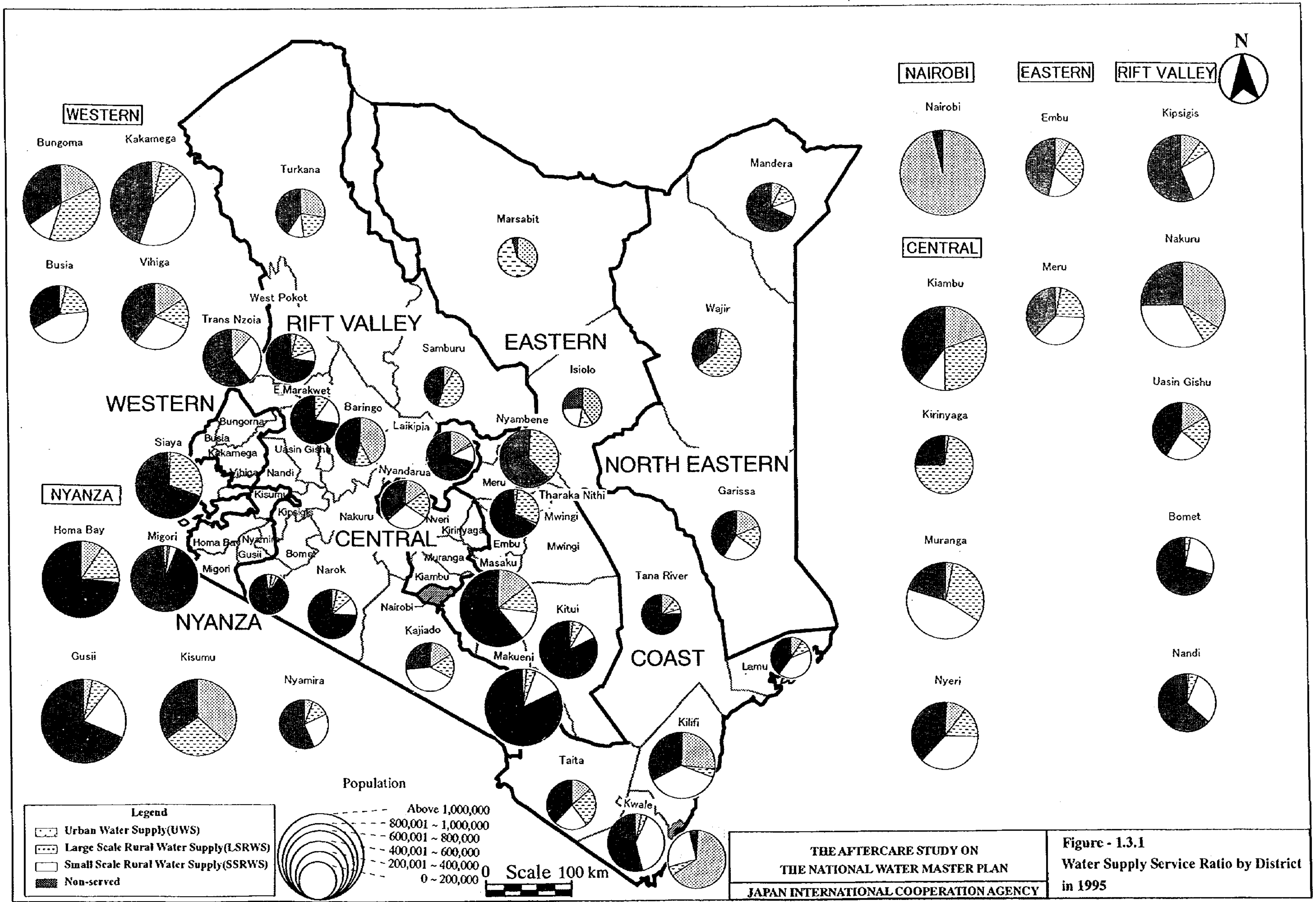
- PART II :WATER SUPPLY DEVELOPMENT PLAN -

FIGURES

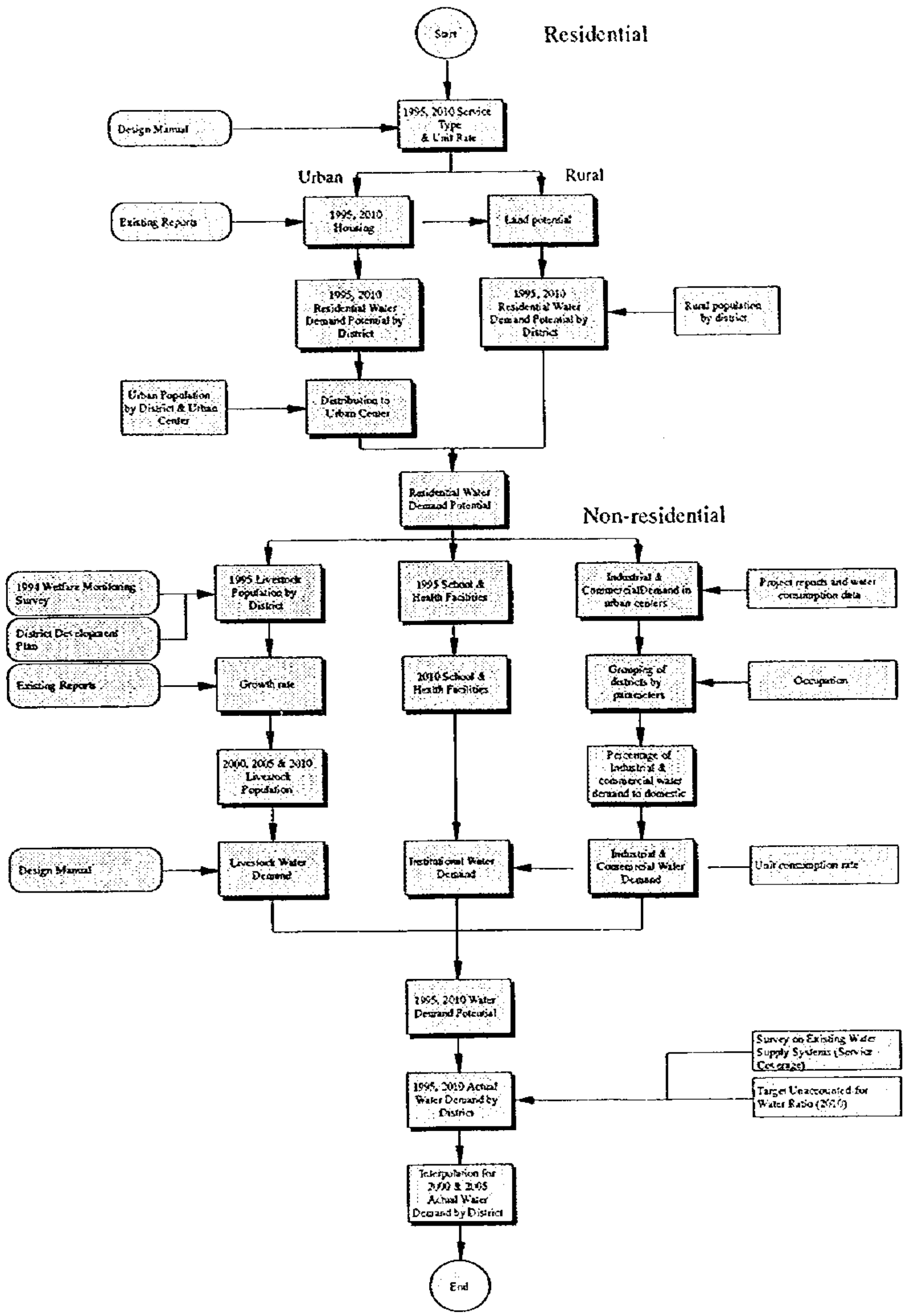


THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN

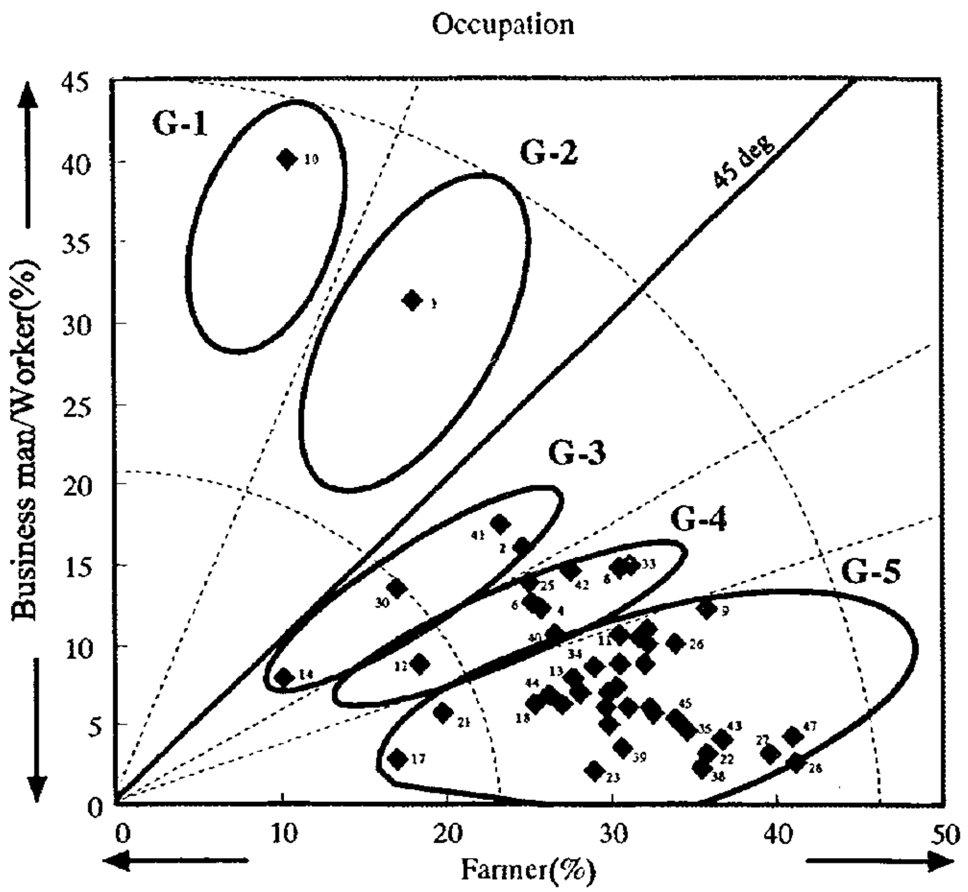
JAPAN INTERNATIONAL COOPERATION AGENCY

Figure - 1.3.1 Water Supply Service Ratio by District in 1995

Review of Water Demand



THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN	**Figure -2.3.1**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Procedures for Water Demand Forecast**

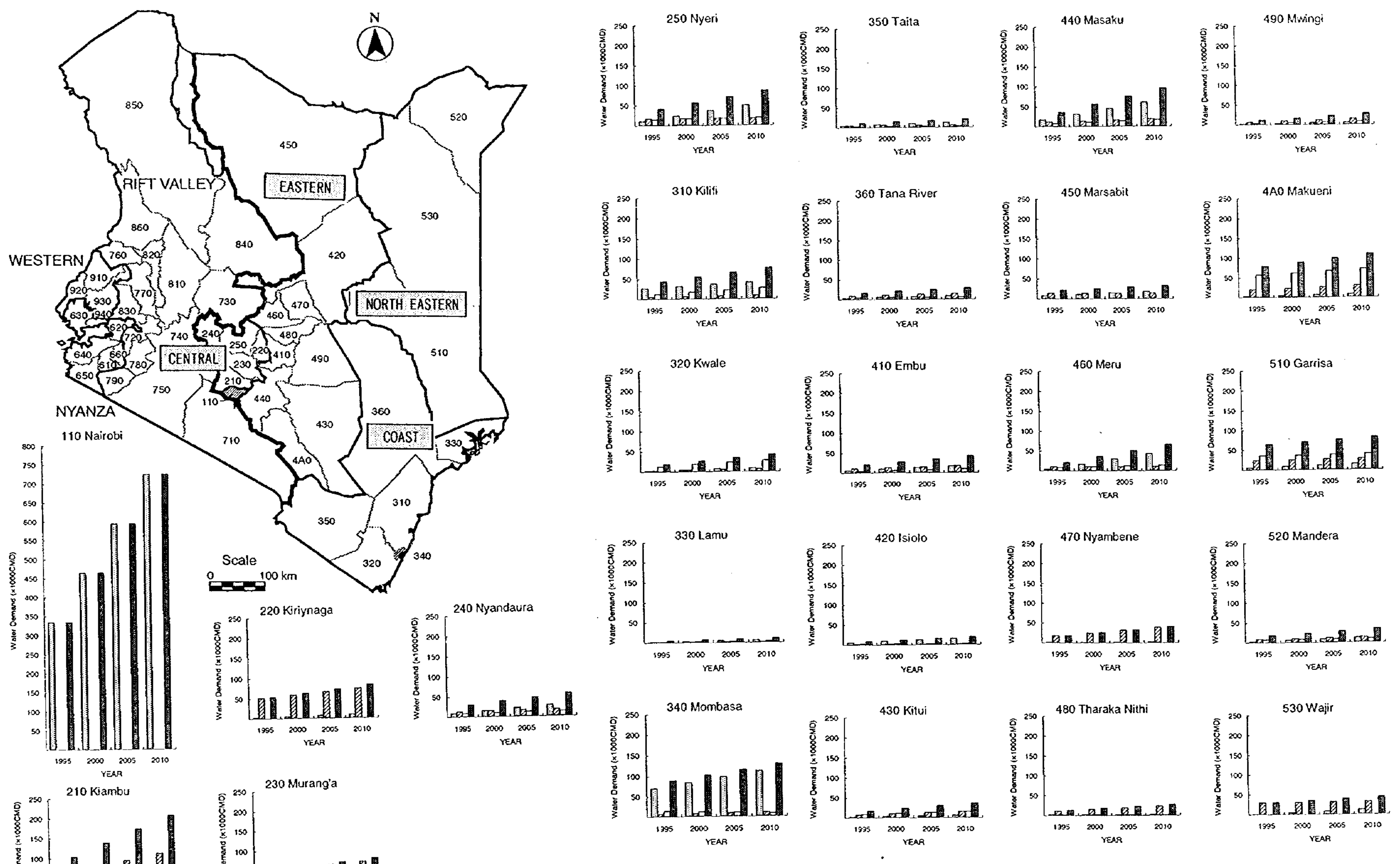


Districts and Grouping

No.	District	Group
1	Nairobi	G-2
2	Kiambu	G-3
3	Kirinyaga	G-5
4	Muranga	G-4
5	Nyandarua	G-5
6	Nyeri	G-4
7	Kilifi	G-5
8	Kwale	G-4
9	Lamu	G-5
10	Mombasa	G-1
11	Taita-Taveta	G-5
12	Tana River	G-4
13	Embu	G-5
14	Isiolo	G-3
15	Kitui	G-5
16	Machakos	G-5
17	Marsabit	G-5
18	Meru	G-5
19	Makueni	G-5
20	Tharaka Nithi	G-5
21	Garissa	G-5
22	Mandera	G-5
23	Wajir	G-5
24	Kisii	G-5
25	Kisumu	G-4
26	Siaya	G-5
27	Homa-Bay	G-5
28	Migori	G-5
29	Nyamira	G-5
30	Kajiado	G-3
31	Kericho	G-5
32	Laikipia	G-5
33	Nakuru	G-4
34	Nandi	G-5
35	Narok	G-5
36	Bomet	G-5
37	Baringo	G-5
38	Elgeyo-Marakwet	G-5
39	Samburu	G-5
40	Trans-Nzoia	G-4
41	Turkana	G-3
42	Uasin-Gishu	G-4
43	West Pokot	G-5
44	Bungoma	G-5
45	Busia	G-5
46	Kakamega	G-5
47	Vihiga	G-5

Note: District grouping was made on the basis of tangential decline from 45 diagonal as shown above.

THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN	Figure - 2.3.2 Farmer vs. Businessman/Worker
JAPAN INTERNATIONAL COOPERATION AGENCY	



Source: The Aftercare Study Team

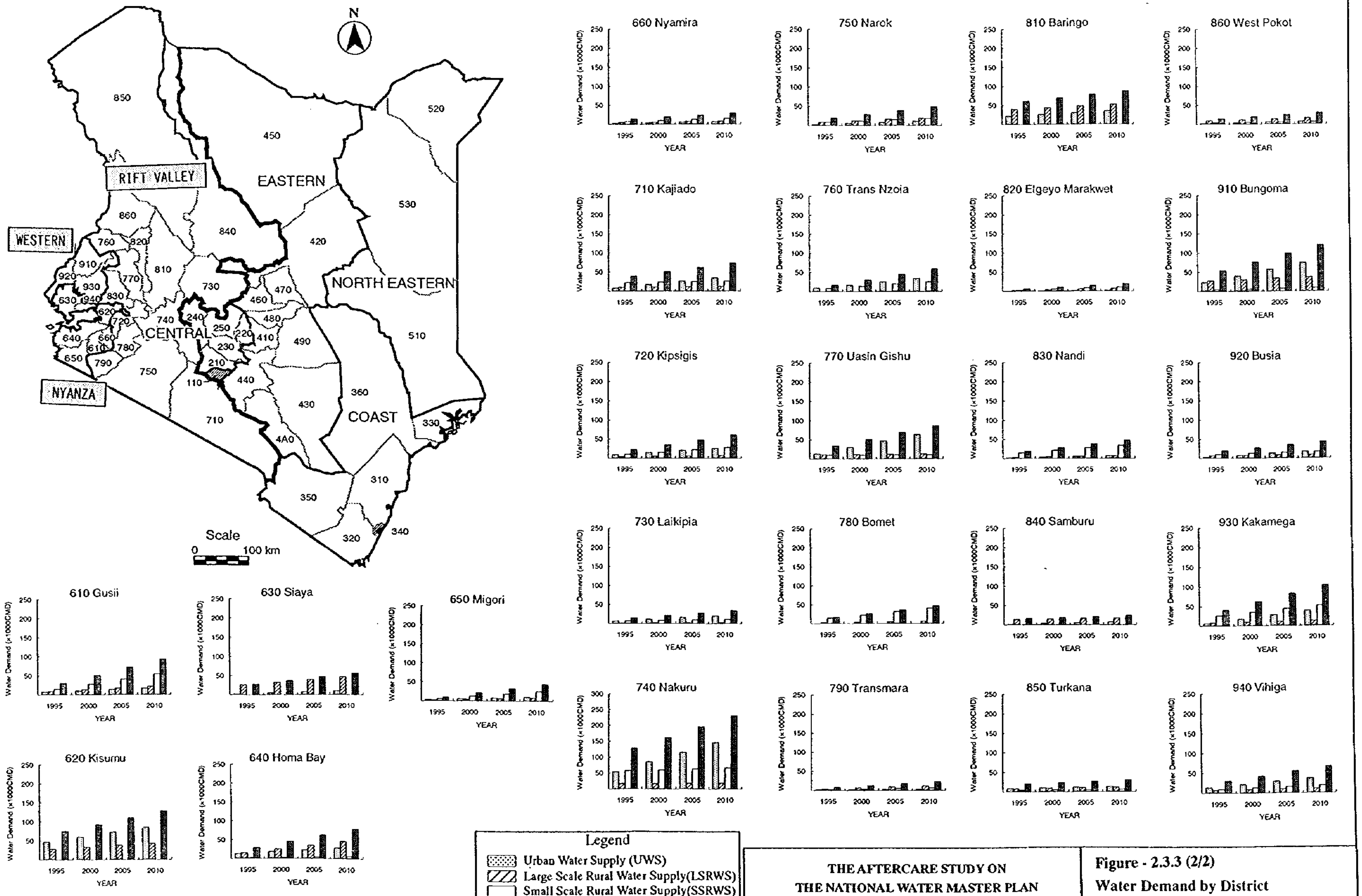
Legend

- Urban Water Supply (UWS)
- Large Scale Rural Water Supply(LSRWS)
- Small Scale Rural Water Supply(SSRWS)
- Total

THE AFTERCARE STUDY ON
THE NATIONAL WATER MASTER PLAN

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure - 2.3.3 (1/2)
Water Demand by District
(1995 - 2010)



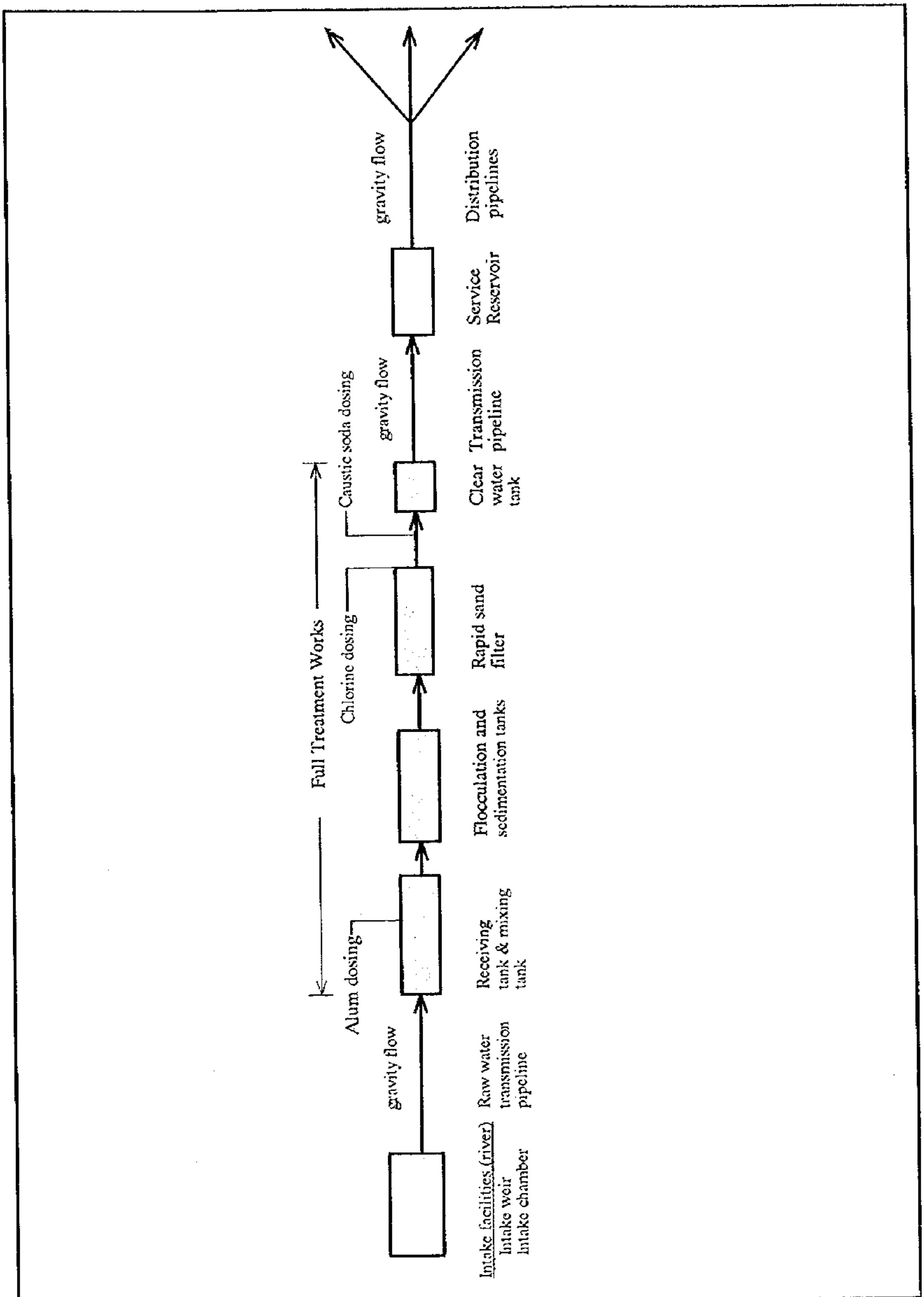
Source: The Aftercare Study Team

Legend
- Urban Water Supply (UWS)
- Large Scale Rural Water Supply(LSRWS)
- Small Scale Rural Water Supply(SSRWS)
- Total

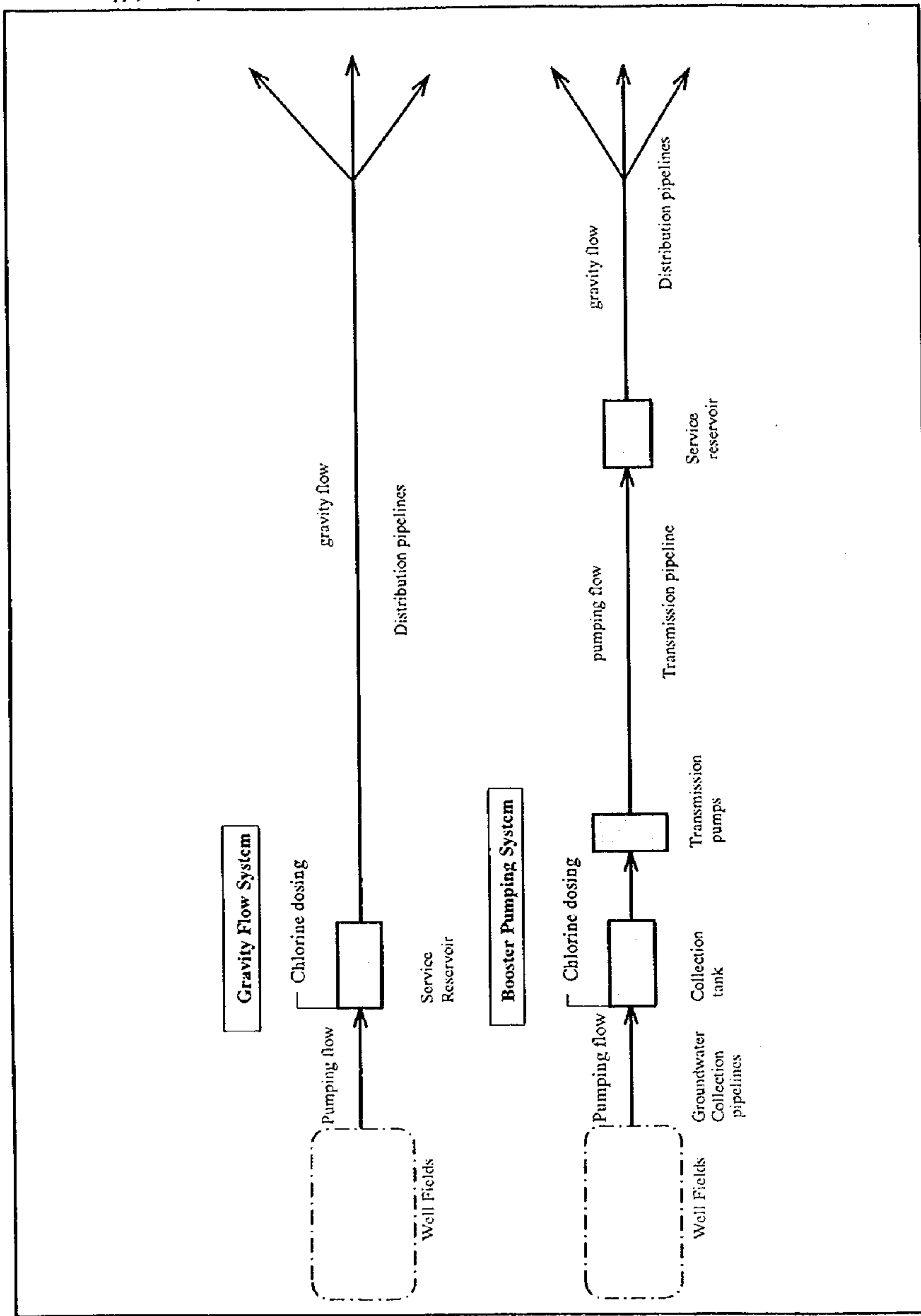
THE AFTERCARE STUDY ON
THE NATIONAL WATER MASTER PLAN

JAPAN INTERNATIONAL COOPERATION AGENCY

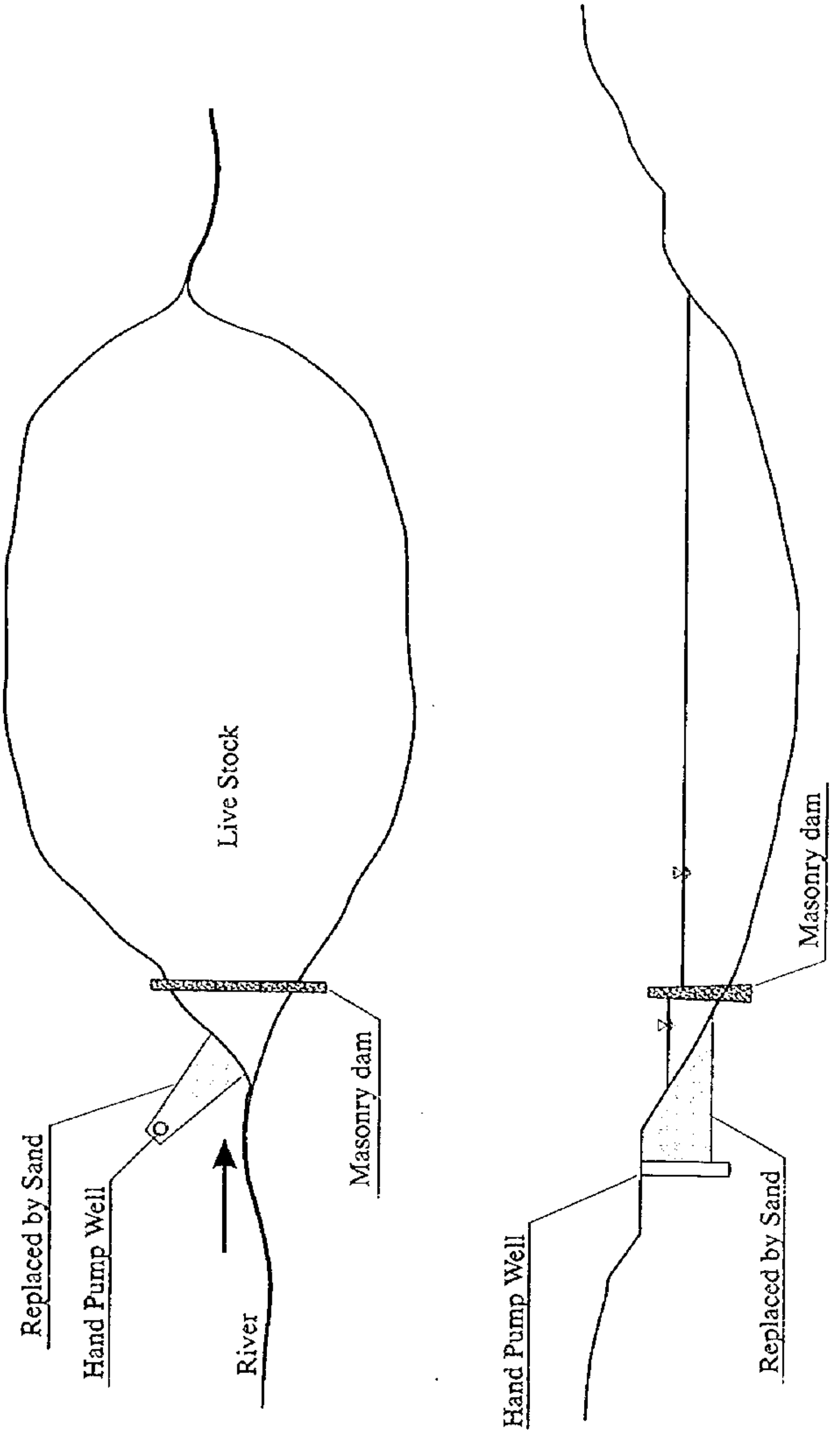
Figure - 2.3.3 (2/2)
Water Demand by District
(1995 - 2010)



