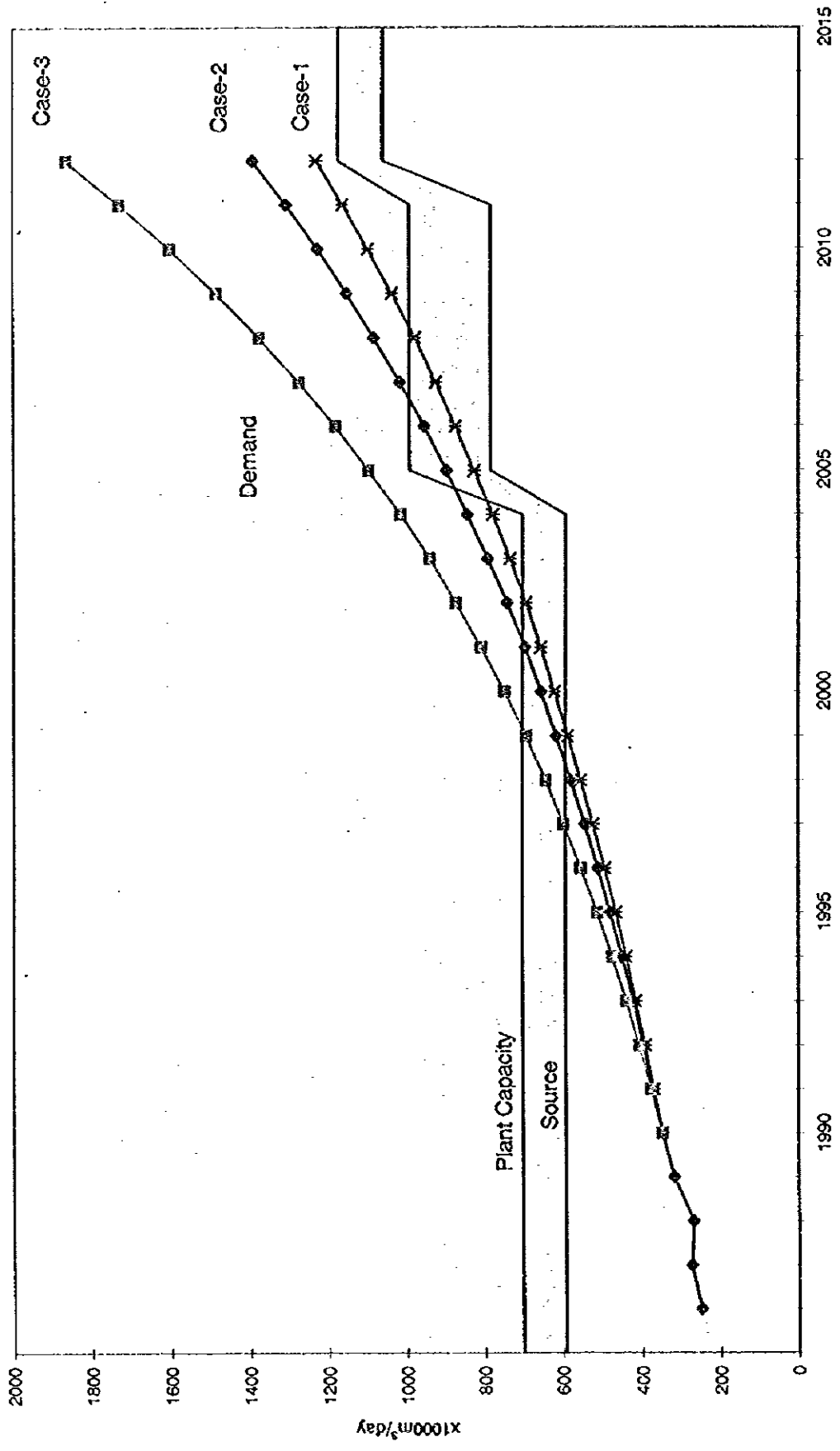


Figure 7.1.3 Water Demand ,Source,and Plant Capacity

2) Water Treatment Works

The Master Plan for Water Distribution considered staged construction of facilities to utilise the water in the Nyagui catchment. The design capacity of the impoundment (288,000m³/day) corresponds to 1.5 times of that of the proposed Kunzwi Dam.

3) Transmission and Distribution System

It is proposed that the future transmission main conveying treated water from the Nyagui catchment to the City of Harare connects to the proposed Outer Ring Main system. This would enable the effective distribution of the Nyagui water to various service reservoirs as required. However, further need of the study for an appropriate distribution system still remains.

7.1.3 Environmental Water Quality Standards

(1) General

In Zimbabwe, the regulation of effluent for wastewater has been enacted; however, the environmental water quality standards have not been established yet. Moreover, there is no informational base upon which to evaluate the present water quality in the water bodies of the country, since it has not yet been established what level of water quality is to be required for the various water uses and for water quality preservation.

To prepare the water pollution control plan for the Upper Manyame River Basin, the establishment of the Environmental Water Quality Standard would be primarily required. The subject water basins are to be classified in consideration of water use and water preservation. Staged goals may be introduced as provisional standards due to the current water pollution status of the water bodies. Water quality checking points are to be established for monitoring purposes.

(2) Environmental Water Quality Standard

Generally, water quality items consist of two categories, i.e., the environmental items represented by BOD and COD as the general indicators of organic pollution load and human health related items including heavy metals, volatile organic chemicals and agricultural chemicals. These items are to be monitored in the water bodies through the year. However, while the river water quantity may not be enough to conduct checking during

the dry season, the lake and dam water should be sufficient enough to comply with the requirement so as to obtain an annual average.

1) Environmental items

The environmental items for rivers as adopted in Japan comprise pH, BOD, SS, DO and a coliform group; and for the lakes Total Nitrogen (T-N) and Total Phosphorus (T-P) are added and COD is replaced by BOD. Standard qualities for these items are determined in accordance with the different purposes of the intended water uses.

The environmental water quality standard is usually set considering the dilution of effluent with river water (1/10-1/100). The following table shows the effluent standards of Zimbabwe. In the application of 1/10 dilution rate to the effluent standard, the environmental water quality standards are in the same level as those in Japan.

Table 7.1.7 Effluent Standard of Wastewater, Zimbabwe

Zone	pH	COD	SS	DO	T-N	T-P
1	6.0-7.5	30 mg/L	10 mg/L	75%	10 mg/L	1.0 mg/L
2	6.0-9.0	60	25	60	10	1.0

a) BOD and COD

Based on the above discussions, the standards for BOD and COD are proposed as shown in Table 7.1.8 .

Class A, "Not greater than 3 mg/l both for BOD and COD" is applied for natural environmental preservation, and for potable water supply and swimming purposes.

Class B, "Not greater than 5 mg/l both for BOD and COD" is applied for fisheries only in consideration of the present guideline for irrigation water "Not greater than 70 mg/L of BOD".

Class C, "Not greater than 10 mg/l for BOD and 8 mg/L for COD" is applied for irrigation water, industrial water use and flow maintenance.

Table 7.1.8 Proposed Classification

BOD for Rivers

mg/L	Natural Environmental Preservation	Potable Water	Swimming Recreation	Fishery	Irrigation	Industrial	Environmental Preservation	mg/L	Proposed Class	Japanese Class	
0	↑	Class-1	↑	Class-1	↑	↑	↑	0	A	AA	
1								1		A	
2								2		B	
3		Class-2	↑	Class-2				3	B	C	
4											4
5		Class-3	↑	Class-3				5	C	D	
6											6
7		Class-1	↑	↑				↑	7	E	
8											8
9											9
10	10										

COD for Lakes

mg/L	Natural Environmental Preservation	Potable Water	Swimming Recreation	Fishery	Irrigation	Industrial	Environmental Preservation	mg/L	Proposed Class	Japanese Class	
0	↑	Class-1	↑	Class-1	↑	↑	↑	0	A	AA	
1								1		A	
2								2		A	
3		Class-2,3	↑	Class-2				3	B	B	
4											4
5		Class-3	↑	Class-3				5	C	C	
6											6
7		Class-1	↑	↑				↑	7	C	
8											8
9											9
10	10										

b) Total Nitrogen and Total Phosphorus

The standards for T-N and T-P are shown in Table 7.1.9 in the same manner as the study of BOD and COD. In the classification, three nutrient grades are applied to the lakes: poor, medium and rich. Neither T-N nor T-P are hazardous substances but they cause algal growth. Under these conditions, the classified grades of T-N and T-P are applied for the respective water uses: fisheries, irrigation water, industrial water use and environmental preservation.

Class A, "Oligotrophic Lake", for potable water supply and swimming purposes. There is no need for any treatment of the water to remove nutrients. The standards of T-N and T-P are not greater than 0.2 mg/l and 0.01 mg/l, respectively.

Class B, "Mesotrophic Lake" for fisheries use. The standards of T-N and T-P are not greater than 0.6 mg/l and 0.05 mg/l, respectively.

Class C, "Eutrophic Lake" for irrigation water, industrial water and flow maintenance. The standards of T-N and T-P are 1.0 mg/l and 0.08 mg/l, respectively.

c) Other items

The standards of pH, DO, SS and Coliform groups that are adopted in Japan may be employed. Table 7.1.10 presents the proposed standards on environmental items.

Table 7.1.9 Classification of Total Nitrogen and Total Phosphorus

T-N for Lakes

mg/L	Natural Environmental Preservation	Potable Water	Swimming Recreation	Fishery	Irrigation Industrial	Environmental Preservation	Eutrophic Class	mg/L	Proposed Class	Japanese Class
0	↓	↑ Class-1,2,3	↑	↑ Type-1	↑	↑	↑ Oligotrophic	0	A	1
0.1							↓	2		
0.2				↓ Class-*			↓	↓ Type-2	↓	B
0.3		↓	4							
0.4		↓ Eutrophic	↓					↓ Type-3	↓	C
0.5				↓						
0.6				↓						
0.7				↓						
0.8				↓						
0.9				↓						
1.0	↓									

T-P for Lakes

mg/L	Natural Environmental Preservation	Potable Water	Swimming Recreation	Fishery	Irrigation Industrial	Environmental Preservation	Eutrophic Class	mg/L	Proposed Class	Japanese Class
0	↓	↑ Class-1,2,3	↑	↑ Type-1	↑	↑	↑ Oligotrophic	0	A	1,2
0.01							↓	3		
0.02				↓ Class-*			↓	↓ Type-2	↓	B
0.03		↓	5							
0.04		↓ Eutrophic	↓					↓ Type-3	↓	C
0.05				↓						
0.06				↓						
0.07				↓						
0.08				↓						
0.09				↓						
0.1	↓									

Table 7.1.10 Proposed Environmental Standard

Rivers

Class	Water Use	BOD	pH	SS	DO	Coliforms Group	Remarks
A	Natural Environmental Preservation Potable Water Swimming and Recreation As in "B,C"	L.E. 3mg/L	6.5-8.5	L.E. 25mg/L	G.E. 5mg/L	L.E. 1000MPN/100ml	
B	Fishery As in "C"	L.E. 5mg/L	6.5-8.6	L.E. 50mg/L	G.E. 5mg/L	-	
C	Irrigation Water Industrial Water Environmental Preservation	L.E. 10mg/L	6.0-8.6	No Suspend Dusts	G.E. 2mg/L	-	

Lakes

Class	Water Use	COD _{Mn}	T-N	T-P	pH	SS	DO	Coliforms Group	Remarks
A	Natural Environmental Preservation Potable Water Swimming and Recreation As in "B,C"	L.E. 3mg/L	L.E. 0.2mg/L	L.E. 0.01mg/L	6.5-8.5	L.E. 25mg/L	G.E. 5mg/L	L.E. 1000MPN/100ml	Oligotrophic Lake
B	Fishery As in "C"	L.E. 5mg/L	L.E. 0.6mg/L	L.E. 0.05mg/L	6.5-8.5	L.E. 50mg/L	G.E. 5mg/L	-	Mesotrophic Lake
C	Irrigation Water Industrial Water Environmental Preservation	L.E. 8mg/L	L.E. 1mg/L	L.E. 0.1mg/L	6.5-8.5	No Suspend Dusts	G.E. 2mg/L	-	Eutrophic Lake

Note ; L.E.: Less than or Equal to
G.E.: Greater than or Equal to

2) Health Related Items

There are many hazardous substances as that pose potential health risks, like heavy metals and agricultural chemicals. These are discharged mainly from specific sources such as industry and farms. Effluent standards for industrial wastewater have been established by the government to control unnecessary influence to the aquatic environment as well as various water uses.