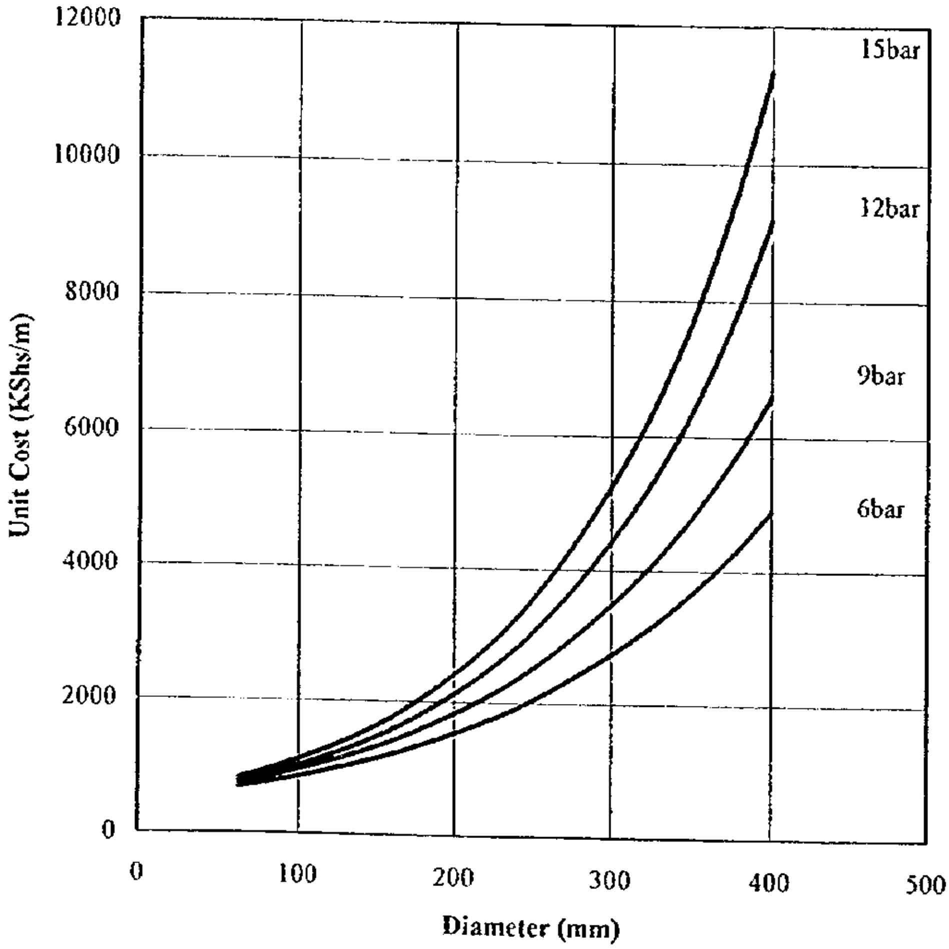
THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN	**Figure – 3.4.1**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Flow Sheet for Urban Water Supply Systems of Surface Water Source**



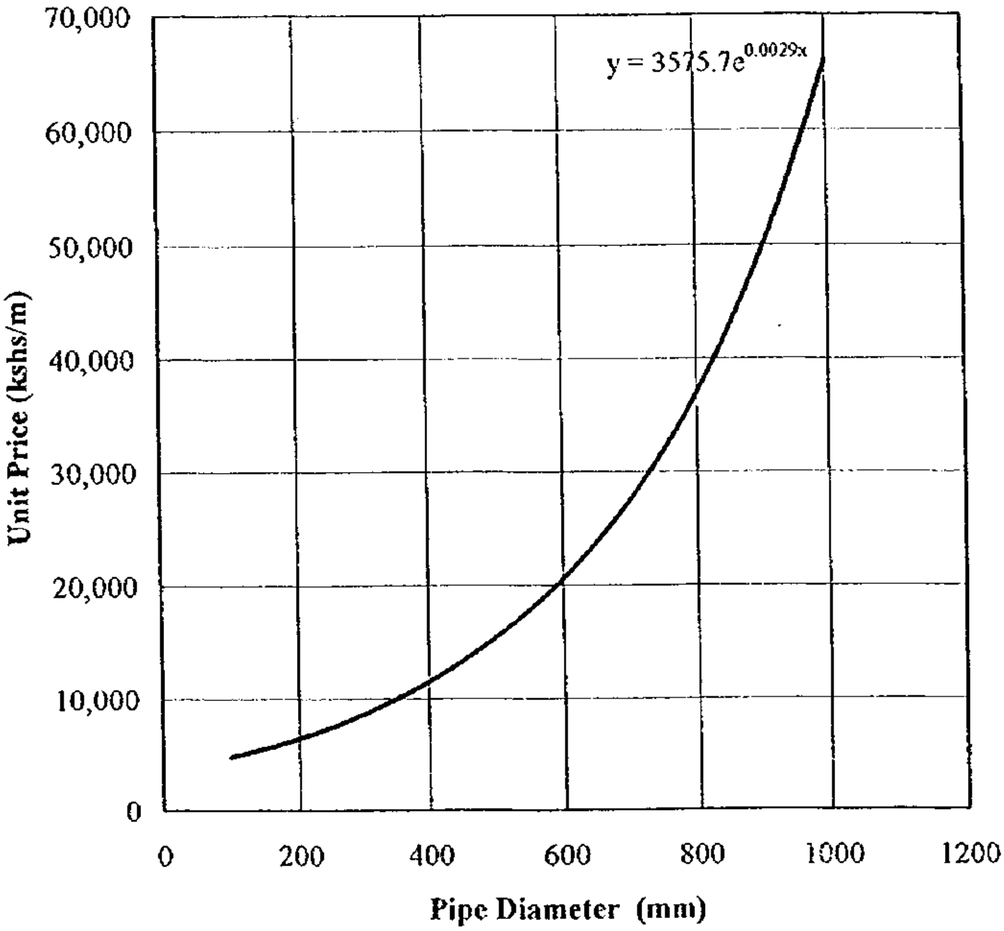
THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN	**Figure – 3.4.2**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Flow Sheet for Urban Water Supply Systems of Groundwater Source (Borehole)**



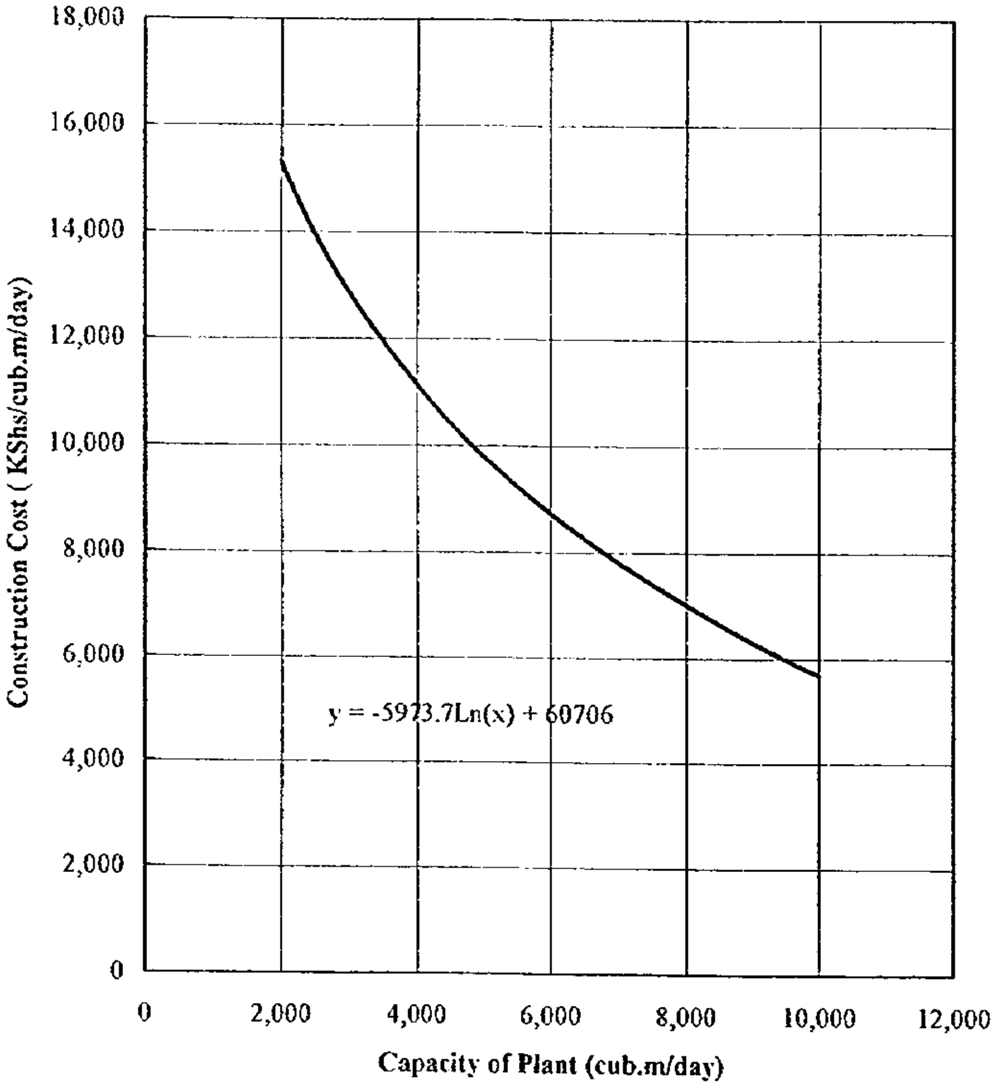
THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN	**Figure - 4.5.1**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Illustration of Earth Pan**



THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN	**Figure - 5.3.1** **Unit Cost of Piping Work (uPVC Pipe)**
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN	Figure - 5.3.2 Unit Cost of Piping Work (Steel Pipe)
JAPAN INTERNATIONAL COOPERATION AGENCY	

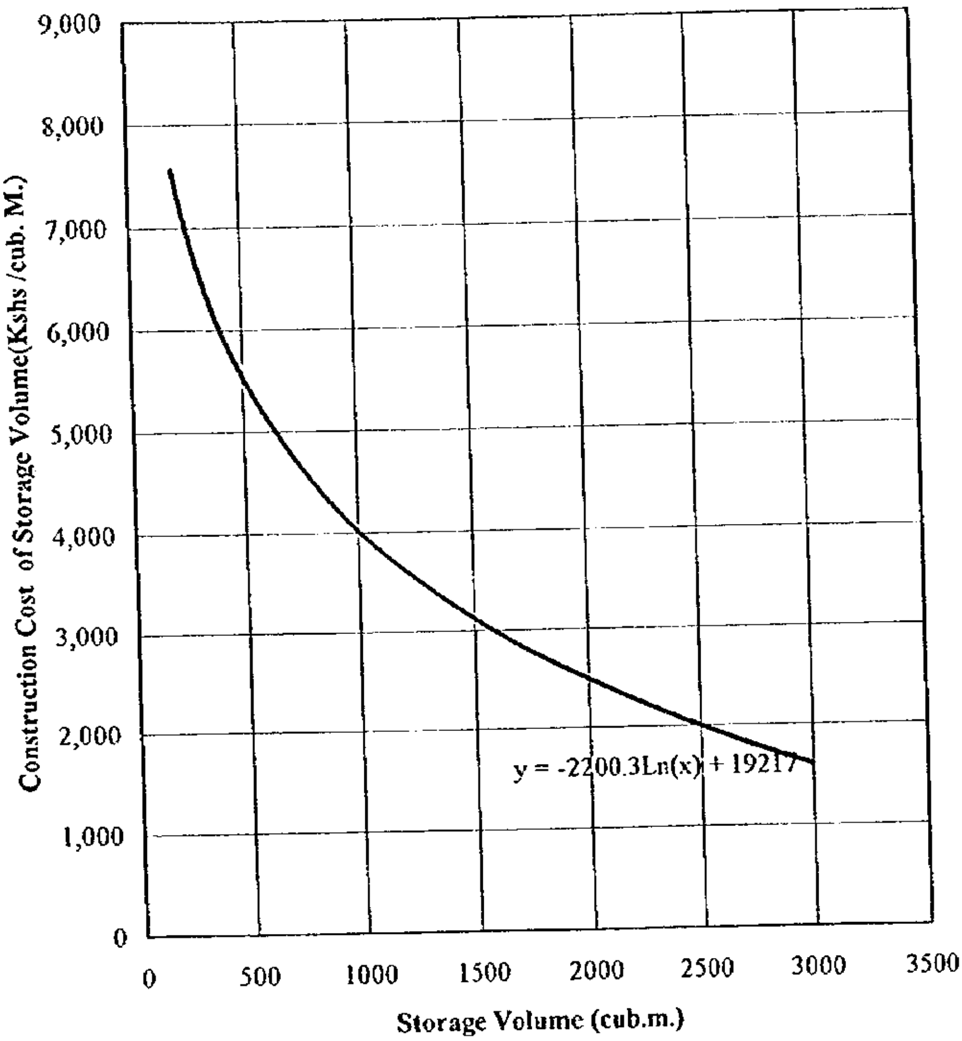


Including:
Site Works
- Operators's House, Gravity Sand Filters
- Laboratory Chemical Tanks, Back Wash Tanks
- Sedimentation Tanks, Clear Water Tanks
- Store Pipeworks Laboratory Equipment
- Electrical and mechanical Works