In view of assuring safety of drinking water sources, it is deemed indispensable to monitor the presence of such hazardous substances in public water body, especially lakes/ dams in the Study Area. In this connection, the government has adopted the "Guideline for Drinking water" of WHO as the national standard. For conservation of water quality in lakes/dams in the Study Area, this standards since the conventional water treatment process can not remove such hazardous substances to acceptable levels for human consumption.

On the other hand, it is not appropriate to apply all of the prescribed items of the said guideline since some chemicals are not presently used or being used in very limited amounts in Zimbabwe. Human health-related items adopted in the Japanese standards are less than that of WHO, however these items are designated mainly considering health damage which have been caused by environmental pollution in the past. Similar situation may likely occur in Zimbabwe, if appropriate guidelines and monitoring are not applied in the subject water body when types of industries presently operated in the Study Area taken into account.

In view of practicability to the present situation in Zimbabwe, it is deemed appropriate to adopt, at least, same items applying respective values based on WHO standards, as presented in Table 7.1.11, while such items other than the Japanese standards shall be subject to add when they are detected in the subject water body through monitoring and/or being introduced in the economic activities.

Table 7.1.11 Environmental Standard for Health Related Items

Unit: mg/l

Item	Proposed Value	Reference Value		
		Guideline for Drinking Water (WHO)	Japanese Standard	Effluent Standard of Waste Water (Zimbabwe)
Arsenic	0.01	0.01	0.01	0.05
Cadmium	0.003	0.003	0.01	0.01
Chromium	0.05	0.05	0.05	0.05
Cyanide	0.07	0.07	ND	0.2
Lead	0.01	0.01	0.01	0.05
Mercury	0.001	0.001	0.001	0.05
Selenium	0.01	0.01	0.01	*
Carbon tetrachloride	0.002	0.002	0.002	*
1,2-dichloroethane	0.03	0.03	0.004	*
1,1-dichloroethylene	0.03	0.03	0.02	*
dichloromethane	0.02	0.02	0.02	*
cis-1,2-dichloroethylene	0.05	0.05	0.04	*
tetrachloroethylene	0.04	0.04	0.01	*
trichloroethylene	0.07	0.07	0.03	*
benzene	0.01	0.01	0.01	*
1,3-dichloropropene	0.02	0.02	0.002	*

*:Items not considered in the effluent standard

(3) Water Quality Classification and Checking Points

Water quality standards are to be determined for the main river and lakes/dams. In this regard, the study basin comprises three lakes/dams: the Seke and Harava dams, Lake Chivero and Lake Manyame, and two sections of the main river connected to the lakes/dams; Manyame River Origin (upstream from the Harava Dam) and the section between Seke dam and Lake Chivero. Figure 7.1.4 shows the subject sub-water bodies. The water quality checking points are to be established for the above-mentioned respective water bodies.

1) Water Quality Classification

Water quality classification shall be done taking into account of present and future water use of the subject sub-basins. The following are proposed classifications by lake/dam or river.

- Lake/Dam

Since the lakes/dams in the study basin are used for drinking water supply and recreational purpose, Class A is required.

- Rivers

The water quality of the river is possible to adopt Class C only to ensure maintenance flow. However, the water is the source of the lakes/dams. In this connection, Class B for fishery use is recommended. Under the current status of river water quality, the classification is practical. While, Class A may be adoptable for the upstream section from Harava Dam in light of the minimal inflow of pollution load in the sub-basin.

2) Water Quality Checking Points

In setting up water quality checking points, it shall be classified into two categories, i.e., "Checking Points" wherein water quality will be legislatively controlled, while "Reference Points" wherein water quality will be monitored basin-wide as reference for "Checking Points".

Table 7.1.12 and Figure 7.1.4 presents the checking/reference points both for lakes/dams and the rivers.

(4) Provisional Standards

In the above study, the water quality classifications were introduced according to the water uses. However, some items are considered difficult to comply with their standards under the present situation. The provisional standards as shown in Table 7.2.13 and Table 7.2.14 would be applied under the following conditions:

1. The provisional standards are to be applied to the items which the proposed standards are not likely to be achieved. At this stage, the items involved are BOD, COD, T-N, and T-P.
2. The provisional standards are required to comply with the present effluent standards of wastewater.
3. Finally, the water quality standards should be followed by the year 2015.

Table 7.1.12 Recommended Water Quality Checking/Reference Points

Water Body	Water Quality Checking/Reference Point				Water Quality
	No.	River/Lake	Lake/dam basin	Location	Classification
River	CR1	Manyame R.	Harava Dam	Before inflow to Harava Dam	A
	RR1	Ruwa R.	Harava Dam	- do -	
	RR2	Nyatsime R.	Lake Chivero	Before the Confluence to Manyame River	
	RR3	Manyame R.	- do -	Before joining with Mukuvisi river	
	RR4	Mukuvisi R.	- do -	Before the confluence to main river	
	CR2	Manyame R.	- do -	Before inflow to Lake Chivero	B
	RR5	Marimba R.	Lake Chivero	Before the confluence to main river.	
	RR6	Muzururu R.	Lake Manyame	Before inflow to Lake Manyame	
	RR7	Gwebi R.	- do -	- do -	
Lake/Dam	CL1	Seke Dam	N.A.	Center of the lake	A
	CL2	Lake Chivero	N.A.	Water intake tower	A
	CL3	Lake Manyame	N.A.	Water intake point for Harare Water Supply	A

Note: CR1 - 2; Checking Point (River)
 CL1 - 3; - do - (Lake)
 RR1 - 7; Reference Point
 N.A.; Not applicable

Table 7.1.13 Provisional Water Quality Standard

Unit: mg/l

Water Body	Lake/River	Period	COD _{Mn}	T-N	T-P
Lake	Seke & Harava Dam	Present	9.4	0.65	0.070
		2000/2005	< 5 B	< 0.4 A-B	< 0.05 B
		2015	< 3 A	< 0.2 A	< 0.01 A
	Lake Chivero	Present	14.9	0.51	0.270
		2000/2005	< 8 C	< 0.4 A-B	< 0.1 C
		2015	< 3 A	< 0.2 A	< 0.01 A
	Lake Manyame	Present	18.9	0.75	0.044
		2000/2005	< 8 C	< 1 C	< 0.03 A-B
		2015	< 3 A	< 0.2 A	< 0.01 A
River	Manyame River Origin	Present	BOD		
			1.1		
			< 5	B	
	Manyame River	Present	1.0		
			< 5	B	
			< 3	B	

Table 7.1.14 Water Quality Standard/Provisional Value

Lakes

Unit: mg/l

No.	Name	Class	Standard			Provisional (2000/2005)		
			COD	T-N	T-P	COD	T-N	T-P
CL1	Seke & Harava Dam	A	< 3	< 0.2	< 0.01	< 5	< 0.4	< 0.05
CL2	Lake Chivero	A	< 3	< 0.2	< 0.01	< 8	< 0.4	< 0.1
CL3	Lake Manyame	A	< 3	< 0.2	< 0.01	< 8	< 1.0	< 0.03

Rivers

No.	Name	Class	BOD	
			Standard	Provisional (2000/2005)
CR1	Manyame R.Origin	A	< 3 mg/L	(< 5 mg/L)
CR2	Manyame R.	B	< 5 mg/L	(< 5 mg/L)

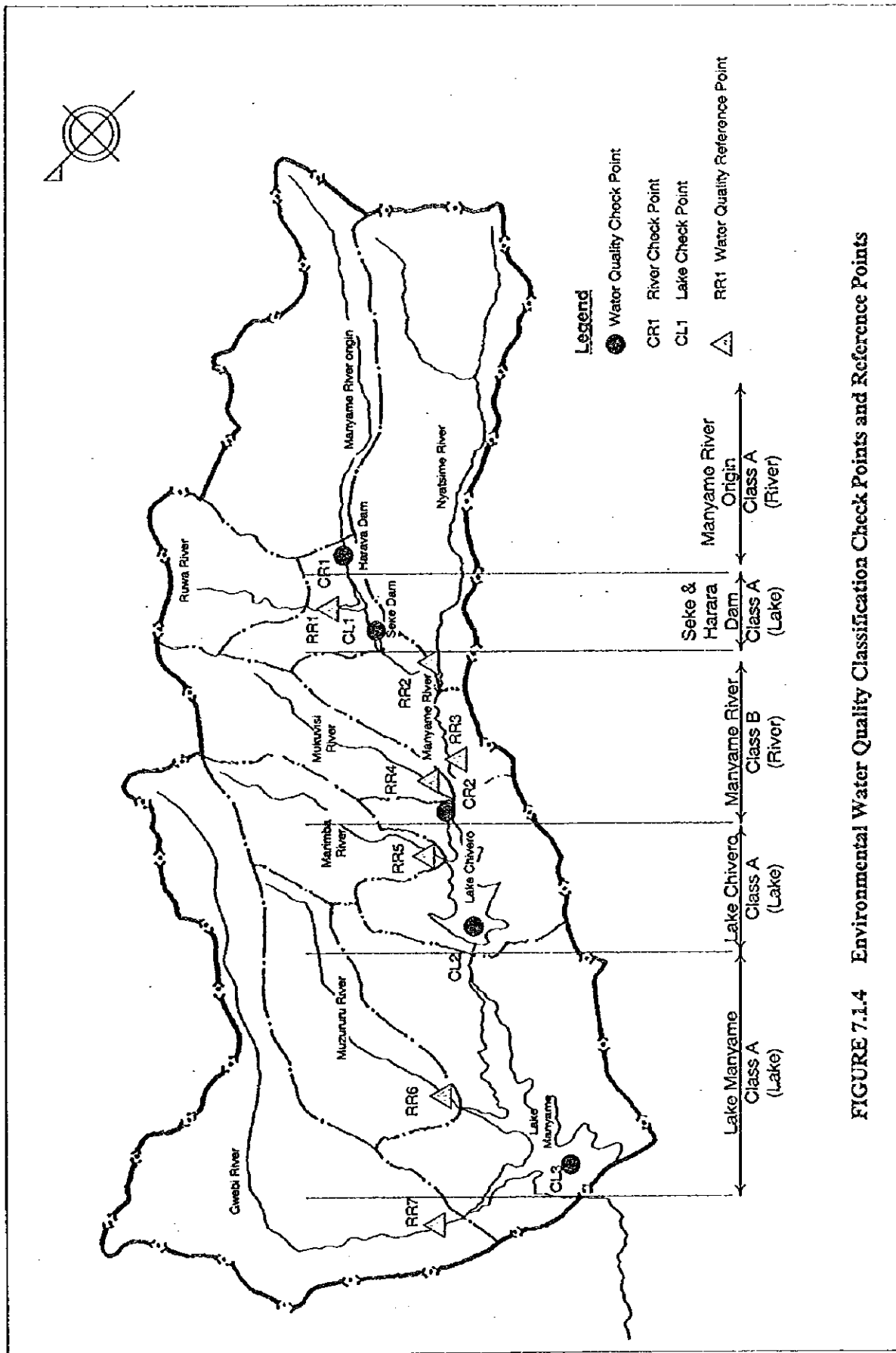


FIGURE 7.1.4 Environmental Water Quality Classification Check Points and Reference Points

7.2 Hydrological Condition of the Rivers and Lakes

7.2.1 Rainfall

The rainfall data of the Harare City (Belvedere) located in the centre of the basin are available to analyse hydrological condition. The weather stations located in the Manyame River Basin are included in Table 7.2.1 and Figure 7.2.1, Section 7.2, Chapter 2, Data Report. The annual rainfall data of the past 30 years (1963 to 1993) are shown in Figure 7.2.1 and the details are shown in Table 7.2.2, Section 7.2, Chapter 2, Data Report. The average annual rainfall is about 830 mm with a range of 445 to 1246 mm. The five and ten years running averages are also shown in the same figure. The five-year running average fluctuates slightly, while the ten year running average almost constant. Thus, a ten-year cycle of rainfall is prevalent in the basin.

The monthly rainfall of the past ten years is shown in Table 7.2.1, and Figures 7.2.2 and 7.2.3. The annual average rainfall in the last ten years is 818 mm with a range of 524 mm to 1094 mm. The monthly average rainfall indicates a dry season from April to October. About 90 % of the annual rainfall is concentrated in the 5 months of the rainy season, and about 25 % of the annual amount is recorded during January. The annual rainfall amount is considerably affected by that of January.

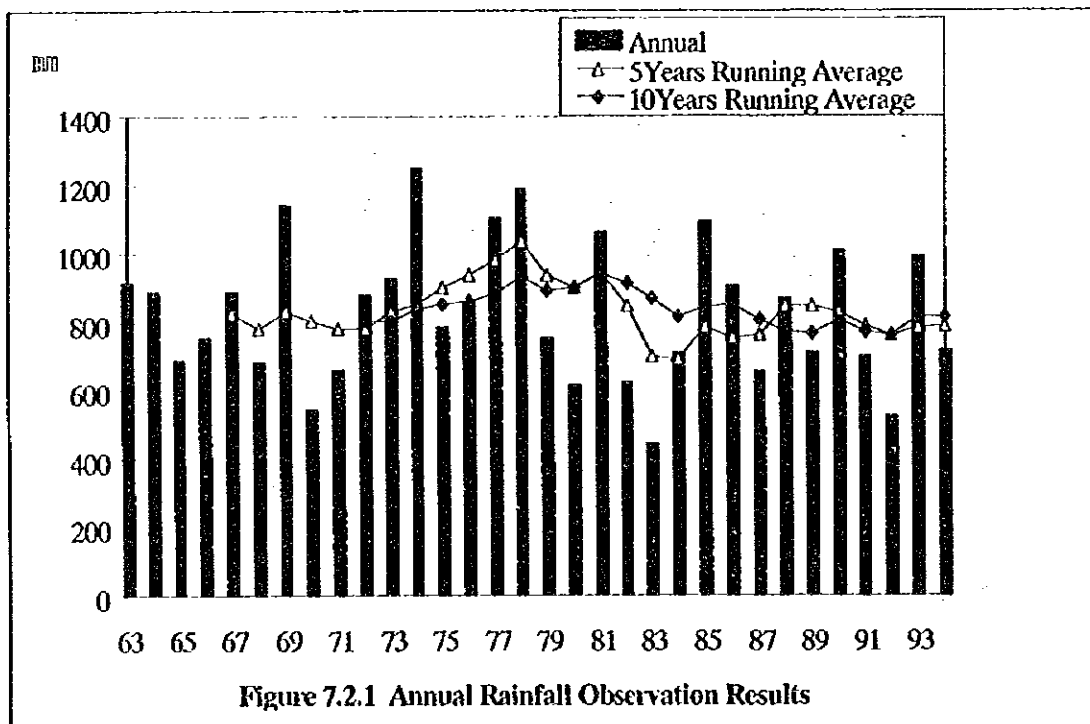
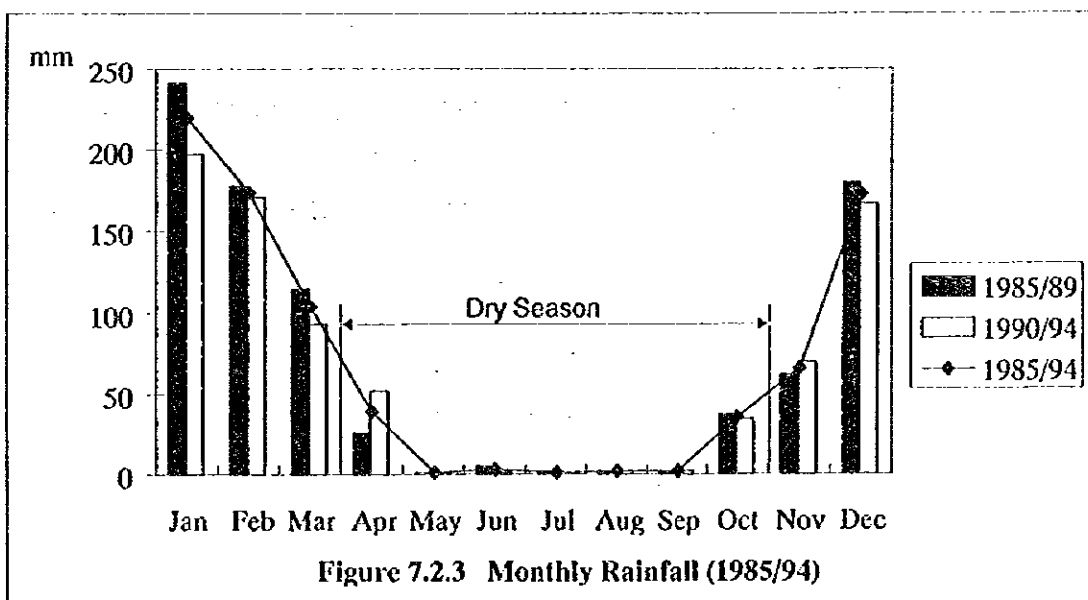
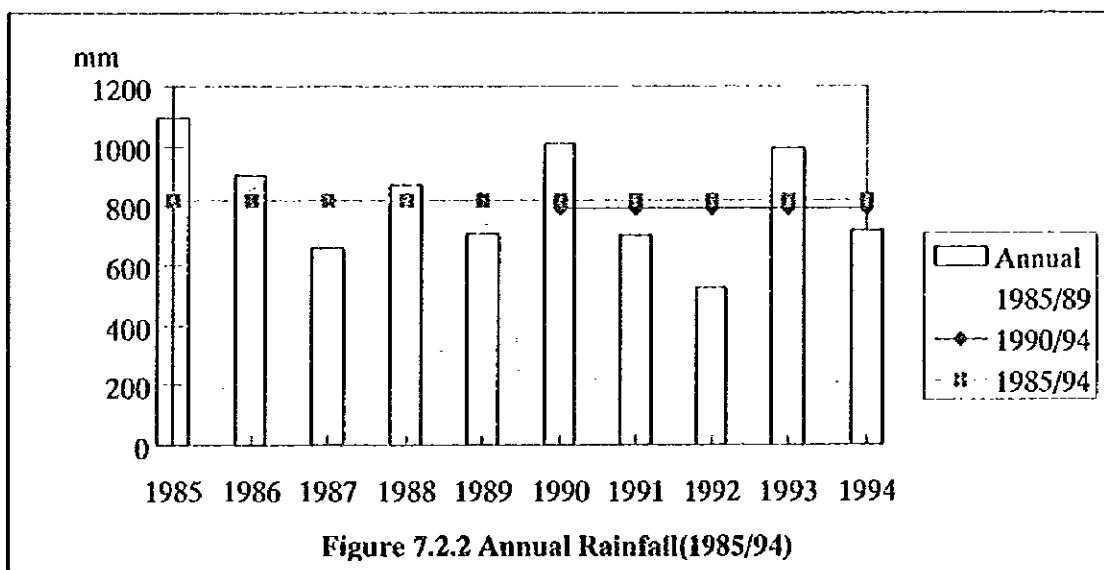


Figure 7.2.1 Annual Rainfall Observation Results

Table 7.2.1 Monthly Rainfall (1985/94)

Unit :mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	379.1	170.8	172.8	2.1	1.2	0.0	8.3	0.0	5.3	50.7	28.5	274.8	1,093.6
1986	254.1	211.9	86.5	68.3	0.0	0.0	0.0	0.1	0.0	46.7	78.5	158.8	904.9
1987	122.9	115.7	68.4	0.0	2.4	0.0	0.0	0.0	2.0	18.2	0.5	326.6	656.7
1988	202.1	183.3	179.2	42.8	0.0	22.0	0.0	0.0	0.0	68.4	87.4	87.5	872.7
1989	246.7	205.4	66.6	15.6	0.0	0.0	0.0	7.9	0.0	0.0	114.7	50.3	707.2
1985/89	241.0	177.4	114.7	25.8	0.7	4.4	1.7	1.6	1.5	36.8	61.9	179.6	847.0
1990	386.8	193.8	78.6	81.0	0.6	0.0	0.0	0.0	0.6	6.5	101.3	161.2	1,010.4
1991	153.0	156.4	94.3	0.6	0.8	0.0	0.0	0.0	3.0	38.5	73.4	180.2	700.2
1992	62.2	25.3	110.5	89.3	4.3	4.9	0.0	0.0	0.0	1.1	24.6	201.3	523.5
1993	158.9	321.2	134.0	65.2	0.0	0.0	0.4	3.8	6.2	19.5	123.5	158.6	991.3
1994	226.7	155.8	46.7	21.4	0.0	0.0	0.0	4.8	0.0	106.0	23.8	132.3	717.5
1990/94	197.5	170.5	92.8	51.5	1.1	1.0	0.1	1.7	2.0	34.3	69.3	166.7	788.6
1985/94	219.3	174.0	103.8	38.6	0.9	2.7	0.9	1.7	1.7	35.6	65.6	173.2	817.8



7.2.2 Flow Rate of the Rivers and Discharge of the Lakes and Dams

As shown in Table 7.2.2 and Figure 3.5.1, several gauging stations are set up to measure the flow rates of the rivers and discharges from the lakes and dams. The measurement results are the base of this analysis.