Exclude : Access Road
- Pumping Station, Power Supply, Preliminaries
- Contingencies

Price Level : 1998

THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN	**Figure - 5.3.3** **Unit Cost of Piping Treatment Work**
JAPAN INTERNATIONAL COOPERATION AGENCY	



Including
Excavation&Backfill
Civil Works, Internal Piping
External Valve, Chamber, W/Piping

Excluding : Access Road
Special Foundation, Preliminaries
Contingencies

Price Level:1998

THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN	Figure - 5.3.4 Unit Cost of Piping Strage Work
JAPAN INTERNATIONAL COOPERATION AGENCY	

Figure-6.3.1(1/5) Implementation Schedule of Urban Water Supply Development Plan

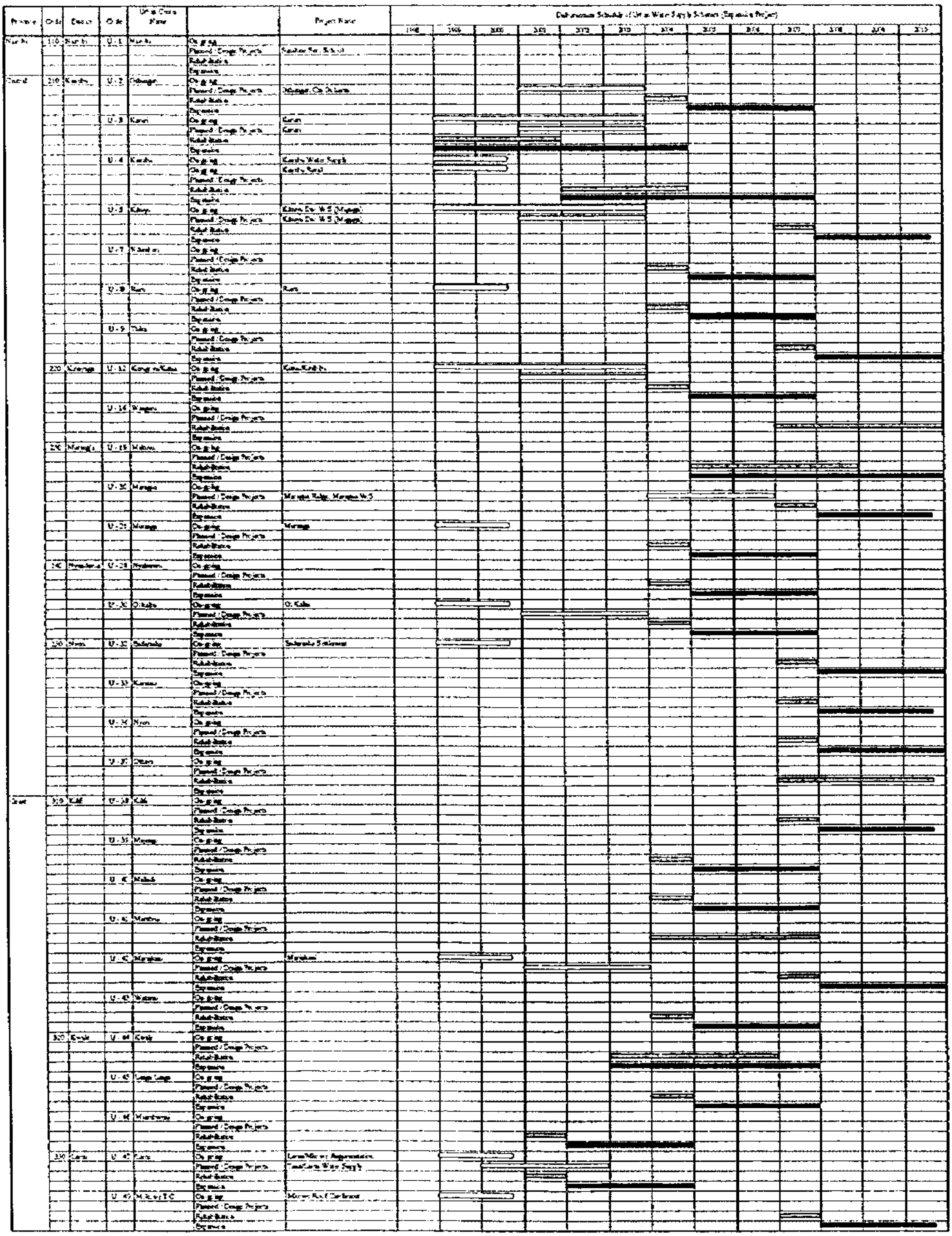


Figure-6.3.1(2/5) Implementation Schedule of Urban Water Supply Development Plan

Province	Code	District	Code	Urban Centre Name		Project Name	Implementation Schedule of Urban Water Supply Schemes (Expansion Project)												
							1998	1999	2000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	340	Malindi	U-52	Malindi	On-going														
					Planned / Design Projects	[illegible]													
					Rehabilitation														
					Expansion														
	350	Taita	U-54	Taveta	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-55	Voi	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-56	Wundanyi	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	360	Tana River	U-58	Garsen	On-going														
					Planned / Design Projects	Garsen													
					Rehabilitation														
					Expansion														
			U-59	Hola	On-going														
					Planned / Design Projects	Hola													
					Rehabilitation														
					Expansion														
Eastern	410	Embu	U-60	Embu	On-going														
					Planned / Design Projects	Embu Water Supply													
					Rehabilitation														
					Expansion														
			U-61	Runyenjes	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	420	Isiolo	U-63	Isiolo	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-64	[illegible]	On-going	[illegible] W.T													
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-65	[illegible]	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	430	Kitui	U-68	Kitui	On-going	Masinga Kitui Water Supply													
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	440	Machakos	U-69	Athi River	On-going														
					Planned / Design Projects	Athi River Water Supply													
					Rehabilitation														
					Expansion														
			U-71	Machakos	On-going														
					Planned / Design Projects	Machakos Urban Water Supply													
					Rehabilitation														
					Expansion														
			U-74	[illegible]	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-77	Kangundo-Tala	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	450	Marsabit	U-79	[illegible]	On-going	[illegible]													
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-80	[illegible]	On-going	[illegible]													
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-82	Marsabit	On-going	Marsabit													
					Planned / Design Projects	Marsabit													
					Rehabilitation														
					Expansion														
			U-83	Moyale	On-going	Moyale Town													
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-84	North Horr	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-85	Sololo	On-going	Sololo													
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	460	Meru	U-86	Meru	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-87	Nkubu	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	470	Nyambene	U-89	Maua	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	480	Tharaka Ni	U-90	Chuka	On-going														
					Planned / Design Projects	Chuka													
					Rehabilitation														
					Expansion														
	[illegible]	Mwingi	U-91	Mwingi	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	[illegible]	Makueni	U-95	Kibwezi	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-98	Mtito Andei	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														

Figure-6.3.1(3/5) Implementation Schedule of Urban Water Supply Development Plan

Province	Code	District	Code	Urban Center Name		Project Name	Development Schedule of Urban Water Supply Systems (Expansion Project)												
							1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
North Eastern	510	Garissa	U-104	Garissa	On-going	Garissa													
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-105	[illegible]	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	520	Mandera	U-108	Elwak	On-going	Elwak													
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-109	Mandera	On-going	Mandera													
					Planned / Design Projects	Mandera													
					Rehabilitation														
					Expansion														
			U-110	Rhamu	On-going	Rhamu													
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	530	Wajir	U-113	Bute	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-114	[illegible]	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-116	Wajir	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
Nyanza	610	[illegible]	U-117	[illegible]	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	620	Kisumu	U-119	Ahero	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-120	Kisumu	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-121	[illegible]	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-122	[illegible]	On-going														
					Planned / Design Projects	[illegible] W.P													
					Rehabilitation														
					Expansion														
	630	[illegible]	U-123	[illegible]	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-125	[illegible]	On-going														
					Planned / Design Projects	[illegible]													
					Rehabilitation														
					Expansion														
	640	Homa Bay	U-129	Homa Bay	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-130	Kendu Bay	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-131	Mbita	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-132	Oyugis	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	650	Migori	U-134	Awendo	On-going														
					Planned / Design Projects	Awendo													
					Rehabilitation														
					Expansion														
			U-135	Kehancha	On-going														
					Planned / Design Projects	Migori/Kehancha, Kehancha													
					Rehabilitation														
					Expansion														
			U-136	Migori	On-going														
					Planned / Design Projects	Migori/Ndhiwa													
					Rehabilitation														
					Expansion														
			U-137	[illegible]	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-138	Rongo	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
	660	Nyamira	U-139	Keroka	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-140	Nyamira	On-going														
					Planned / Design Projects	Nyamira UWS & Sewerage													
					Rehabilitation														
					Expansion														
Rift Valley	710	Kajiado	U-142	Kajiado	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-14[illegible]	Magadi	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														
			U-14[illegible]	Namanga	On-going														
					Planned / Design Projects	Namanga													
					Rehabilitation														
					Expansion														
			U-144	Ngong	On-going	Ngong													
					Planned / Design Projects	Ngong													
					Rehabilitation														
					Expansion														
			U-145	Loitokitok	On-going														
					Planned / Design Projects	[illegible] (Loitokitok)													
					Rehabilitation														
					Expansion														
			U-146	Ongata Rongai	On-going														
					Planned / Design Projects														
					Rehabilitation														
					Expansion														

Figure-6.3.1(4/5) Implementation Schedule of Urban Water Supply Development Plan

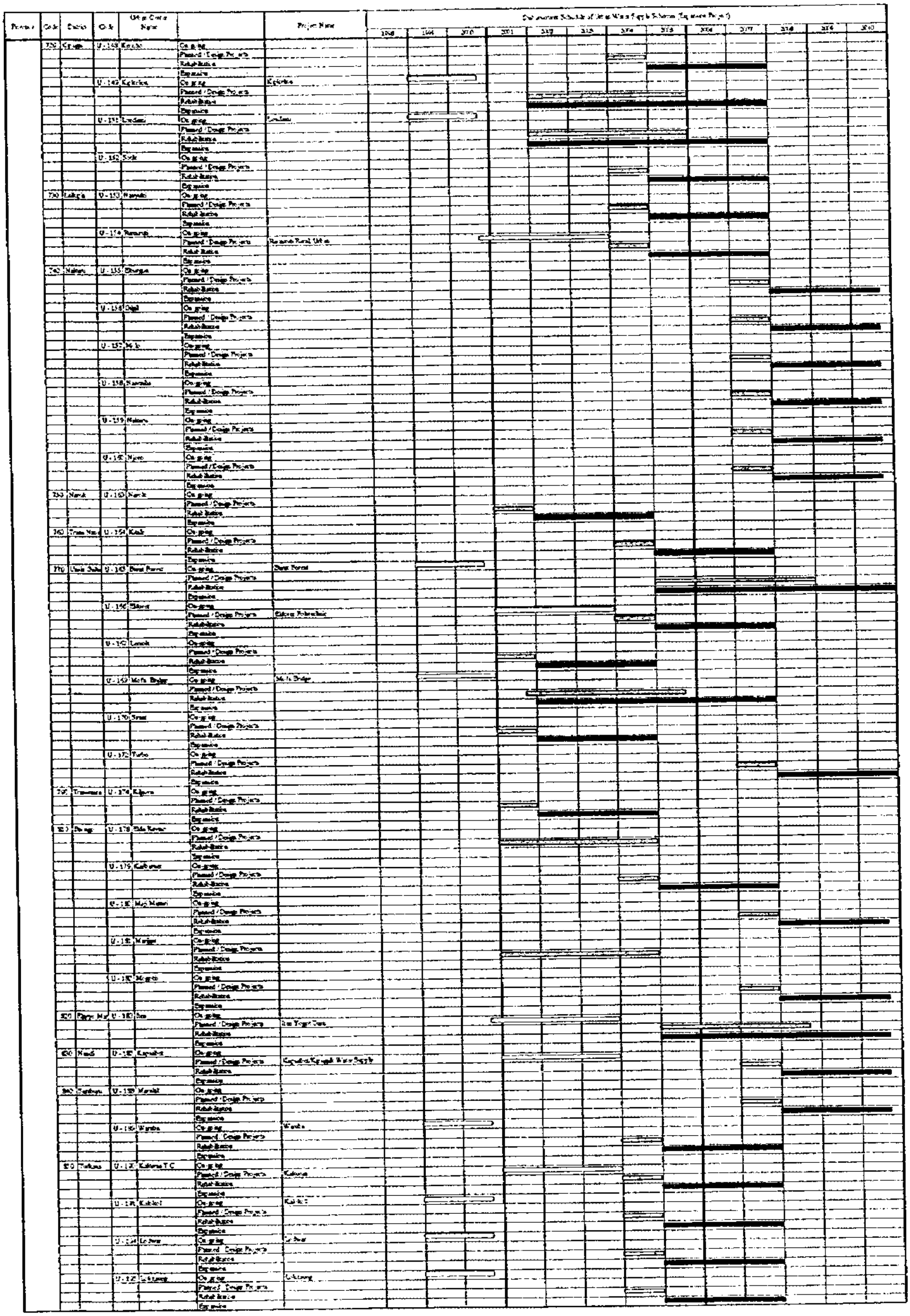


Figure-6.3.1(5/5) Implementation Schedule of Urban Water Supply Development Plan

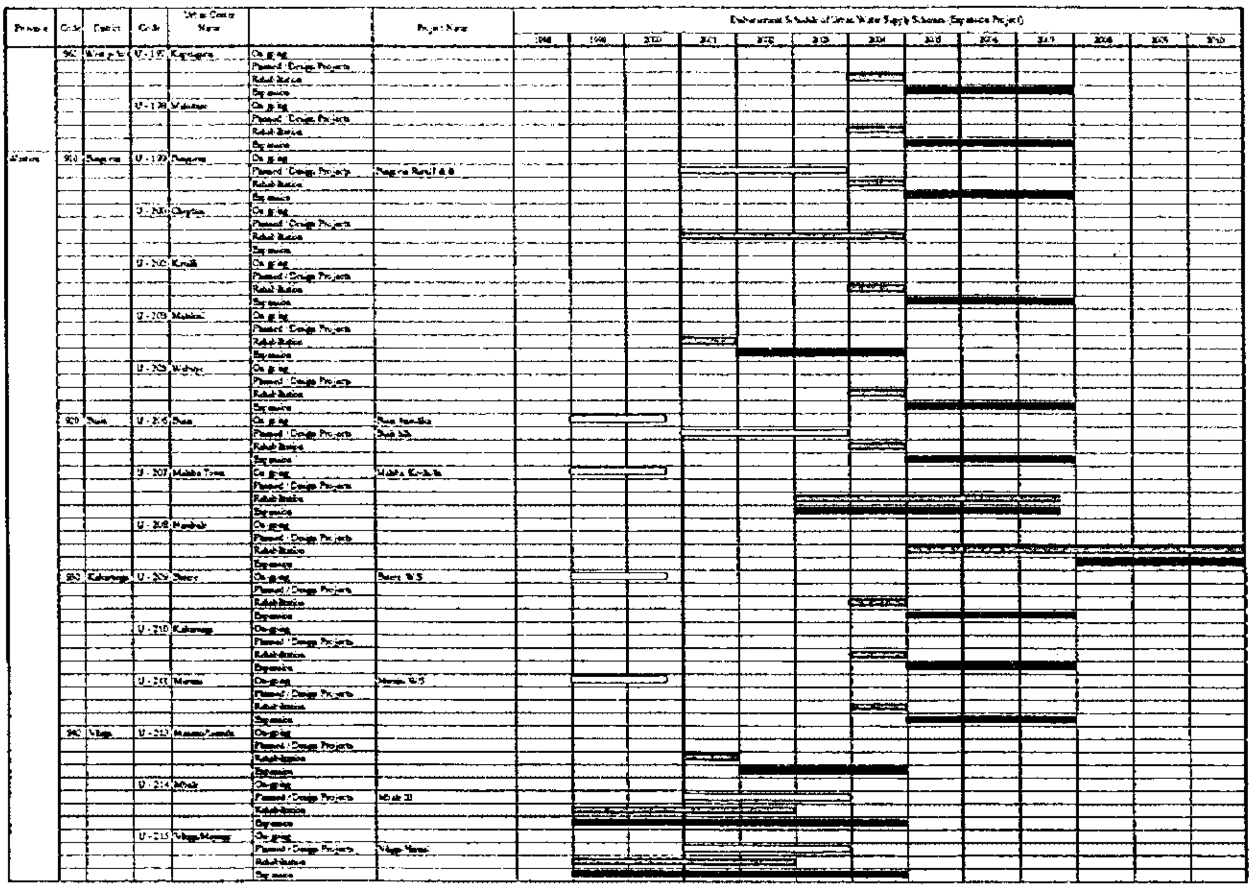


Figure - 6.3.2(1/4) Implementation Schedule of Large Scale Rural Water Supply Development Plan