(1) Flow Rate

The annual average of flow rates in the Manyame River (before the confluence of Harava Dam and Lake Chivero), the Mukuvisi River, and the Marimba River in the last ten years, starting from 1985, are shown in Table 7.2.3 and graphically shown in Figure 7.2.4.

In addition, the fluctuation of the last ten-year monthly average values and rates is shown in Table 7.2.4 with graph of fluctuation ratio in Figure 7.2.5, and the details are shown in Table 7.2.3 (1) to 7.2.3 (4), Section 7.2, Data Report.

Table 7.2.2 Data Availability on Flow Rate and Discharge

Item	No.	Name	Location	Measured Period	Data Contents
Flow Rate	C81	Manyame Origin	Before the confluence of Harava Dam	1974 Oct. to 1995 Sep.	Monthly run-off
	C21	Manyame R.	Before the confluence of Lake Chivero	1957 Oct. to 1995 Sep.	- do -
	C22	Mukuvisi R.	- do -	1953 Oct. to 1995 Sep.	- do -
	C24	Marimba R.	- do -	1953 Oct. to 1995 Sep.	- do -
Discharge	C3	Seke Dam	Discharge point	1951 Oct. to 1995 Sep.	- do -
	C17	L.Chivero	Discharge point	1953 Oct. to 1995 Sep.	- do -
	C89	L.Manyame	Discharge point	1976 Oct. to 1995 Sep.	- do -

Table 7.2.5 and Figure 7.2.6 show the relationship between rainfall and the flow rate. The average run-off ratios in the last ten years are 7 to 8% at the two observatories respectively on the Manyame River, while 14 to 22% on the Mukuvisi and the Marimba River.

The average run-off ratio of the rivers in the whole of Zimbabwe are reported at 8%, which coincides with that of the Manyame River. The average run-off ratio of the Mukuvisi and the Marimba Rivers seem to be largely influenced by the STWs' effluent.

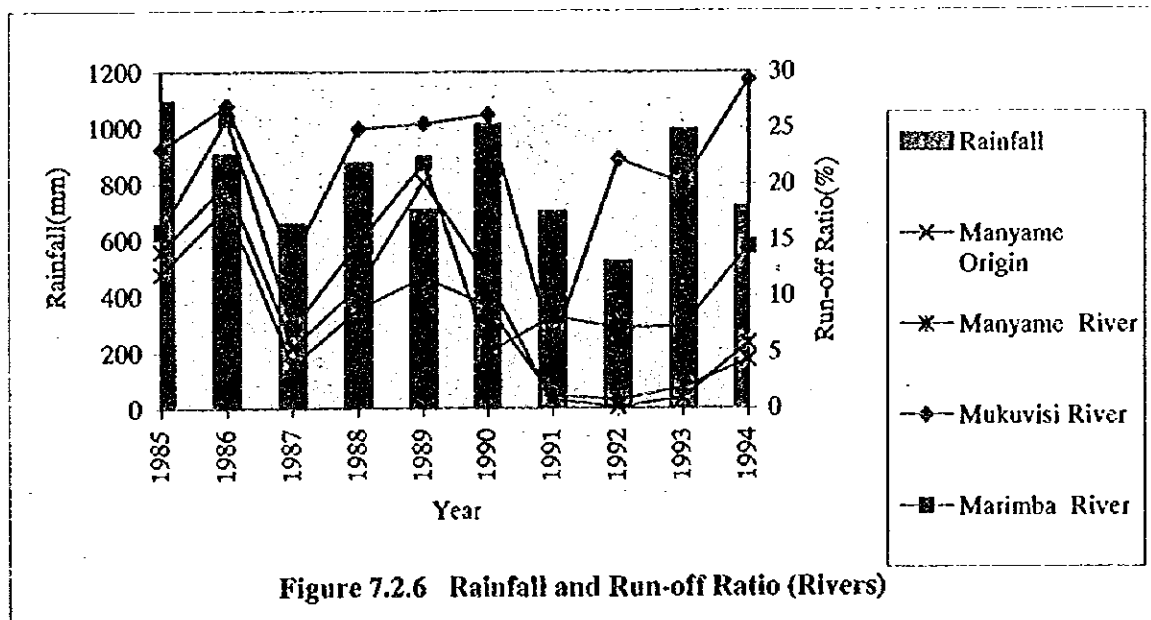
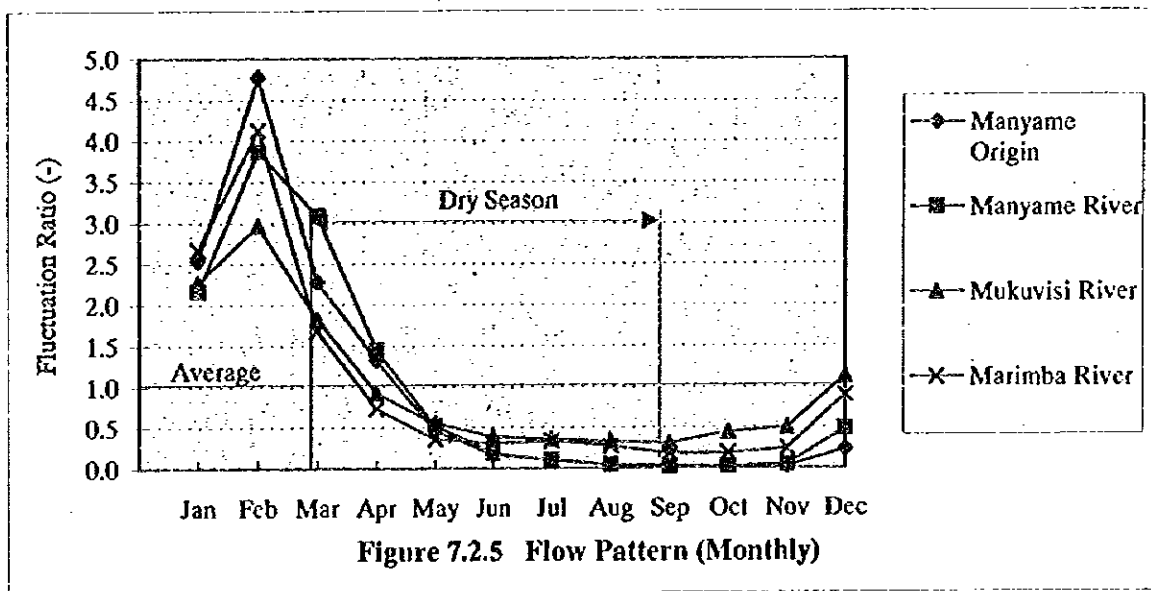
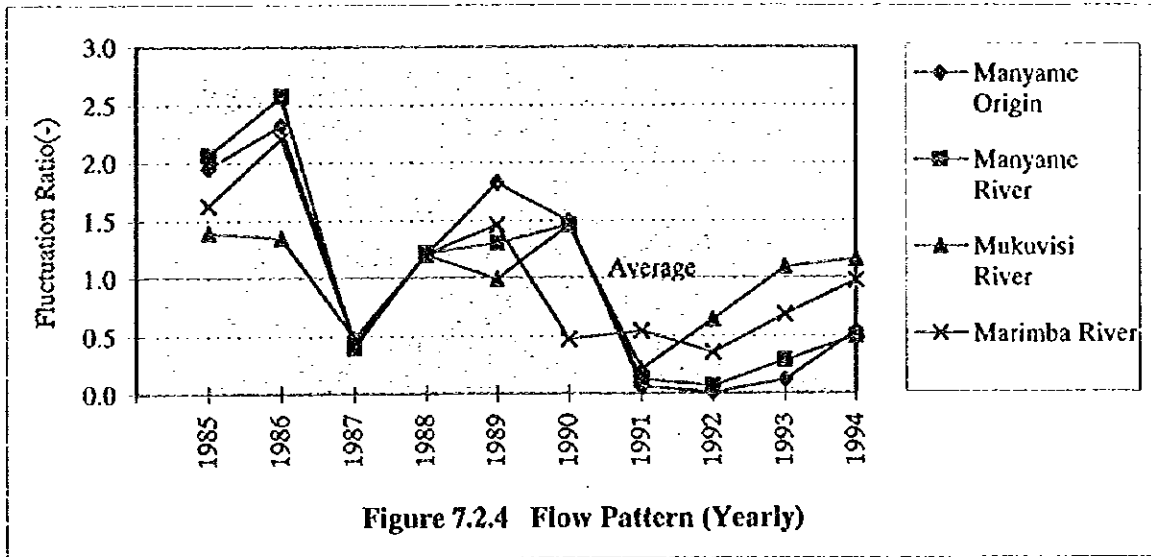


Table 7.2.3 Annual Average Flow Rate

	River	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Ave.
Flow Rate x1000 m ³ /day	Manyame Origin	198	236	47	122	185	152	7	1	12	54	101
	Manyame R.	547	682	106	323	345	387	34	17	77	130	265
	Mukuvisi R.	159	154	55	137	113	167	24	73	125	132	114
	Marimba R.	102	138	28	76	91	30	34	22	43	61	62
Fluctuation Ratio (-)	Manyame Origin	1.95	2.33	0.46	1.21	1.83	1.50	0.06	0.01	0.12	0.54	1.00
	Manyame R.	2.07	2.57	0.40	1.22	1.30	1.46	0.13	0.07	0.29	0.49	1.00
	Mukuvisi R.	1.39	1.35	0.48	1.20	0.99	1.46	0.21	0.64	1.10	1.16	1.00
	Marimba R.	1.63	2.21	0.44	1.22	1.46	0.47	0.54	0.36	0.69	0.98	1.00

Table 7.2.4 Monthly Average Flow Rate

	River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Flow Rate x1000 m ³ /day	Manyame Origin	260	489	234	136	47	17	11	4	3	2	2	24	102
	Manyame R.	576	1028	820	385	139	50	27	11	4	7	13	128	266
	Mukuvisi R.	259	337	208	105	63	45	40	37	35	51	57	128	114
	Marimba R.	168	258	105	46	23	19	21	17	11	12	15	56	63
Fluctuation Ratio (-)	Manyame Origin	2.54	4.77	2.28	1.33	0.46	0.17	0.10	0.04	0.03	0.02	0.02	0.23	1.00
	Manyame R.	2.17	3.87	3.09	1.45	0.52	0.19	0.10	0.04	0.02	0.03	0.05	0.48	1.00
	Mukuvisi R.	2.27	2.97	1.83	0.92	0.55	0.39	0.36	0.32	0.31	0.44	0.50	1.13	1.00
	Marimba R.	2.68	4.12	1.68	0.73	0.36	0.31	0.34	0.28	0.18	0.19	0.24	0.90	1.00

Table 7.2.5 Annual Average Run-off Ratio (Rivers)

Unit: %

River	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Ave.
Manyame Origin	14.0	20.1	5.5	10.8	20.2	11.6	0.7	0.2	0.9	5.8	9.0
Manyame R.	11.9	18.0	3.8	8.8	11.6	9.1	1.2	0.8	1.9	4.3	7.1
Mukuvisi R.	23.1	27.0	13.3	24.9	25.4	26.2	5.5	22.2	20.0	29.3	21.7
Marimba R.	15.8	25.8	7.1	14.7	21.9	5.0	8.2	7.2	7.3	14.4	12.7

(2) Discharge from Lakes and Dam

The annual averages of discharge are shown in Table 7.2.6 and Figure 7.2.7. The last ten-year monthly averages of the discharge from lakes and dams are shown in Table 7.2.7 and graphically in Figure 7.2.8, and based data are shown in Table 7.2.3 (5) to 7.2.3 (7), Section 7.2, Data Report. These data clearly show water management practices of the Seke Dam, Lake Chivero and Lake Manyame. The Seke Dam and Lake Chivero have not discharged water during the dry season, while Lake Manyame has discharged through the year. The purpose of constant discharge at Lake Manyame is to ensure maintenance flow for the lower reaches. The relation between rainfall and discharge is shown in Table 7.2.8 and Figure 7.2.9.

Table 7.2.6 Annual Average Discharge

	Lake/Dam	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Ave.
Discharge Flow x1000 m ³ /day	Seke Dam	434	482	92	193	278	139	5	0	0	54	168
	L.Chivero	39	92	4	181	56	79	0	0	0	0	45
	L.Manyame	134	483	226	171	27	225	80	72	56	76	155
Fluctuation Ratio (-)	Seke Dam	2.59	2.87	0.55	1.15	1.66	0.83	0.03	0.00	0.00	0.32	1.00
	L.Chivero	0.87	2.04	0.09	4.01	1.24	1.75	0.00	0.00	0.00	0.00	1.00
	L.Manyame	0.87	3.11	1.46	1.10	0.17	1.45	0.52	0.46	0.36	0.49	1.00

Table 7.2.7 Monthly Average of Discharge

	Lake/Dam	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Discharge Flow x1000 m ³ /day	Seke Dam	351	918	487	202	56	10	5	1	6	2	1	5	170
	L.Chivero	28	191	211	102	12	1	0	0	0	0	0	0	45
	L.Manyame	55	19	40	453	183	155	155	202	191	138	143	109	154
Fluctuation Ratio (-)	Seke Dam	2.06	5.39	2.86	1.19	0.33	0.06	0.03	0.00	0.03	0.01	0.01	0.03	1.00
	L.Chivero	0.62	4.20	4.64	2.24	0.28	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	L.Manyame	0.36	0.13	0.26	2.95	1.19	1.01	1.01	1.32	1.24	0.90	0.93	0.71	1.00

Table 7.2.8 Annual Average Run-off Ratio (Lakes and Dam)

Unit: %

Lake/Dam	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Ave.
Seke Dam	18.3	24.5	6.5	10.2	18.1	6.3	0.3	0.0	0.0	3.5	8.8
L.Chivero	0.6	1.7	0.1	3.4	1.3	1.3	0.0	0.0	0.0	0.0	0.8
L.Manyame	1.2	5.1	3.3	1.9	0.4	2.1	1.1	1.3	0.5	1.0	1.8

(3) Relationship between Water Level and Storage

The annual averages of the water level compared to the full capacity level of lakes and dams are shown in Table 7.2.9 and Figure 7.2.10, and the storage volume in lakes are shown in Table 7.2.4, Section 7.2, Data Report. The monthly averages are shown in Table 7.2.10 and Figure 7.2.11. In applying these water levels to the storage volume, the H-V curve is obtained as shown in Table 7.2.11 and Figure 7.2.12. The relationship between water level and storage volume is explained by the following equation.

$$y = (x/100)^{1.83} \times 100$$

x: Water level (%), y: Available Volume (%)

The results of the equation with regards to the measured level, and the storage volume of the lakes and dams are shown in Figure 7.2.13 and Figure 7.2.14.

Table 7.2.9 Annual Average Water Level of Lakes/Dams

Unit: %

Lake/Dam	1989	1990	1991	1992	1993	1994	1995	Ave.	1990/94
Harava Dam	83.7	82.2	16.3	0.0	66.9	86.2	14.9	50.0	50.3
Seke Dam	85.5	75.5	22.0	3.1	50.6	49.8	9.5	42.3	40.2
L.Chivero	96.0	97.8	93.4	78.6	73.0	89.7	68.2	85.2	86.5
L.Manyame	95.4	95.6	80.4	61.2	55.4	37.7	28.0	64.8	66.1

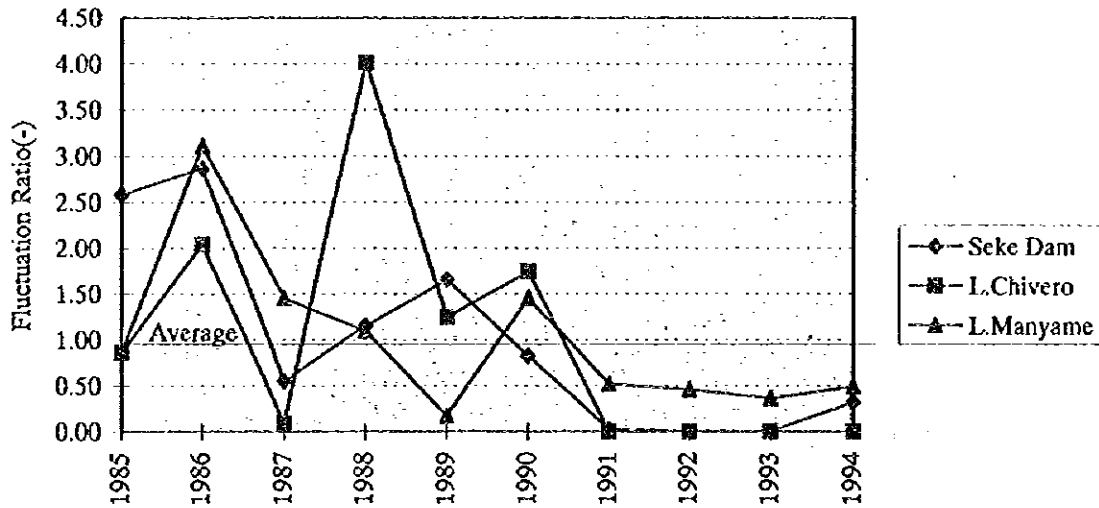


Figure 7.2.7 Discharge Pattern (Yearly)

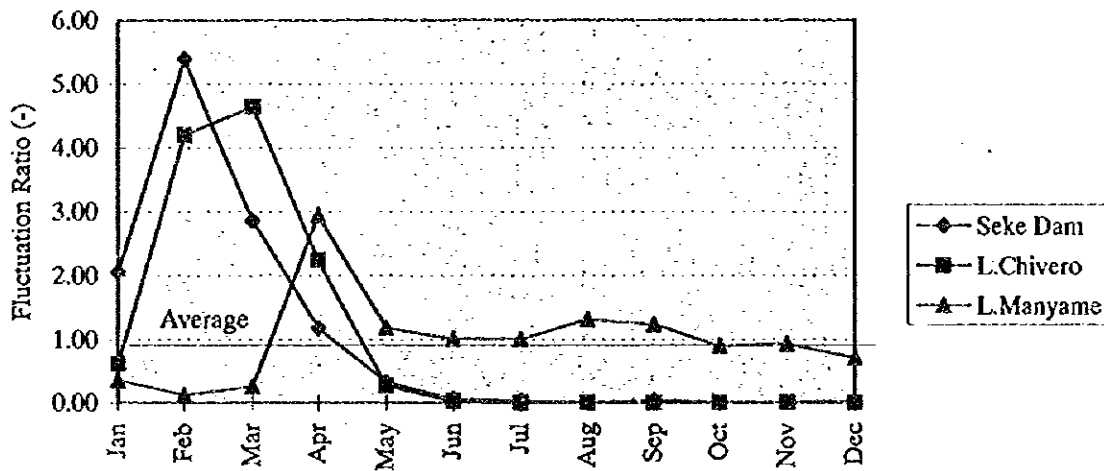


Figure 7.2.8 Discharge Pattern (Monthly)

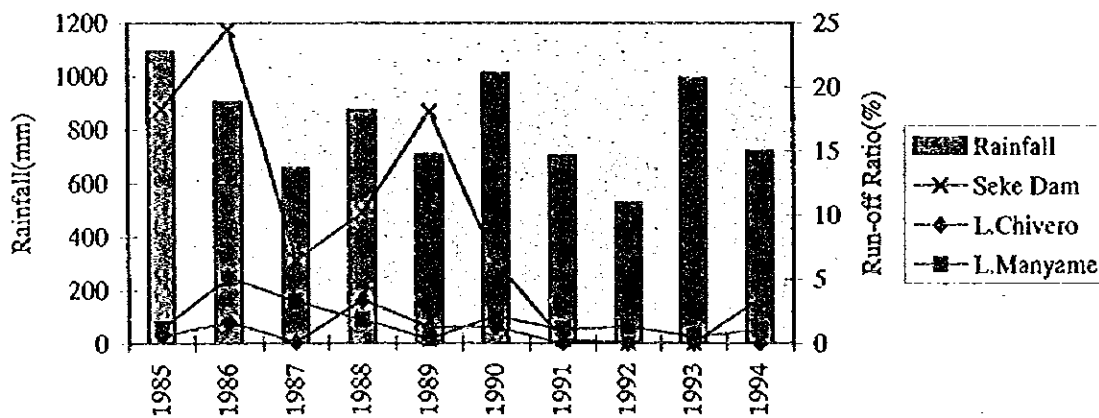


Figure 7.2.9 Rainfall and Run-off Ratio (Lakes and Dam)

Table 7.2.10 Monthly Average Water Level of Lakes and Dams

Unit; %

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Harava Dam	58.7	65.1	65.5	60.1	59.4	54.7	52.6	50.2	44.1	35.2	30.3	24.4	50.0
Seke Dam	45.1	61.0	57.9	61.3	49.3	35.6	38.8	32.2	33.9	30.9	35.5	25.7	42.3
L.Chivero	87.7	91.8	91.5	90.8	89.5	87.7	85.8	83.7	81.4	78.6	76.7	77.4	85.2
L.Manyame	67.0	71.0	70.9	69.9	68.2	66.8	65.2	63.2	61.6	59.1	57.5	57.7	64.8