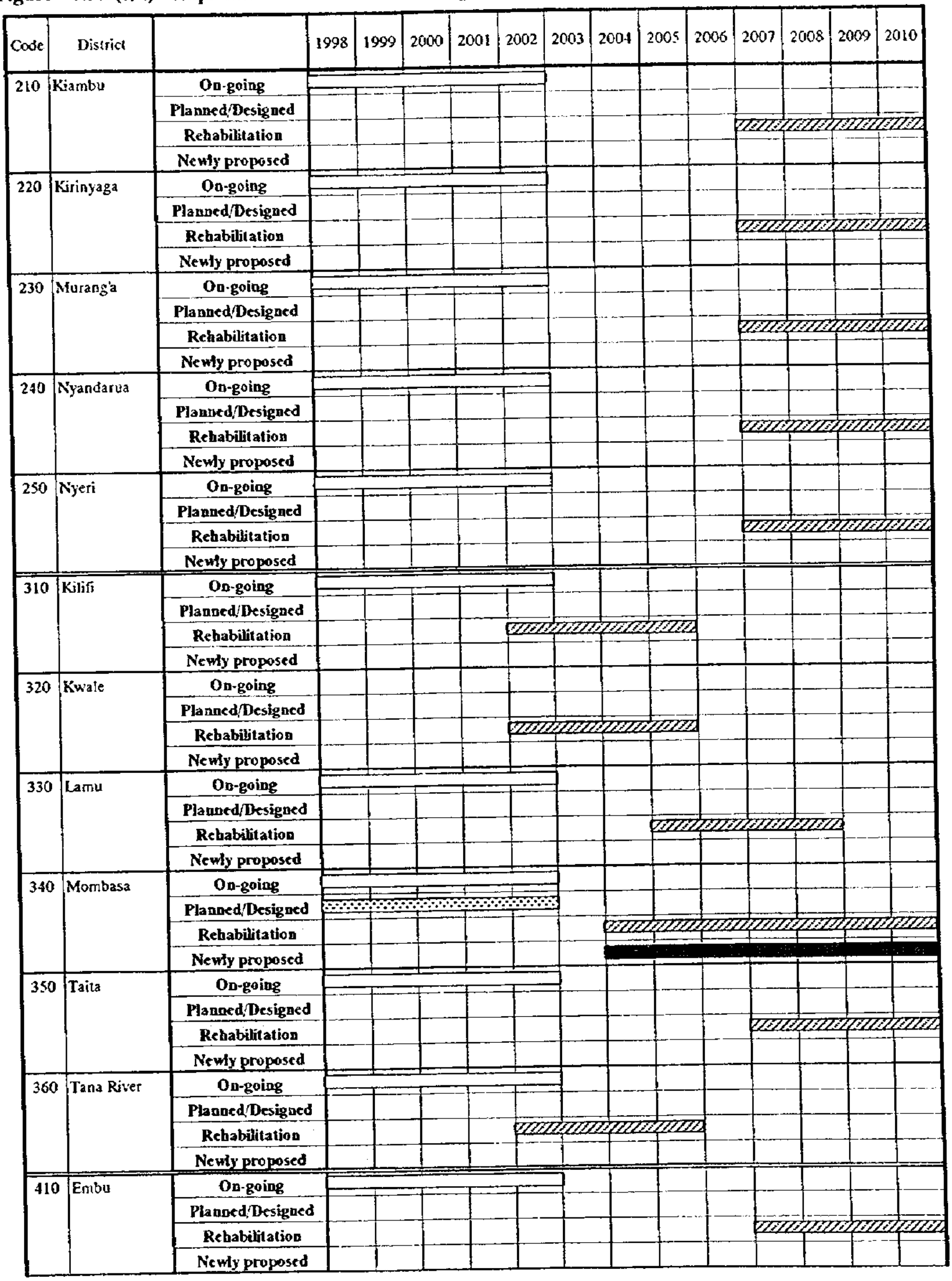


Figure - 6.3.2(2/4) Implementation Schedule of Large Scale Rural Water Supply Development Plan

Code	District		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
420	Isiolo	**On-going**	■	■	■	■	■								
		Planned/Designed													
		Rehabilitation										■	■	■	■
		Newly proposed													
430	Kitui	**On-going**	■	■	■	■	■								
		Planned/Designed													
		Rehabilitation					■	■	■	■					
		Newly proposed													
440	Masaku	**On-going**	■	■	■	■	■								
		Planned/Designed													
		Rehabilitation								■	■	■	■		
		Newly proposed													
450	Marsabit	**On-going**	■	■	■	■	■								
		Planned/Designed													
		Rehabilitation								■	■	■	■		
		Newly proposed													
460	Meru	**On-going**	■	■	■	■	■								
		Planned/Designed													
		Rehabilitation										■	■	■	■
		Newly proposed													
470	Nyambene	**On-going**	■	■	■	■	■								
		Planned/Designed													
		Rehabilitation										■	■	■	■
		Newly proposed													
480	Tharaka Nithi	**On-going**	■	■	■	■	■								
		Planned/Designed	■	■	■	■	■								
		Rehabilitation										■	■	■	■
		Newly proposed													
490	Mwingi	**On-going**	■	■	■	■	■								
		Planned/Designed	■	■	■	■	■								
		Rehabilitation		■	■	■	■	■	■	■					
		Newly proposed		■	■	■	■	■	■	■					
4A0	Makueni	**On-going**	■	■	■	■	■								
		Planned/Designed													
		Rehabilitation					■	■	■	■					
		Newly proposed													
510	Garissa	**On-going**	■	■	■	■	■								
		Planned/Designed													
		Rehabilitation								■	■	■	■		
		Newly proposed													
520	Mandera	**On-going**													
		Planned/Designed	■	■	■	■	■								
		Rehabilitation		■	■	■	■	■	■	■					
		Newly proposed		■	■	■	■	■	■	■					
530	Wajir	**On-going**	■	■	■	■	■								
		Planned/Designed	■	■	■	■	■								
		Rehabilitation		■	■	■	■	■	■	■					
		Newly proposed		■	■	■	■	■	■	■					

Figure - 6.3.2(3/4) Implementation Schedule of Large Scale Rural Water Supply Development Plan

Code	District		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
610	Gusii	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation								▨	▨	▨	▨		
		Newly proposed													
620	Kisumu	On-going	▭	▭	▭	▭	▭								
		Planned/Designed	░	░	░	░	░								
		Rehabilitation										▨	▨	▨	▨
		Newly proposed													
630	Siaya	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation								▨	▨	▨	▨		
		Newly proposed													
640	Homa Bay	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation								▨	▨	▨	▨		
		Newly proposed													
650	Migori	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation					▨	▨	▨	▨					
		Newly proposed													
660	Nyamira	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation								▨	▨	▨	▨		
		Newly proposed													
710	Kajiado	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation								▨	▨	▨	▨		
		Newly proposed													
720	Kipsigis	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation					▨	▨	▨	▨					
		Newly proposed													
730	Laikipia	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation								▨	▨	▨	▨		
		Newly proposed													
740	Nakuru	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation										▨	▨	▨	▨
		Newly proposed													
750	Narok	On-going	▭	▭	▭	▭	▭								
		Planned/Designed	░	░	░	░	░								
		Rehabilitation		▨	▨	▨	▨	▨	▨	▨	▨				
		Newly proposed		■	■	■	■	■	■	■	■				
760	Trans Nzoia	On-going	▭	▭	▭	▭	▭								
		Planned/Designed													
		Rehabilitation										▨	▨	▨	▨
		Newly proposed													

Figure - 6.3.2(4/4) Implementation Schedule of Large Scale Rural Water Supply Development Plan

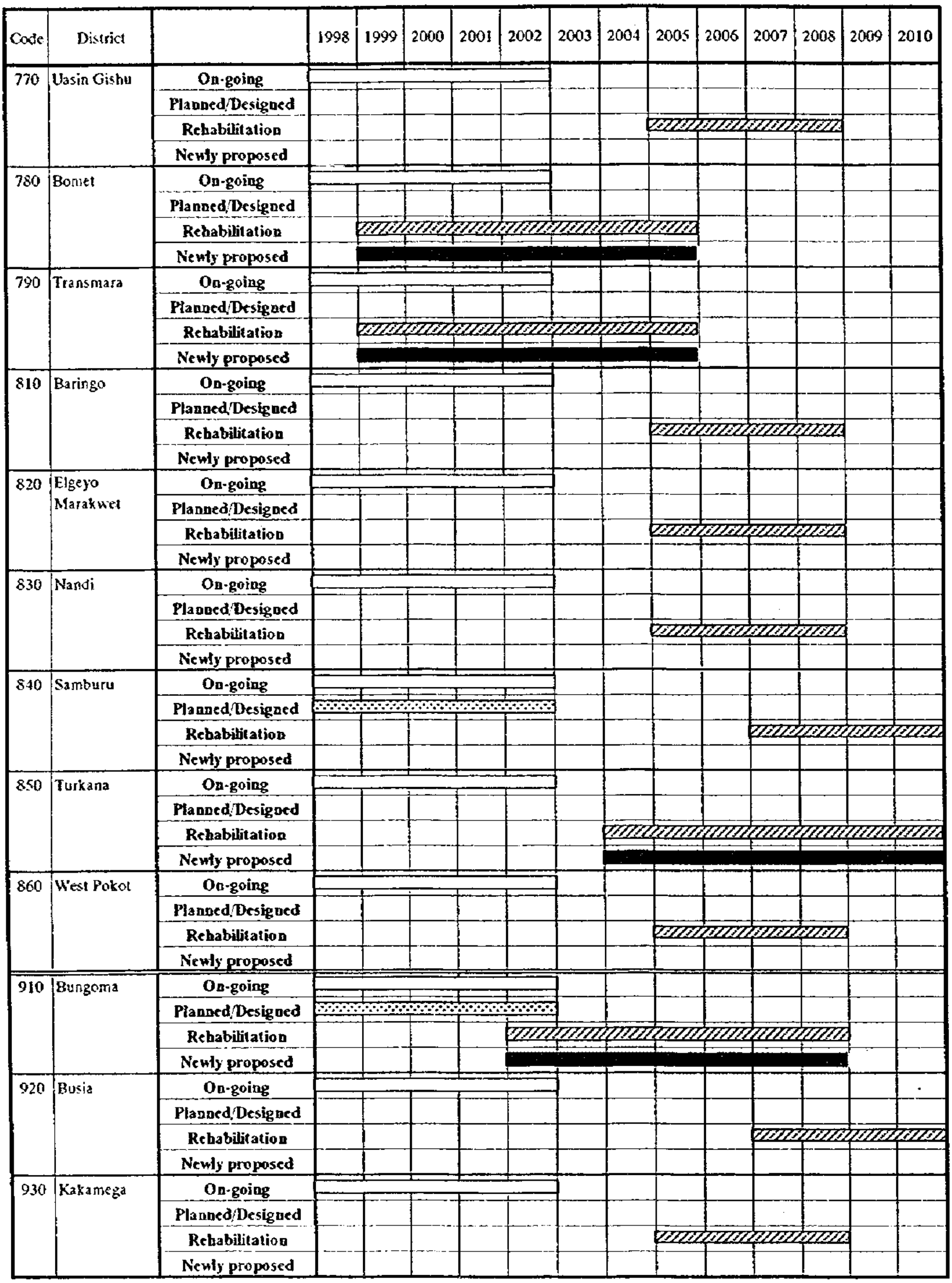


Figure - 6.3.3(1/4) Implementation Schedule of Small Scale Rural Water Supply Development Plan

	District		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
210	Kiambu	On-going	─	─	─	─	─								
		Planned/Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed									■	■	■	■	■
220	Kirinyaga	On-going	─	─	─	─	─								
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
230	Muranga	On-going	─	─	─	─	─								
		Planned/Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed									■	■	■	■	■
240	Nyandarua	On-going	─	─	─	─	─								
		Planned/Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed													
250	Nyeri	On-going	─	─	─	─	─								
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
310	Kilifi	On-going	─	─	─	─	─								
		Planned/Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed				■	■	■	■	■					
320	Kwale	On-going	─	─	─	─	─								
		Planned/Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed				■	■	■	■	■					
330	Lamu	On-going	─	─	─	─	─								
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
340	Mombasa	On-going	─	─	─	─	─								
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
350	Taita	On-going	─	─	─	─	─								
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
360	Tana River	On-going													
		Planned/Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed				■	■	■	■						
410	Embu	On-going	─	─	─	─	─								
		Planned/Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed										■	■	■	■
420	Isiolo	On-going	─	─	─	─	─								
		Planned/Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed													
430	Kitui	On-going	─	─	─	─	─								
		Planned/Designed													
		Rehabilitation													
		Newly proposed				■	■	■	■						
440	Masaku	On-going	─	─	─	─	─								
		Planned/Designed													
		Rehabilitation													
		Newly proposed							■	■	■	■	■		

Figure - 6.3.3(2/4) Implementation Schedule of Small Scale Rural Water Supply Development Plan

	District		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
450	Marsabit	On-going	□	□	□	□	□								
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
460	Meru	On-going	□	□	□	□	□								
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
470	Nyambene	On-going	□	□	□	□	□								
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
480	Tharaka Nithi	On-going	□	□	□	□	□								
		Planned/Designed	▒	▒	▒	▒	▒								
		Rehabilitation													
		Newly proposed										■	■	■	■
490	Mwingi	On-going	□	□	□	□	□								
		Planned/Designed	▒	▒	▒	▒	▒								
		Rehabilitation													
		Newly proposed							■	■	■	■			
4A0	Makueni	On-going	□	□	□	□	□								
		Planned/Designed	▒	▒	▒	▒	▒								
		Rehabilitation													
		Newly proposed				■	■	■	■	■					
510	Garissa	On-going	□	□	□	□	□								
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
520	Mandera	On-going	□	□	□	□	□								
		Planned/Designed													
		Rehabilitation													
		Newly proposed				■	■	■	■						
530	Wajir	On-going													
		Planned/Designed													
		Rehabilitation													
		Newly proposed													
610	Gusii	On-going	□	□	□	□	□								
		Planned/Designed	▒	▒	▒	▒	▒								
		Rehabilitation													
		Newly proposed							■	■	■	■	■		
620	Kisumu	On-going	□	□	□	□	□								
		Planned/Designed	▒	▒	▒	▒	▒								
		Rehabilitation													
		Newly proposed										■	■	■	■
630	Siaya	On-going	□	□	□	□	□								
		Planned/Designed	▒	▒	▒	▒	▒								
		Rehabilitation													
		Newly proposed													
640	Homa Bay	On-going	□	□	□	□	□								
		Planned/Designed	▒	▒	▒	▒	▒								
		Rehabilitation													
		Newly proposed							■	■	■	■			
650	Migori	On-going	□	□	□	□	□								
		Planned/Designed	▒	▒	▒	▒	▒								
		Rehabilitation													
		Newly proposed				■	■	■	■	■					
660	Nyamira	On-going	□	□	□	□	□								
		Planned/Designed	▒	▒	▒	▒	▒								
		Rehabilitation													
		Newly proposed					■	■	■	■	■	■			

Figure - 6.3.3(3/4) Implementation Schedule of Small Scale Rural Water Supply Development Plan

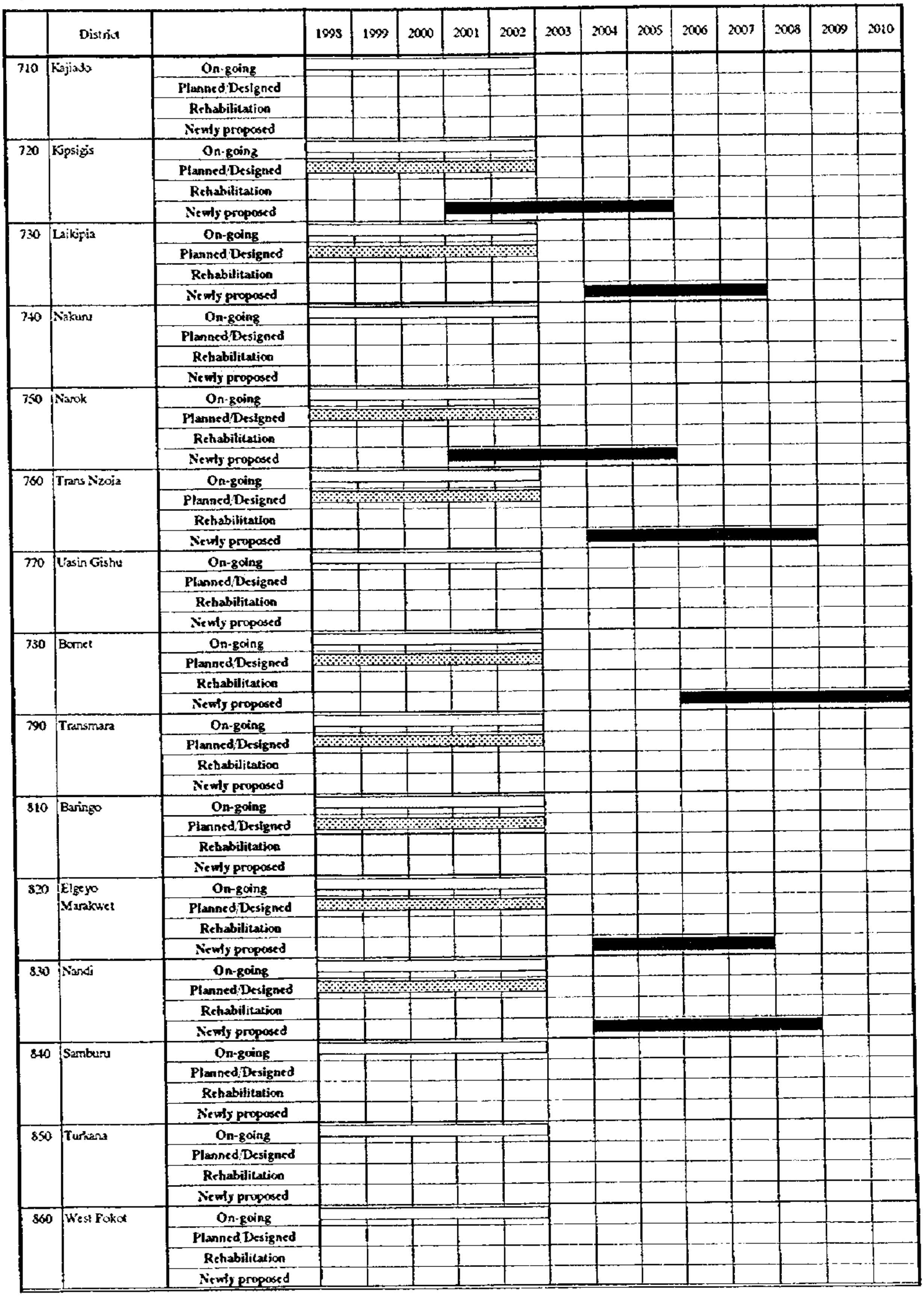


Figure - 6.3.3(4/4) Implementation Schedule of Small Scale Rural Water Supply Development Plan

	District		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
910	Bungoma	**On-going**	□	□	□	□	□								
		Planned Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed					■	■	■	■	■	■			
920	Busia	**On-going**	□	□	□	□	□								
		Planned Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed									■	■	■	■	■
930	Kakamega	**On-going**	□	□	□	□	□								
		Planned Designed	░	░	░	░	░								
		Rehabilitation													
		Newly proposed					■	■	■	■	■	■			
940	Vihiga	**On-going**	□	□	□	□	□								
		Planned Designed													
		Rehabilitation													
		Newly proposed					■	■	■	■	■	■			

Figure - 6.3.4 Implementation Schedule of Livestock Water Supply Development Plan.

Province	Code	Dsitrict	Nos	Total Storage Capacity (1,000m³)	Cost (1,000US$)
Central	210	Kiambu	3	150	92
	220	Kirinyaga	3	150	92
	230	Muranga	3	150	92
	240	Nyandarua	4	200	122
	250	Nyeri	3	150	92
Coastal	310	Kilifi	3	150	92
	320	Kwale	7	350	214
	330	Lamu	2	100	61
	340	Mombasa	1	50	31
	350	Taita	2	100	61
	360	Tana River	14	700	427
Eastern	410	Embu	5	250	153
	420	Isiolo	2	100	61
	430	Kitui	14	700	427
	440	Masaku	11	550	336
	450	Marsabit	15	750	458
	460	Meru	6	300	183
	470	Nyambene	5	250	153
	480	Tharaka Nithi	6	300	183
	490	Mwingi	7	350	214
	4A0	Makueni	79	3,950	2,410
North-Eastern	510	Garissa	98	4,900	2,989
	520	Mandera	23	1,150	702
	530	Wajir	39	1,950	1,190
Nyanza	610	Gusii	5	250	153
	620	Kisumu	6	300	183
	630	Siaya	6	300	183
	640	Homa Bay	4	200	122
	650	Migori	2	100	61
	660	Nyamira	4	200	122
Rift Valley	710	Kajiado	28	1,400	854
	720	Kipsigis	4	200	122
	730	Laikipia	8	400	244
	740	Nakuru	33	1,650	1,007
	750	Narok	16	800	488
	760	Trans Nzoia	2	100	61
	770	Uasin Gishu	5	250	153
	780	Bomet	6	300	183
	790	Transmara	3	150	92
	810	Baringo	44	2,200	1,342
	820	Elgeyo Marakwet	2	100	61
	830	Nandi	5	250	153
	840	Samburu	18	900	549
	850	Turkana	12	600	366
	860	West Pokot	12	600	366
Western	910	Bungoma	4	200	122
	920	Busia	3	150	92
	930	Kakamega	6	300	183
	940	Vihiga	3	150	92
Total			299	169,204	30,500

Implementation Schedule: 2000, 2005, 2010

Legend: ▭ : Studies, surveys, detailed design, financial arrangements, etc.

■ : Construction

PART III

SEWERAGE DEVELOPMENT PLAN

THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN

SUPPORTING REPORT

PART III : SEWERAGE DEVELOPMENT PLAN

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CHAPTER 1 SANITATION SECTOR BACKGROUND

1.1 National Target and National Water Policy

1.1.1 Sector Objectives

The broad national objective for the development of the sewerage sector is stated in the draft 1996 National water policy recently approved by government: *To supply water of good quality and in sufficient quantities to meet the various needs while ensuring the safe disposal of wastewater and environmental protection.* The objectives of the NWP are clearly directed at sustainable development with emphasis on protecting the water environment.

To meet these objectives the following policy framework has been proposed by the Government:

(1) Development to meet water demands

The Government will continue to play a leading role in sector development while continuing to encourage the full participation of the communities and the private sector. The Government, therefore, collaborates with the donor community, beneficiary communities, Non-Governmental Organisations (NGO) and the private sector in mobilising the necessary human and financial resources required. The Government remains committed to creating an enabling environment for all actors to operate effectively and will adopt a diminishing role in the direct implementation of water supply and sanitation projects.

The Government will continue to promote the development of appropriate water and sanitation facilities in rural areas as a means of attracting viable economic activities.

(2) Technology

The Government will remain committed to the use of appropriate technology that users fully understand. Efforts will be made to vet the technologies being introduced into the sector in a manner that will not obstruct the introduction of technological breakthroughs in the field of water development. Traditional technologies will be introduced with modifications where necessary.

(3) Monitoring system

The ministry in charge of water affairs will develop with other actors a comprehensive water sector monitoring system including country level collaboration in order to have access to reliable socioeconomic, institutional, technical, and financial data. The information will be used to support the policy formulation and regulatory process.

(4) Operation and maintenance

In line with Government policy of cost sharing, the ministry in charge of water supply will fully encourage active participation of beneficiaries in the development and operation of water supplies. In this regard the Government will continue to promote the development of water supplies that are self-sustaining, and where beneficiaries themselves are encouraged to take full responsibility for operating and maintaining such systems.

(5) Wastewater Disposal Systems

Development of water supplies in the urban areas will be accompanied by corresponding sewerage development systems to handle wastewater. In particular, wastewater from industrial sectors will be properly treated before discharging it into natural river courses. Strict water quality standards will be established to protect all water bodies receiving wastewater. In urban and minor urban areas, sanitation will be developed concurrently with water supply systems aimed at protecting peoples health and water resources from pollution. In rural areas, on-site sanitation will be developed where economically and technically viable.

1.1.2 Sector Strategy

Most of the water supply systems are owned and operated by the Government (NWCPC inmost cases). Local authorities (municipal councils in most cases) are responsible for the operation of wastewater disposal system. Only nine (9) municipal undertakers are responsible for providing water supply and sewerage services together.

Sewerage development is largely the responsibility of MOLA although MWR also has some regulatory and advisory functions. MOLA's current strategy for sewerage development in Kenya is to complete on-going projects in large urban centres and focus on the development of basic infrastructure (including sewage) in smaller urban centres throughout the country in order to curb rural-urban migration.

NWMP (1992) proposed a sewerage development plan proposed to meet the stated water sector objectives. NWMP presented a list of 158 projects to be completed between 1992 and 2000 at a total estimated cost of approximately 452 million $US. The number of priorities has unfortunately outweighed the funding available and little progress has been achieved.

The "Public Investment Program 1997-2001" (PIP), identified 21 sewerage development projects **Table - 1.1.1**. Four priority projects have now been completed, and two should be commissioned in late 1998. The remaining 15 projects will only proceed if donor funding can be obtained.

A review of District Development Plans (DDP) is summarised in **Table - 1.1.2** and identifies a total of 29 on-going and planned sewerage projects (7 of these projects are also identified in the PIP: Kapsabet, Meru, Wajir, Nyeri, Embu, Karatina, Chuka). The status of projects is identified in the following table.

Status '97	1	2	3	Grand-total
PIP	12	3	6	21
DDP	21	1	0	22
Total	35	4	4	43

Note: 1 - projects under investigation, planning or design (require funding to proceed)
2 - projects under implementation (funding has been obtained for construction)
3 - projects completed, under operation & maintenance
Source: PIP = project investment plan, DDP = district development plan

A review of project status reveals that only the projects funded by donors have been completed. Relatively few projects are implemented compared to the large number of sewerage development projects identified in the various plans. It is therefore essential that future sector strategies be developed to overcome implementation constraints. In general, the constraints that have hindered the development of sewerage in the past are:

1) Insufficient investment funding for new infrastructure resulting in a reduction in service levels.
2) Insufficient operating revenue to fund operations and recurring expenses resulting in little or no maintenance, inadequate staffing levels, low pay, and difficulty in attracting qualified operators.

1.2 Assistance by Donors

Since the establishment of MWR in 1974, many bilateral and multi-lateral donors have extended support to various projects and programmes implemented by the Government in the sanitation sector. Since 1992 almost eighty percent (80%) of all investment funding in the sewerage sector has come from donor aid. The strategies in the sector vary widely:

1) institutional strengthening before infrastructure
2) rehabilitate existing before building new
3) provide sewerage in urban centres that do not have services
4) provide sanitation in slum areas

In sharp contrast to the many water supply development projects in Kenya there has been only limited activity by donors in sewerage development. More recently donors have recognised that improving water supply conditions also creates a corresponding need to provide for adequate wastewater disposal. Most donors now include sanitation and waste water disposal as an integral part of their water sector development strategy. Unfortunately most sewerage development activity is still driven by priorities identified for water supply development. Donors have, therefore, not yet addressed many of the sewerage sector priorities that are identified in this study.