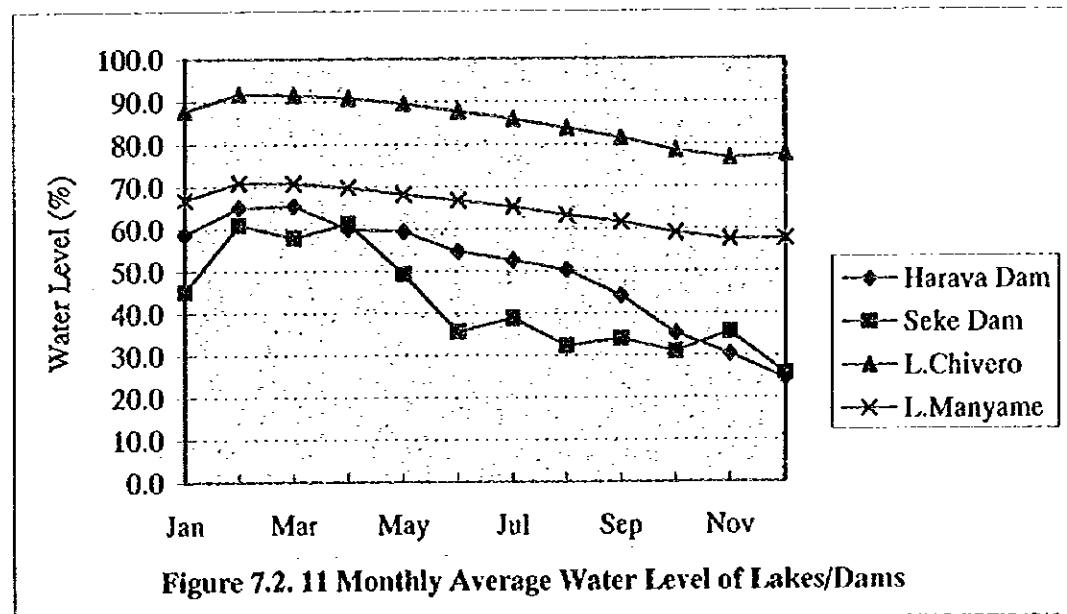
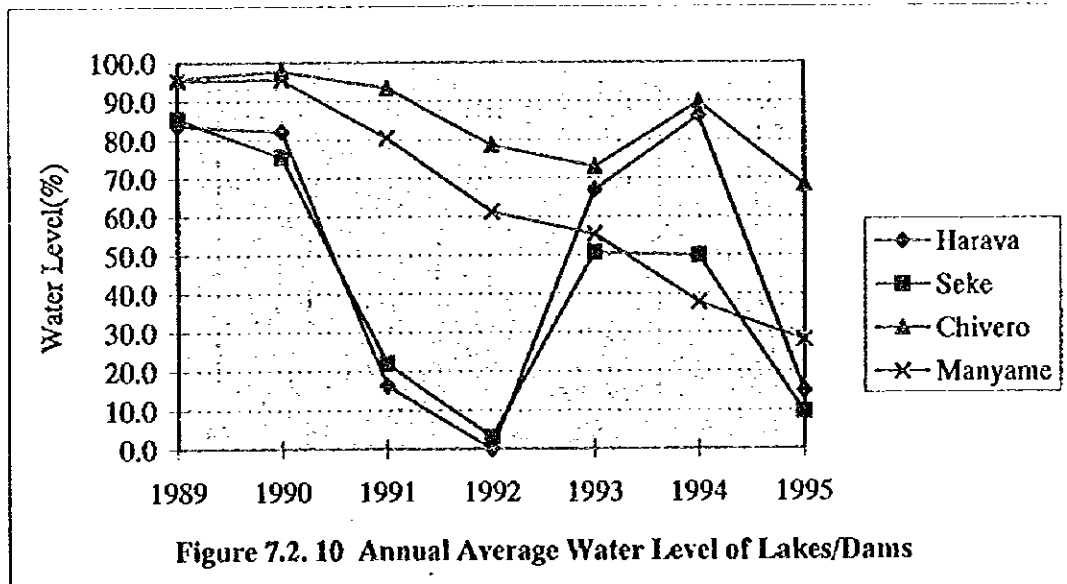
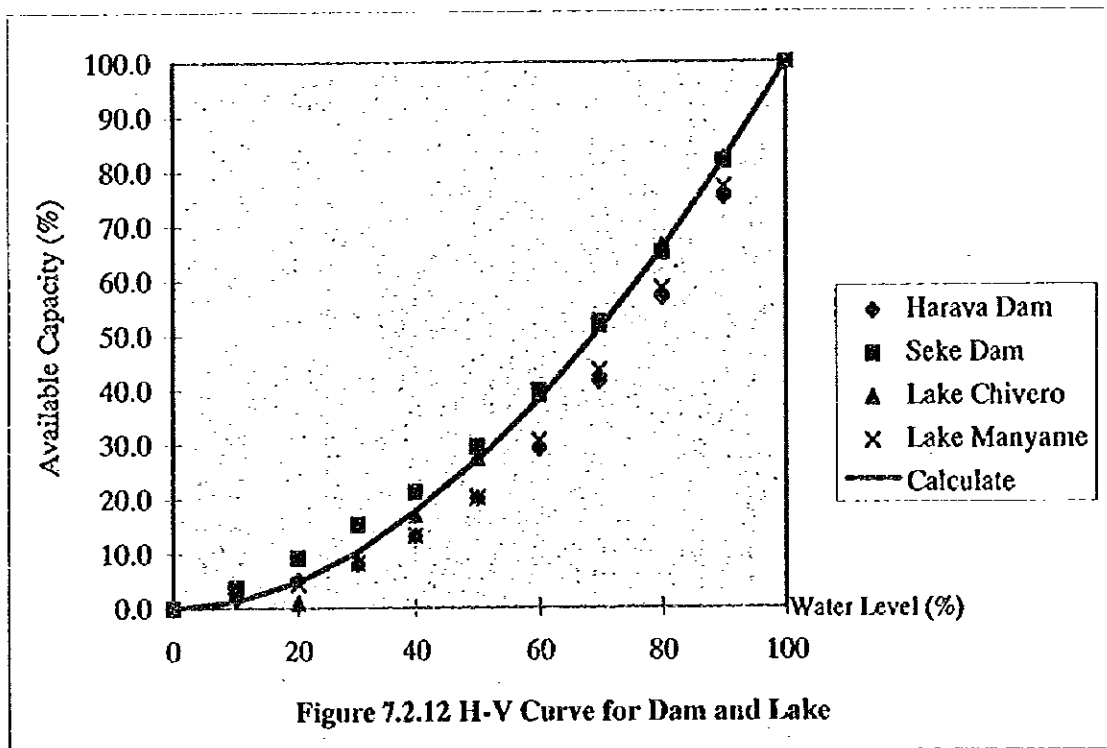
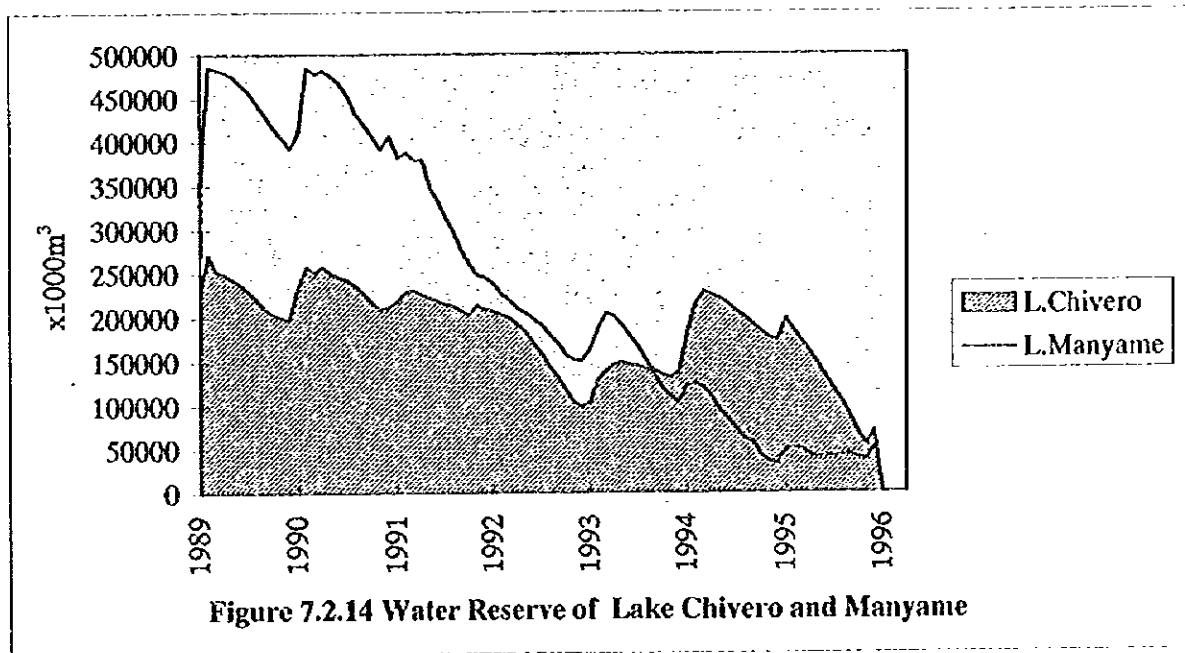
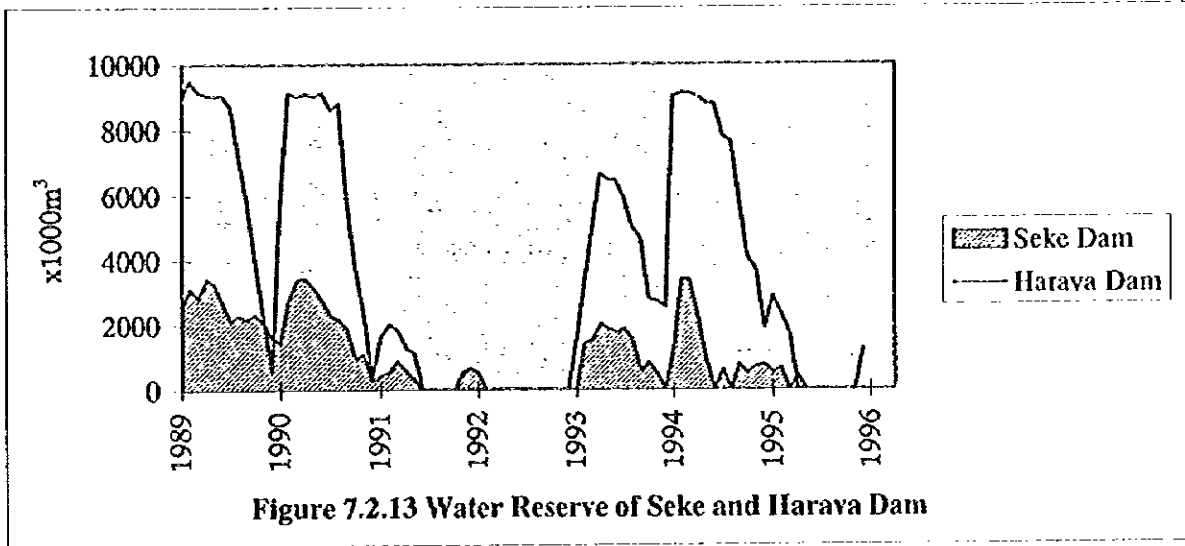


Table 7.2.11 H-V Curve of Lakes and Dams

Available Level (%)	Available Capacity (%)			
	Harava Dam	Seke Dam	Lake Chivero	Lake Manyame
100	100.0	100.0	100.0	100.0
90	75.3	81.8	82.4	77.2
80	56.9	65.1	66.3	58.6
70	41.6	52.5	51.9	43.7
60	29.2	39.9	39.2	30.7
50	20.2	29.6	27.5	20.3
40	13.3	21.3	17.1	13.3
30	8.1	15.3	8.5	8.3
20	5.2	9.2	1.0	4.5
10	1.7	3.7	n.a.	n.a.
0	0.0	0.0	0.0	0.0
Deapth (m)	10.65	5.795	15.3	14.25
Max Capacity (x1000m3)	9,026	3,380	247,181	480,236





7.2.3 Flow Rate Estimation and Flow Balance

The flow pattern of the rivers, water level and discharge rate of the lakes are analysed to come up with the flow balance in the entire study basin. Based on such results, the control factors which affect water pollution analysis were clarified.