A list of donor supported projects is shown below:

Donor	Objective	Project/studies	Benefits
African Development Fund	Provide required sewerage infrastructure	Sewage treatment works and reticulation in Bungoma, Muranga, and Kisii	Improve urban socio-economic conditions
Germany	Promote community based approaches	Eldoret sanitation Kericho sanitation Nyeri	Design of new sewage treatment works and system improvements New treatment works completed Nyeri, Eldoret and Kericho have commercialised operations by established Water and Sanitation companies.
Japan	Support in every aspect of sewage sector by conducting studies, training, institutional capacity building and sewerage development projects.	Nakuru sewage treatment works Kisumu	To reduce pollutant load to lake Nakuru Rehabilitate and expand sewerage facilities to service growing population
Saudi Arabia	Provide infrastructure	Mombassa sewerage (in-progress)	Provide a new sewage treatment facility and trunk sewers to service West Mainland
World Bank	To reduce poverty To promote equitable, efficient and sustainable development To promote policy reforms, institutional adoption and capacity building	First and second Nairobi W/S and sanitation projects. Third w/s project due for completion in 1997	Improving water supply and sanitation in slum areas of Nairobi.
UNICEF	Develop sustainable water and sanitation projects by strengthening operation and maintenance capacity.	Five year programme under Child Survival and Protection Project to provide access to safe drinking water and sanitation facilities	Suitable excreta disposal facilities for 10,000 people and disposal of liquid wastes in slum areas of Nairobi

CHAPTER 2 PRESENT SANITATION CONDITIONS

2.1 Existing Sanitation Systems and Populations Served

2.1.1 Domestic Wastewater Disposal

(1) Data Available for planning

Relatively little information exists on the state of sewerage development and sanitation practices in Kenya's urban centres. Statistics are available from only two sources:

1) 1989 Census providing figures on total urban populations by type of sanitation.
2) 1994 Welfare Monitoring Report providing statistics on accessibility to sanitation by type.

Results of the 1989 census indicate that approximately 39% of the total urban population had access to waterborne sanitation (28% connected to public sewers) while 57% depended on pit latrines. Similar results are reflected in a 1994 Welfare Monitoring Report showing that 55.7% of the urban population still relied on pit latrines while 41% had access to waterborne sanitation (no estimates for sewer connections). Data from both sources is summarised in **Table - 2.1.1**.

(2) Sewerage Facilities Survey

At present in Kenya there are 38 sewage treatment facilities located in 30 urban centres. The location of urban centres with public sewerage systems is shown in **Figure - 2.1.1**.

In 1995 a JICA expert (Mr. Morita) compiled a report that described in detail for the first time the sewerage schemes in operation for each urban centre in Kenya. The report described for each urban sewerage scheme the treatment process, and physical condition and provided estimates of the number of people connected to sewerage in each urban centre. From the information provided in the report it was estimated that only 16% of the urban population in 1995 were connected to sewerage. This number differs significantly from 1989 and 1994 statistics.

In order to provide a better picture on the current status of sewerage development and accessibility to sanitation facilities it was decided that each existing sewerage scheme should be surveyed in detail as part of the aftercare study. An investigation of 30 existing sewerage schemes in 26 urban centres was carried out. Information for the other 4 urban centres not covered by the survey was compiled from existing JICA studies for Meru, Isiolo, Nakuru, Kisumu. The existence of a sewerage scheme in Karatina was discovered at the end of the field assignment by the study team during a review of literature on the performance of ponds in Kenya. Information reported for Karatina is therefore incomplete. The urban centre of Voi was removed from the initial survey list because the small sewage lagoon serving a few hundred people in a small housing development has been abandoned and is dry.

Information on the existing sewerage facilities was collected from site visits and by distributing a questionnaire survey. Appointments were made with the body responsible for operating the sewerage schemes prior to distributing the questionnaire. This ensured that the right person received the questionnaire and that accurate information was received. Where possible the questionnaires were given to the Town Engineer or the General Manager. In their absence, the questionnaire was given to the sewage foreman or superintendent. The following information was collected:

1) Extent of sewerage coverage within the urban area i.e. proportion of the population served.
2) Comparison between the amount of water supplied and the resulting effluent quantity to the sewerage works
3) History of the system's development
4) Efficiency of the sewage treatment works and method of effluent disposal
5) Industrial wastewater discharges and disposal systems
6) Method of sludge treatment and disposal at the treatment works
7) Operation and maintenance data, management and organisation data.
8) Extent of on-site sanitation, method of septage handling and disposal.

The information collected in the questionnaires was checked through discussions and any missing information was added. Where drawings of existing sewerage facilities were not attached to the questionnaires, efforts were made to locate them. Upon collecting the surveys the site was visited with the person who filled the questionnaire in order to confirm the data received as well as assess the general condition of sewage treatment works and sewer reticulation. In the course of site visits the following issues were discussed:

1) Operating problems with the existing system
2) The municipality's or town council's plans to correct the problems
3) The frequency of undertaking certain maintenance requirements

Obtaining complete information was not possible in most cases because data and records are generally not available or not kept up to date. Many problems were encountered in the data collection:

1) In some cases the section head assigned the questionnaires to a junior person unfamiliar with the system.
2) Lack of drawings showing sewer reticulation
3) Lack of design data
4) Lack of current operation data such as flow records
5) Reluctance to compile revenue and expenditure data
6) Bad attitude to the importance and purpose of the data being collected

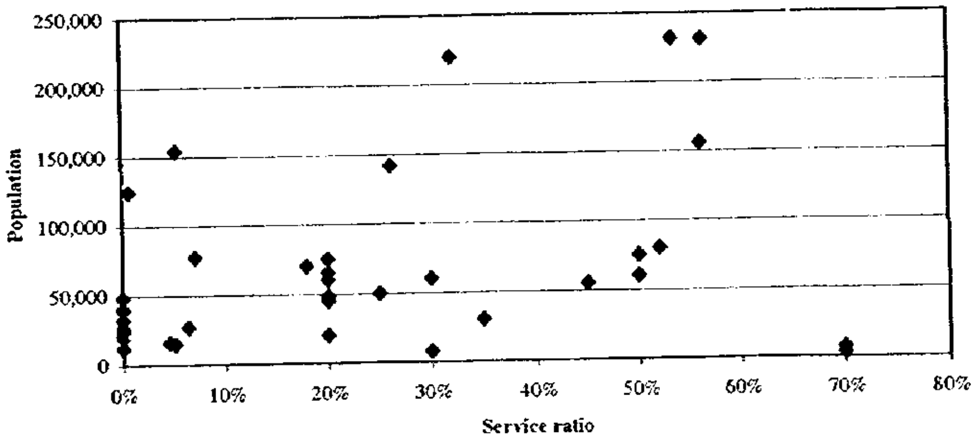
The questionnaire and the data that was collected for each sewerage scheme is presented the data book on sewerage inventory. An analysis of sewer coverage by population size indicates that all large population centres (>100,000) have some form of waterborne sewerage, however most urban centres with a population less than 20,000 have no sewerage systems.

Population range (000's)	No. of urban centres with sewerage	No. of urban centres without sewerage	Total
300 < P	2	0	2
300 > P > 100	8	0	8
20 < P < 100	16	8	24
P < 20	4	177	181
Total	30	185	215

An assessment of the information available from reports and the survey results indicates that the percentage of the population connected to sewerage ranges from 5 to 70% as shown below:

% sewered population range	Urban centres	Number of urban centres in group
0-10	Ngong, Machakos, Meru, Voi, Isiolo	5
10-20	Bungoma, Webuye, Busia, Embu, Kisii, Mombasa, Kapsabet, Homa Bay	8
20-30	Nyeri, Athi River	2
30-40	Eldoret, Kiambu, Nyahururu, Muranga	4
40-50	Nanyuki, Nairobi, Naivasha, Kitale, Kakamega	5
50-60	Kericho, Kisumu, Nakuru Thika	4
60-70	Limuru, Karatina	2
Total		30

A plot of population size versus service ratio for each urban centre (28 urban centres excluding Nairobi & Mombasa) is shown below. It indicates there is no definite relationship between population size and service ratio.



(3) Population Served

With the results of the survey it is possible to estimate the current status of sewerage development in Kenya. The total urban population in 1998 is approximately 6.5 million, estimated by interpolating between 1995 and 2000 population forecasts. Based on the information compiled from various sources during this study, sewerage schemes have been developed in 30 urban centres serving an estimated 1.8 million people or 28% of the total urban population. This leaves approximately 4.7 million urban dwellers (72%) without the benefits or convenience of waterborne sewerage. Overall the average service coverage in urban centres has not improved since the 1989 census, but it has managed to just keep pace with population growth. The 28% does not reflect the fact that the majority of urban centres have no sewerage schemes at all. Nor does it reflect the fact that many existing sewerage and treatment works are inoperative, overloaded or not providing the required level of treatment.

2.1.2 On-site Sanitation

Access to Sanitation

A survey of 756 households in 39 urban centres across Kenya was conducted as part of this study to obtain information on water use and sanitation practices and living conditions. In addition, a separate on-plot sanitation survey was carried out for 50 households in 5 urban centres where there are currently no sewerage facilities and a need has been expressed (Garissa, Malindi, Maragua, Mumias, Wajir). The survey methodology and results are presented in the data book on household survey.

Results of the household surveys indicate that access to sanitation in 1998 has probably not improved much from the figures reported in the 1994 Welfare Monitoring Report and the 1989 Census. A rather high 46.6% of the urban population surveyed reported using pit latrines while 47.1% reported access to waterborne facilities such as pour flush or cistern toilets. Combining the results of the household survey with the results of the sewerage schemes it is possible to estimate the percentages of the urban population served by different methods of wastewater disposal as follows:

Method of disposal	% of urban population
Main Sewer	28
Pit Latrine	47
Septic/Cesspool	23
No sanitation (bush)	2

Source: JICA Study team survey

The prevalent water source and sanitation facilities in the urban households surveyed are piped water supply systems and pit latrines. Results of cross tabulations at the national level indicate that waterborne diseases tend to afflict people living in households with no sanitation, those which use pit latrines, pour flush toilets, and bucket latrines are more than people living in households with cistern flush facilities.

Symptoms of illness were also reported in the five urban centres selected for on-site sanitation survey. About 80% of the symptoms are water related. They were worse in Malindi and Wajir where shallow wells are a major source of water.

It is difficult to make any firm conclusions from the results of the survey because the sample size is small, however, the following general observations can be made:

1) Water related diseases are prevalent in areas where shallow wells are the major source of drinking water.
2) About half of the people who receive piped water supply use pit latrine for sanitation indicating a large percentage of the population disposes of wastewater to the environment.
3) Pit latrines are the most common type of on-site sanitation facilities and septic tanks are rarely used probably due to high cost of installation and maintenance. Ventilated improved pit latrines are gaining popularity.
4) Latrines are rarely de-sludged.
5) The use of buckets as a means of effluent disposal is prevalent in Wajir and appears to be a considerable health hazard.

Pit Latrines

Where the ground is permeable and the water table low, pit latrines operate well, although they are usually not very hygienic and only deal with excreta and not other wastewater. Actual conditions are site specific and it is very difficult to draw anything more than general conclusions about the continued use of pit latrines.

Many pit latrines are constructed in congested areas as observed in Nairobi. In these congested conditions replacement of a filled pit is not possible necessitating emptying; however, results of the on-plot sanitation survey indicate that latrines are rarely de-sludged. Many latrines are built in impermeable ground, or in ground where the water table is high. MOLG has identified a need to improve sanitation in 16 urban centres where water table and soil conditions make pit latrines and septic tanks unsuitable. These are identified in the projects listed in the public investment plan and the district development plan presented in chapter 2.

Septic Tanks

Approximately 23% of the total urban population use waterborne toilet facilities connected to a septic tank or cesspool. Most septic tanks are concrete structures of various designs with effluent from the tank discharged into a soak-away pit or drainage tiles. These installations are suitable only in cases where the ground is permeable and where there is no danger of contaminating underground water supplies.

According to the WHO report in 1973, most of the septic tanks in Kenya were too small and in the absence of any standards this situation likely persists. WHO also reported that a great many tanks where located on unsuitable ground and most had illegally overflows to nearby drainage ditches or low lying areas.

Septic tank installations in Mombasa, Kilifi, Malindi, and Lamu are polluting ground water supplies. The soak away pits along the coastal areas are usually dug down to the ground water table. Local residents who have insufficient supply from the regular water distribution system use ground water contaminated by soak-away pits

Septic Sludge

The survey questionnaire asked municipalities to provide information on method of de-sludging, quantity of sludge, and method of disposal. Results of the survey for each urban centre can be found in the data book. Sludge from septic tanks and cesspools are removed infrequently and usually only when the tank is full and upsets the plumbing. Sludge from septic tanks is normally removed by the municipality using a vacuum truck. Most municipalities own at least one vacuum truck but in many cases these are out of order or very old. Thus, tanks are de-sludged infrequently because the municipality vehicles are often unavailable. Private commercial companies also provide services but these are costly, typically in the range of 3,000 to 5,000 shillings per trip, infrequent, and unreliable. The disposal of sludge is unregulated and is often jumped in a nearby drainage ditch, garbage dump, field, or where they exist at sewage treatment facilities. The uncontrolled collection and discharge of sludge is a health hazard and damaging to the environment.

Sullage

Sullage is domestic wastewater that has been used for washing or in food preparation. Sullage is usually discharged into public sewers where they are connected. Generally in Kenya, sullage is discharged onto the ground or drained into shallow ditches or surface water drains. It is estimated that at least 85% of the urban population has piped water supply. In sharp contrast, only 28% of the urban population has a sewer connection. The obvious conclusion is that disposal of untreated wastewater into the urban environment is widespread creating a potentially a serious health hazard as well as being a source of pollution. Wastewater was observed in most drainage ditches in the urban centres visited by the team.

2.1.3 Industrial Wastewater Disposal

The existing situation on industrial wastewater in Kenya is not well documented. There is very little data available on the number of industries in Kenya or the amounts of water used, treated, and discharged. MWR kept a database of industrial effluents in the past but it is now out of date. MWR has a Water Quality and Pollution Control Division responsible for regulating pollution control, monitoring water quality, drinking water surveillance, water and wastewater analysis and data documentation and processing. Sadly, it is severely crippled by a lack of resources to inspect industries, monitor, collect, and analyse data. Local authorities are responsible for enacting sewer use bylaws, enforcing them, and monitoring industries for compliance. Only Nakuru has the staff and equipment in place to monitor and enforce trade effluent bylaws. Other municipalities have bylaws but no enforcement capability.

In general where public sewerage systems exist, factories usually discharge their effluents into the sewers. In many cases, however, wastewater is discharged without pre-treatment into nearby watercourses.

Aggressive growth targets for industrial development have been set by the Government. Sessional paper No. 2 of 1996 "Industrial Transformation to the Year 2000" targets growth of highly capital intensive and heavy industries to achieve double-digit rates of 12 to 15%. This high growth rate will have serious implications on the water supply and sewerage sectors. The uncontrolled disposal of industrial wastewater could not only degrade the water environment, it could also seriously jeopardise the quality of drinking water supplies, making it difficult to treat and provide safe potable water.

2.2 Physical Condition of Sewerage Systems

Source of data

The results of the survey carried out during this study are used extensively to prepare an inventory of sewerage infrastructure and to assess physical conditions in each urban centre. A summary of urban sewerage schemes is provided in **Table - 2.2.1**. The data sheets located in the data book provide a physical description of the sewerage facilities as well as observations on operation and maintenance, and rehabilitation needs.

A limited sampling programme of wastewater treatment plants throughout Kenya was carried out in January 1998. A single discrete sample was taken of the influent and effluent at 26 sewage treatment works. Where the receiving stream is a river, a sample of the river water was taken upstream and downstream of the discharge point to assess potential environmental impacts. Sampling at Kisumu, Isiolo, Meru, and Nakuru where considered unnecessary because their performance is already documented in recent JICA studies. Results are discussed in later sections of the report.