The average figures of the last ten years (1985-1994) are utilised for the analysis, since a ten-year cycle pattern of rainfall is observed. Examination points are the lakes and before and after confluences of major rivers. The Seke and Harava Dams are regarded as one water body, because they are adjoin and their rated capacities and catchment areas are comparatively small. Figure 7.2.18 shows locations of the study points. The flow balance of the lake is studied referring to annual average of the flow rates, while the annual and dry season averages was used for the flow rates of the rivers. The factors to be examined are shown in Table 7.2.12 and the details of flow rate estimation and flow balance are shown in Section 7.2.1, Chapter 2, Supporting Report.

Table 7.2.12 Factors for the Study of Flow Balance

Flow	Item	Factors
Inflow	Rivers	-Measured value (Annual and dry season averages) -Specific discharge amount estimated (in case of no data available) -Sewage effluent amount
	Direct Rainfall	-Full Surface area of lake x rainfall amount
	Direct Area	-Specific discharge rate estimated; Runoff rate
Outflow	Evaporation	-Surface area of lake x Evaporation rate
	Water Intake	-Records of Intake
	Discharge	-Measured value
Balance	Water level of the lake	-Measured value
	Ground water recharge and others	-Assumption

(1) River Flow

The average flow rates at present are estimated using available data on both annual and dry season bases. However, specific discharges estimated are adopted in case no data is available.

1) Specific Discharge Rate

The daily average flow rates in the year and during the dry season are summarised in Table 7.2.13. There is no inflow of effluent discharged from the STW upstream of the Harava Dam. As described in sub-section 7.2.2, the average run-off ratio in the Manyame River basin is 8.7% in the last ten years, which is almost same as that in whole of Zimbabwe (8%). The specific discharge rates are shown in Table 7.2.13.

Table 7.2.13 Specific Discharge Rate Rate

	1985/94		Catchment Area (km ²)
	Annual	Dry	
Flow Rate (m ³ /day)	102,000	31,000	
Specific Flow Rate (m ³ /day km ²)	215	65	474

2) Influence of STW Effluent

Effluent discharged constantly from the STWs affects the flow rate of the rivers. Presently, simultaneous flow rates observation upstream and downstream of the STWs is not conducted. Under these conditions, the flow rates at a certain point of the river are different between measured data (flow implies discharged effluent) and those estimated using specific discharge rate in the subject basin. Additional flow to the rivers is calculated considering effluent discharge from the STWs. The following are conditions/assumptions for the calculation of the flow rates for water pollution analysis:

- a) Flow rates in the river comprise base river water and effluent discharged directly from the STWs and through the irrigation area.
- b) The influences to river water by the discharged effluent are to be considered in the sub-river basin where the STWs and irrigation area exist.
- c) Annual or dry season average figures are applied for the calculation.

The losses of the STWs' effluent discharged by evaporation and underground infiltration and, adverse inflow of groundwater are disregarded in item a) (100 % run-off to the river). While, the specific discharge from irrigated areas is considered to be same as the natural river basin (8 %).

Inflow to the rivers derived from the STWs is estimated as shown in Table 7.2.16 using the following equation:

$$y = x_1 + 0.08x_2$$

y : Flow caused by STW effluent

x₁ : STW effluent (discharge to the rivers)

x₂ : STW effluent (transmitted to farmland)

The difference of flow between measured data and estimated figure of using specific flow rate Marimba River almost coincides with effluent amount discharged from the STW. The details are shown in Section 7.2, Chapter 2, Supporting Report.

Present flow (m³/day) of the main river and major sub-rivers is presented in Table 7.2.14 and Figure 7.2.15(1).

Table 7.2.14 Present Daily Flow of the Rivers

Unit: m³/day

River	Natural Flow Rate		S.T.W.		Total Flow Rate		Catchment Area (km ²)
	Annual	Dry	Annual	Dry	Annual	Dry	
Manyame Origin	102,000	31,000	0	0	102,000	31,000	A 474.0
Ruwa R.	42,000	13,000	600	600	42,600	13,600	B 195.0
Seke D/S					170,000	40,000	A 115.0
Nyatsime R.	77,600	33,900	18,400	15,100	96,000	49,000	B 580.0
Manyame R.	247,600	73,900	18,400	15,100	266,000	89,000	A 1530.0
Mukuvisi R.	86,300	25,900	27,700	28,100	114,000	54,000	A 230.0
Marimba R.	43,800	2,700	19,200	18,300	63,000	21,000	A 215.0
L.Chivero			6,700	6,500			
L.Chivero D/S					45,000	16,000	A
Muzururu R.	67,000	20,000	0	0	67,000	20,000	B 310.0
Gwebi R.	166,000	50,000	200	200	166,200	50,200	B 770.0
L.Manyame D/S					154,000	211,000	A

Note: A-measured flow

B-modified flow (effluent of STWs is added to natural flow)

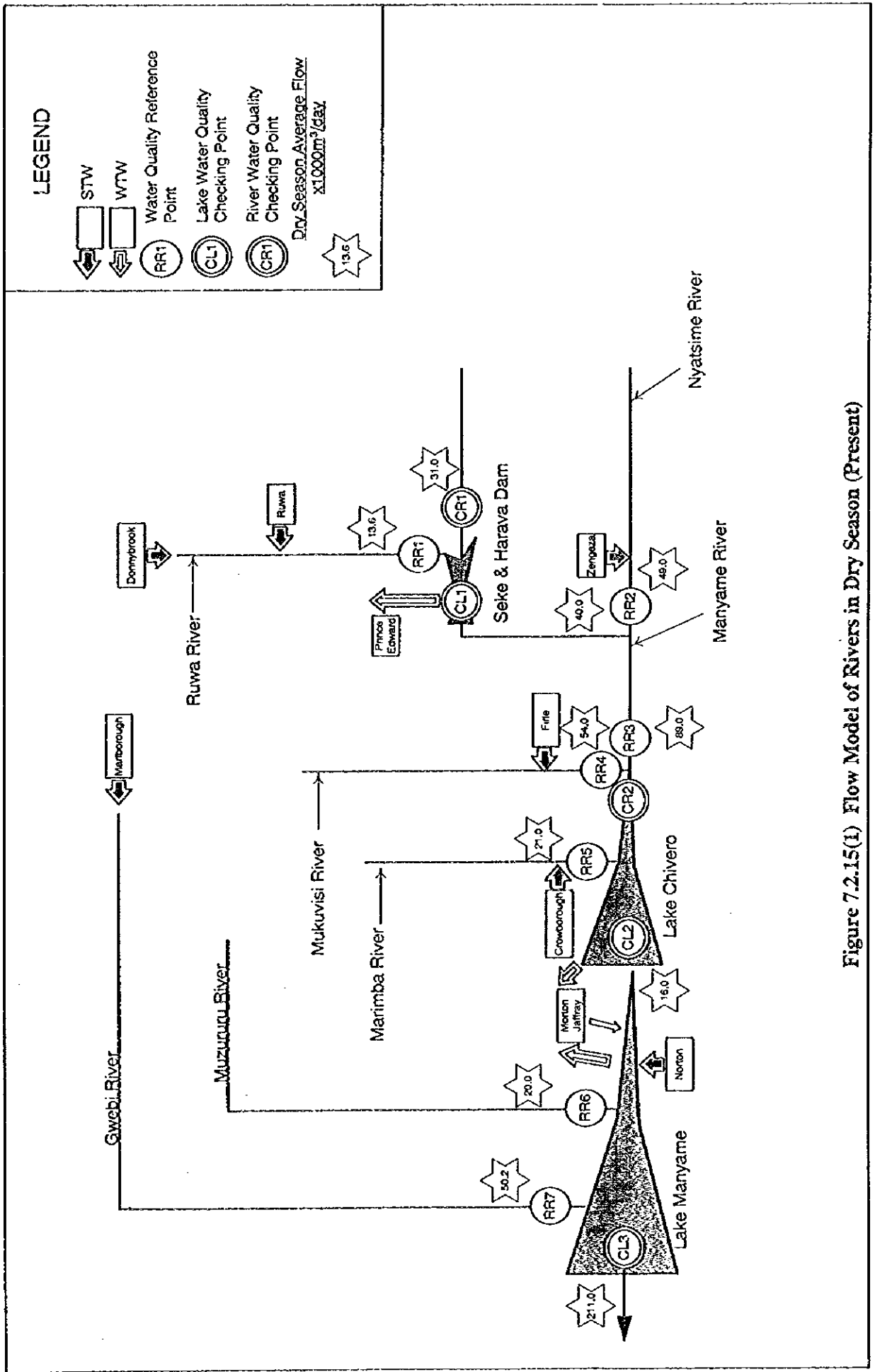


Figure 7.2.15(1) Flow Model of Rivers in Dry Season (Present)

(2) Direct Rainfall into the Lake

Direct inflow of rainfall into the lake/dam is considered to the full surface area without any losses. The details are included in Section 7.2, Chapter 2, Supporting Report.

(3) Direct Area Run-off

The direct area run-off into the lake/dam through small rivers/channels is using specific discharge rate of river basin. The details are shown in Section 7.2, Chapter 2, Supporting Report.

(4) Evaporation

According to the study on Lake McLwaine (1982), the evaporation from Lake Chivero is estimated at 1291- 2005 mm(Average 1541 mm). The amount of evaporation is estimated using surface area of the lake/dam at the average water level and average evaporation of 1541 mm/. The surface area of the lake/dam is estimated using H-V curve shown in sub-section 7.2.2 (0.88 power of lake level). The details are shown in Section 7.2, Chapter 2, Supporting Report.

(5) WTWs Water Intake

The WTWs water intake amount at each lake/dam is estimated using its record during 1994-96 and the record of the water pumped amount during 1986-94. The details are shown in Section 7.2, Chapter 2, Supporting Report.

(6) Flow Balance at the Lakes/Dams

The balances between inflow and outflow in annual average at respective lakes/dams are summarised in Table 7.2.15 and flow model covering subject basin is presented in Figures 7.2.15(2) and 7.2.16. The deference between inflow and outflow still remains after excluding the change of the storage volume. It may be derived from the groundwater influence and the measurement and estimation errors.

Table 7.2.15 Inflow and Outflow Water Balance at Lakes/Dams

Unit: x1000m³/day

Name	Inflow	Outflow
Seke And Harava Dam		
Manyame River	102.0	
Ruwa River	42.6	
Direct Rainfall	7.4	
Direct Area Run-off	25.0	
Evaporation		7.1
Prince Edward		20.5
Discharge		170.0
Subtotal	177.0	197.6
Difference Between Inflow and Outflow	-20.6	
Change of Storage Volume		
Adjustment Volume *1	-20.6	
Lake Chivero		
Manyame River	266.0	
Mukuvisi River	114.0	
Marimba River	63.0	
Direct Rainfall	58.9	
Direct Area Run-off	55.7	
Evaporation		96.4
Morton Jaffray		164.3
Discharge		45.0
Subtotal	557.6	305.7
Difference Between Inflow and Outflow	251.9	
Change of Storage Volume	30.0	
Adjustment Volume *1	221.9	
Lake Manyame		
Lake Chivero	45.0	
Muzururu River	67.0	
Gwebi River	166.2	
Direct Rainfall	182.0	
Direct Area Run-off	109.2	
Evaporation		233.4
Morton Jaffray	97.6	225.9
Discharge		154.0
Subtotal	667.0	613.3
Difference Between Inflow and Outflow	53.7	
Change of Storage Volume	-19.0	
Adjustment Volume *1	72.7	

*Note ; *1: Groundwater influence and errors derived from measurement and estimation

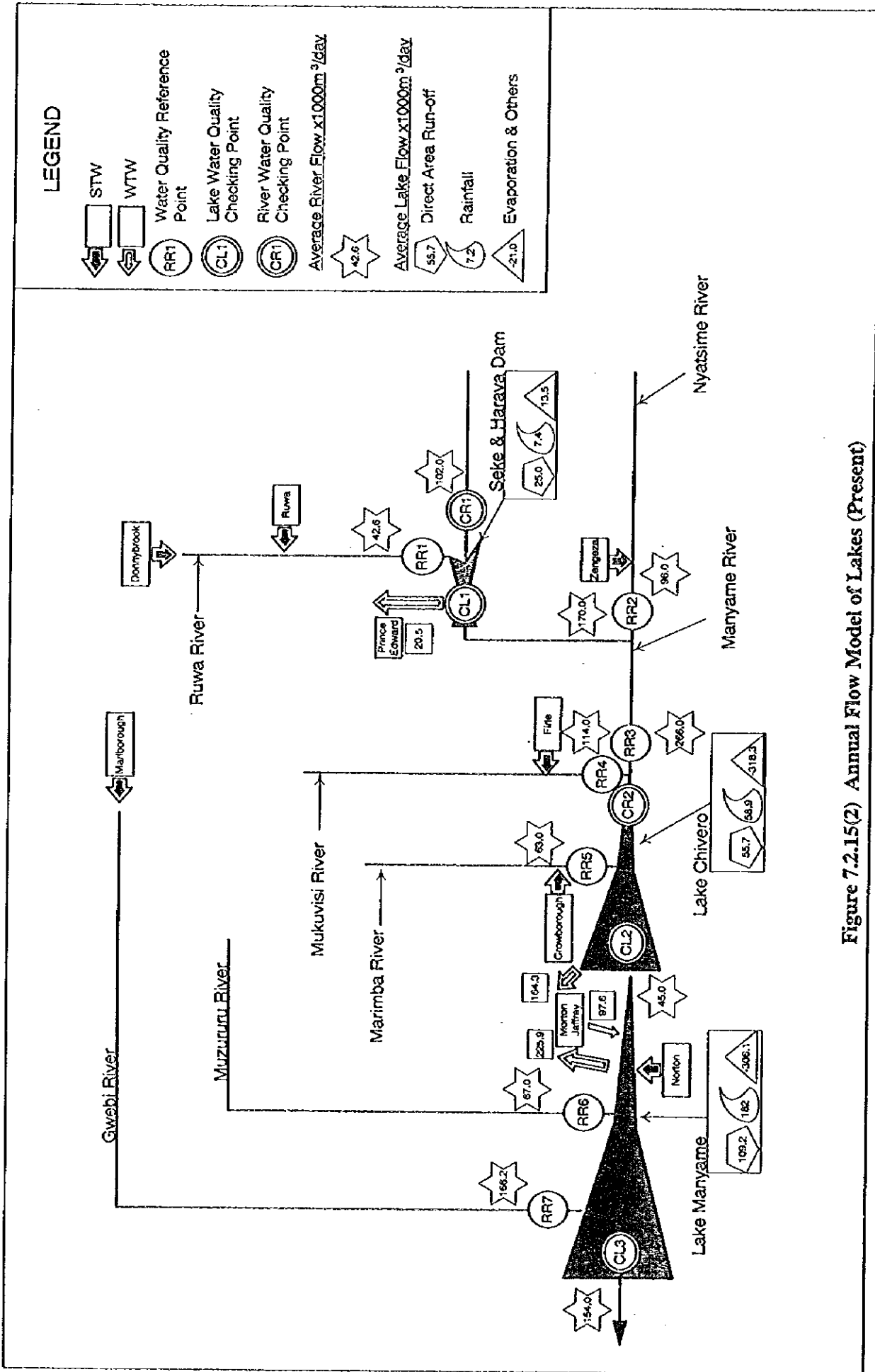


Figure 7.2.15(2) Annual Flow Model of Lakes (Present)

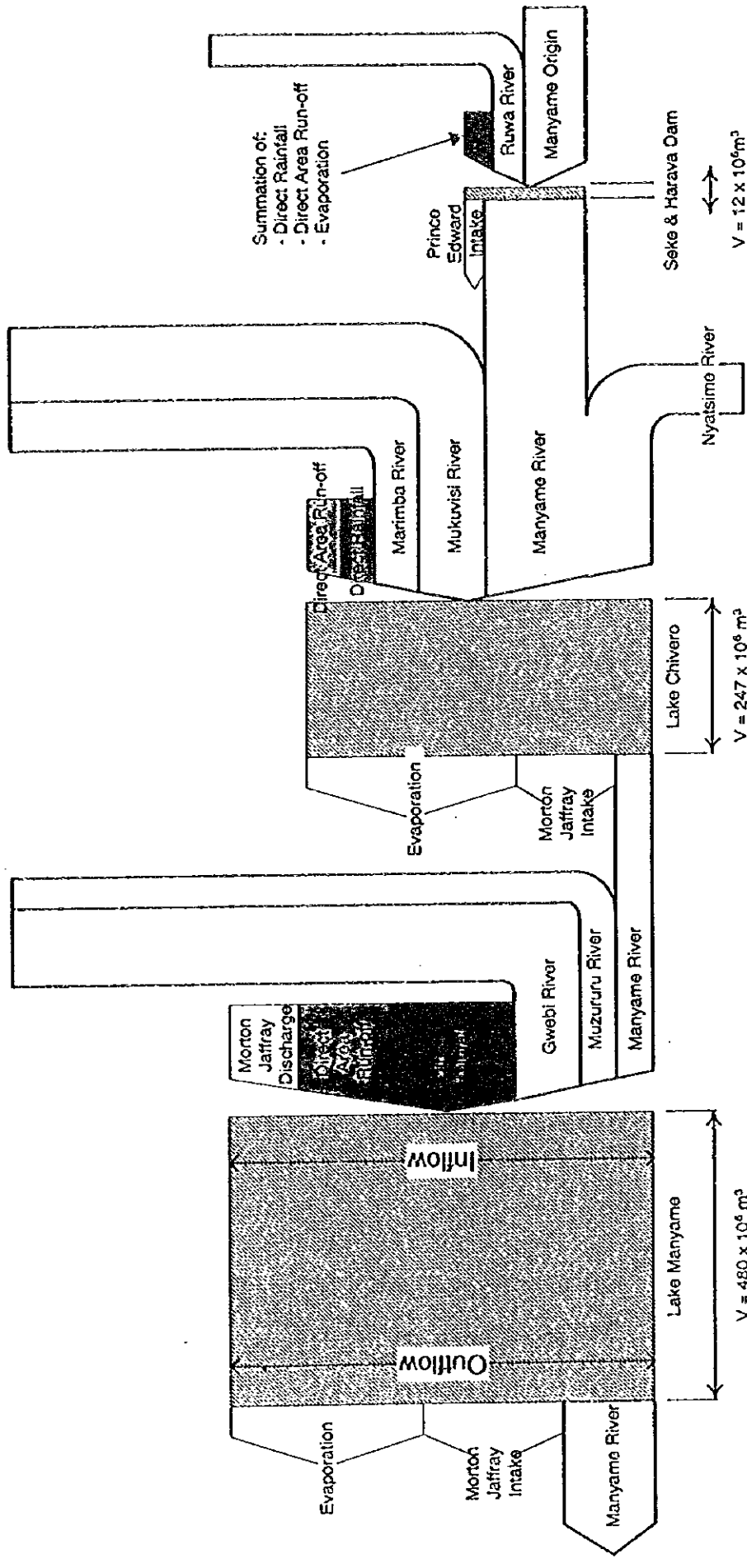


Figure 7.2.16 Annual Flow Balance (Present)

(7) Flow Balance in the Future

The natural flow rates of the rivers are largely influenced by the rainfall amount which fluctuates year by year. The future flow rates are therefore assessed based on the average rainfall amount in the past 10 year period.

On the other hand, human activities such intake for water supply and discharge of treated wastewater, etc. also affect the flow rates. Particularly, the effluent of the STWs is significant on the flow rates.

The future flow rates is prepared in Table 7.2.16 considering the discharge volume of STWs proposed in Table 12.2.7. The STWs discharge flow directly to the rivers is equivalent to the projected sewage inflow to the adopted BNR treatment process. The detailed calculation is included in Section 7.2, Chapter 2, Supporting Report.

The present discharge flow from Lake Manyame is assumed to be kept through the future, assuming that intake amount at the WTW will be controlled with reference to treated effluent amount.

The average flow rates in the past 10 years are used for the present and future pollution analysis (1995) both for rivers and lakes. Effluent discharged from the Zengeza STW is excluded for the present analysis of rivers, because the present water quality of the river is not affected.

The flow balance by scenario are shown in Table 7.2.17 and the flow models to be adopted in analysis of rivers/lakes by scenario are shown in Figure 7.2.17 and 7.2.18, respectively.