A 1997 research monograph published by the British ODA entitled "An Evaluation of Waste Stabilisation Ponds in Kenya", Mara, Alabaster, et al., also provides excellent information on the operating conditions at eight public waste stabilisation ponds namely, Eldoret, Isiolo, Karatina, Kisumu, Kitale, Nanyuki, Nyahururu, and Thika. This document is also used as a guide to the design of ponds in Kenya.

Through the efforts of GTZ, the Small Towns Development Program has created an inspection unit that has produced some informative facilities inspection reports. Although most of these reports are dated early '90's, they contain information that describes typical conditions encountered in Kenya. They provide an excellent source of information on existing conditions in: Eldoret, Kisumu, Kericho, Kitale, Nyeri, Nakuru, Nyahururu, and Thika.

2.2.1 Sewer Reticulation

Unfortunately, local authorities surveyed in the Study provided very little information on the physical condition of sewer reticulation making it impossible to comment on actual sewer conditions and rehabilitation needs. Information is generally not available because sewer operators lack the sewer inspection programmes that are needed to collect the data. In fact most authorities do not even have accurate sewer inventories to identify pipe size, age, and location.

The total length of sewer pipe installed varies greatly between urban centres, ranging from 0.07 m/capita in Kakamega to the unusually high value of 8.89 m/capita in Kapsabet where a sewerage scheme has recently been completed. If Kapsabet is not included, the average is 1.14 m per capita which is low indicating insufficient development of sewer reticulation in most urban centres.

The table below summarises the results of the survey in 22 urban centres where information could be obtained. The large number of persons per sewer connection indicates the prevalence of schemes where there are many housing units within a plot sharing the sanitation facility and to some extent also indicates that sewerage reticulation is generally underdeveloped.

Range of persons per sewer connection	Urban centres	Number of urban centres
0-10	Webuye, Embu, Ngong, Kakamega, Limuru, Machakos, Homa Bay	7
10-20	Busia, Kiambu, Thika, Nanyuki, Nyahururu, Naivasha, Nyeri, Eldoret	8
20-30	Kisii, Kitale, Muranga	3
30-40	Kapsabet, Athi River	2
Over 40	Bungoma, Kericho	2
Total		22

Inventories are available for 3 urban centres: Mombasa, Nakuru, and Kisumu and the percent distribution by pipe size is shown below:

Sewer Diameter (mm)	Kisumu	Mombassa	Nakuru
<150		12%	59%
150 - 200	6%	78%	18%
200 - 300	51%	4%	10%
300 - 400	17%	1%	
450	2%	2%	8%
525	7%		
600	8%	3%	5%
675	9%		
Population (persons)	130,000	21,534	123,500
Length (m)	14,287	20,880	86,156
Length per capita	0.11	0.97	0.67

Most sanitary sewers in Kenya are separate from storm water drainage sewers. In practice, however, surface water finds its way into most sanitary sewers and these operate more like combined sewers except no provision is made for relieving wet weather flows. The entry of storm water into sewers is uncontrolled and during wet weather contributes to frequent overflow of sewage out of manholes, and flooding of treatment works.

In the typical mid size urban centres, sewers have usually been provided in the main commercial area, usually along one or two main streets, or through a main commercial block and a few housing estates in the vicinity of the city centre. Other areas, which are typically less densely populated, are usually not sewered. The number of people with sewage connections is significantly lower than the number of people with water supply connections.

In the past sewerage development in many smaller urban centres was limited to a small drainage area and although some capacity was provided for future growth, the hydraulic capacity of trunk mains in general has now been exceeded. In several large urban centres, for example, Thika and Kakamega, trunk mains of 150 mm in diameter serve a population of 11,700 and 5,400 respectively. The 150 mm trunk sewers experience frequent blockages. The present design criteria in Kenya specify 225 mm diameter as the minimum size for a public sewer.

Newly constructed sewers (last ten years) are generally in good working order despite a general lack of preventative maintenance such as regular cleaning and inspection. New sewers are generally designed to achieve self-cleansing velocities based on projected existing wastewater flows. In addition, trunk sewers are usually oversized to provide spare capacity for future flows. Unfortunately, in many cases projected wastewater flows have not materialised because of water rationing or the unwillingness of consumers to connect to sewers. As a result, flows are too low to provide self-cleansing velocities. Low flows lead to operating problems such as accumulation of sedimentation, which reduces hydraulic capacity, and septic sewage, which causes pipe corrosion and treatment process difficulties.

The vast majority of sewers where constructed in the 50s, 60s, and 70s have never been inspected. Local experience indicates that many are in poor structural condition. In several urban centres the trunk sewers installed in central areas over twenty years ago are only 150 mm in diameter. Development has exceeded the available hydraulic capacity of older sewers resulting in frequent blockages, overflows, and surface flooding.

The expansion of sewerage networks generally takes place at a slow pace due to lack of funds. Most of the funding has been focused on improving treatment works to meet effluent quality criteria.

2.2.2 Treatment Facilities

Based on existing information gathered during this Study it would appear that sewerage systems where they exist are designed with the intent of treating all the sewage that is collected. Of course there are conditions where overflows to the environment occur but in general most sewage flows to a treatment facility.

Waste stabilisation ponds are the preferred treatment method and are used in 25 out of 38 treatment works. These generally operate problem free with the exception that most of the older ponds are filling with sludge and vegetation, which generally reduces retention times and thus treatment efficiency.

Conventional treatment works using biological attached growth filters are found in only 6 urban centres. With the exception of Kericho, which has recently been rehabilitated with funding from GTZ, and Nyeri, which is well maintained, these conventional systems do not operate properly due to organic overload and mechanical failures. In every case, conventional treatment works are operated without any process monitoring or control. Sampling is limited to influent and effluent with little or no sampling of process parameters to guide the operators in optimising treatment efficiency. Operator intervention, adjusting sludge recycle rates for example, is minimal.

The remaining treatment works consist of oxidation ditches (3) and aerated lagoons (3). Except for the recently commissioned ('86) facility in Nyharuru, oxidation lagoons and ditches do not operate well due to mechanical failure of aerators and sludge re-circulation pumps.

Results of the facilities survey indicates that per capita flows in Kenya are relatively low and in many cases are insufficient for the proper operation of sewers. **Table - 2.2.2** provides a comparison between the amount of potable water supplied and the amount of wastewater received at sewage treatment works in each urban centre. The table also provides a summary of per capita sewage contributions. The sewage received at the treatment works from the served population varies from 23 to 628 lpcd. The average of 177 lpcd appears to be reasonable since it includes not only domestic flow but also industrial flows and groundwater infiltration. The per capita flow in seven urban centres is below 75 lpcd, which is the minimum acceptable flow required to keep sewers functional. This can be explained in most cases by low per capita water consumption due to inadequate water supply systems. In a few cases the quantities of water returned to the treatment works are larger than the quantities consumed. This is probably an indication of high levels of groundwater infiltration and/or industries that have their own source of water but discharge to the sewers. The urban centres where water supply conditions appear to be unable to support waterborne sewerage and systems that appear to suffer from high inflow and infiltration are shown below:

Sewage flow	Water supply > than 100 lpcd	Water supply < 100 lpcd
Sewage flow < 75 lpcd	Nyeri, Kericho, Mombassa, Homa Bay, Naivasha	Nakuru, Busia
Comments	A high proportion of the water is used and not returned to sewer.	Water supply conditions are inadequate to support waterborne sewerage system.
Sewage flow > amount of water supplied	Machakos, Nyahururu, Nanyuki	
Comments	High levels of infiltration or contributions from sources that have private water supplies	

The water supply conditions in the following non-sewered urban centres are inadequate to support waterborne sewerage systems: Garissa, Kabarnet, Mandera, Maragua, Narok, and Wajir.

In general, most of the recently constructed sewage works are operating far below their design capacity. The low flow rates can be attributed to:

1) Low rate of sewer connections
2) Inadequate water supply systems resulting in low per capita water consumption
3) Diversion of raw sewage for irrigation

The older treatment works (1980's) are generally hydraulically and organically overloaded, a condition attributed to: (i) population growth beyond design capacity, (ii) reduction in designed treatment capacity due to sludge accumulation or mechanical failure of the process, (iii) Aging sewer reticulation resulting in more infiltration of ground and surface water.

Status of Treatment Works

Status	Urban centre	Number
Overloaded	Embu, Homa Bay, Kisumu conventional, Meru, Machakos, Mombasa (both), Nanyuki, Ngnong, Nyahururu, Nairobi (both), Eldoret (both), Thika	15
Operating at design capacity	Busia, Kapsabet, Kakamega (both), Karatina, Kericho,	6
Not operating	Limuru, Voi	2
Operating below capacity	Athi River, Bungoma, Isiolo, Kiambu, Kisii, , Kisumu ponds, Kitale (both), Muranga, Naivasha, Nyeri (both), Nakuru (both), Webuye	15

2.2.3 Treated Water Disposal

(1) Rivers and Inland Lakes

In Kenya, treatment plant effluent is discharged into a receiving body of water. Out of 30 urban centres with sewage treatment works, 24 discharge into rivers or streams, 8 of which flow into Lake Victoria. Two (2) urban centres discharge directly into Lake Victoria (Homa Bay & Kisumu). Three (3) urban centres discharge into environmentally sensitive, closed inland lakes Nakuru, Naivasha, and Baringo.

(2) Coastal areas

Mombassa discharges sewage with only primary treatment directly into the ocean only a short distance from shore. There is great cause for concern over the impact of effluent from coastal cities and hotels on sensitive coral reefs and beaches that accounts for an important share of the tourism industry in Kenya.

(3) Irrigation

The use of treatment plant effluent for agricultural irrigation is not documented but is likely not widespread, occurring informally in a few isolated cases. There have been reported cases of diverting raw wastewater before it reaches the treatment plant for agricultural irrigation. Although these reports could not be confirmed during site investigations there is probably some evidence to support the statement. In several urban centres the amount of wastewater returned to the treatment works is much less than the amount supplied per capita even when making allowances for water lost in the distribution system.

(4) Effluent Quality Standards

The laws of Kenya that deal with water pollution are contained in the Water Act. This act establishes that all water in Kenya is the property of the government and that the minister responsible for water development has the duty of maintaining the quality of those resources. The act provides the necessary legal framework for the minister to monitor, and enforce the provisions of the act. The Water Pollution Control Section WPCS of MWR is the body responsible for setting of effluent standards that are required for the discharge of effluents to a watercourse. The national effluent standards for the direct discharge of an effluent into a watercourse are shown in **Table - 2.2.3.**

These standards are based on the British "Royal Commission" 20:30 standard that is in common use in many countries around the world. How the standard was developed must be clearly understood before it can be applied to any given situation. The 20 BOD and 30 SS limit were recommended by the Eighth Report of the Royal Commission in 1912 on the basis of UK River conditions. The aim of the standard was to ensure that the effluent did not increase the BOD above 4 mg/ℓ or lower the dissolved oxygen below 4 mg/ℓ in the receiving stream. This was to protect fish and other aquatic life in the receiving stream. The standard recommended by the commission did not include any bacteriological limits and assumed a dilution factor in the receiving stream of at least eight. In recent years it has been recognised that bacteriological limits is an important consideration for most tropical rivers and MWR added a limit on the number of faecal coliforms to 5000 per 100 mℓ.

Since municipal councils own and operate sewage treatment works, they have the legal responsibility to ensure that effluent from the treatment works complies with the standards issued by WPCS. Most municipal councils have, therefore, adopted the national standard into their local bylaws. In some cases such as Thika the local standard is much stricter, reducing faecal coliforms to 1000 per 100 mℓ. In Nakuru the standard limits BOD to 10 mg/ℓ and nitrate as N to only 5 mg/ℓ. It is difficult to achieve these limits with normal treatment processes, particularly those related to nutrient concentrations. In Nakuru, tertiary treatment in the form of rock filters and grass plots was added to achieve compliance. In many cases it may be that the cost of complying with the discharge standards may be more than is affordable by municipal councils and industry. In such cases it might be necessary to make a decision to accept lower standard for particular parameters.

More specific standards are developed as the need arises for discharges from various agriculture, industrial, and commercial sources of wastewater to public sewers and watercourses. Discharge standards for industrial effluent into public sewers are also shown in **Table - 2.2.3.**

Since municipal councils are responsible for accepting or refusing industrial wastewater into the public sewer, most have adopted some form of trade effluent standards in order to protect the sewerage infrastructure, and prevent upsets to the treatment process.

2.2.4 Treatment Plant Performance

A limited sampling programme of wastewater treatment plants throughout Kenya was carried out in January 1998. A single discrete sample was taken of the influent and effluent at 26 sewage treatment works. Where the receiving stream is a river, a sample of the river water was taken upstream and downstream of the discharge point to assess potential environmental impacts. Sampling at Kisumu, Isiolo, Meru, and Nakuru where considered unnecessary because their performance is well documented in recent JICA studies; their results are incorporated into this report for comparison.

Results are shown in **Table - 2.2.4** (1 to 4). The typical composition of untreated domestic wastewater is provided in **Table - 2.2.5** as a reference point for comparing the test results.

(1) BOD/COD ratio and per capita BOD loading

The BOD/COD ratio is an indicator of the biodegradability of the wastewater. Domestic wastewater is highly degradable with a typical ratio of 0.4 to 0.8. The presence of industrial wastewater will lower or increase this ratio depending on the waste's biodegradability. A comparison of data available for 27 facilities indicates that 9 facilities had a ratio greater than 0.5 indicating high organic content. The majority of treatment works had low ratios caused by either high levels of non-degradable industrial wastes (i.e. high COD) or in some cases acute water shortages leading to settling of biologically degradable solids in the sewers (i.e. abnormally low BOD).

The highest recorded ratio was 0.82 for Nakuru and 0.71 for Busia and Thika. The lowest value of .16 was for Kitale and is likely due to acute water shortages.

Extremely high COD values are recorded at Kericho, Kisii, Murang'a, Naivasha, and Kitale. This result is difficult to explain since these locations are not heavily industrialised. Contrary to expectations, the COD values in urban centres with large industrial areas (Thika, Kariobangi, Eldoret) are within the normal range for domestic sewage of 500 mg/ℓ (medium) and 1000 mg/ℓ (strong).

(2) BOD per capita

The estimated BOD per capita obtained from the results of this study varied tremendously from 13 mg/ℓ to 97 mg/ℓ with and average of 83 mg/ℓ. BOD contribution per capita varies from 13 g/day to 134 g/day. The normal range in Kenya is 48 to 60 g/c/day with a value of 50 g/c/day used in design. No conclusions can be drawn from these results since they are greatly affected by the amount of industrial wastewater discharged into the sewers and the amount of groundwater infiltration and surface water intrusion.

(3) Performance of the treatment works - BOD removal

On average the influent BOD is strong at most treatment works indicating that individual water consumption is low. The samples obtained at the treatment works ranged from 875 mg/ℓ to 200 mg/ℓ with an average BOD of 480 mg/ℓ. The low figure of 90 mg/ℓ at Limuru cannot be explained.

BOD removal is a measure of treatment efficiency. Despite the fact that most plants are organically overloaded, BOD removal efficiencies are generally quite good ranging from 24% to 97. Ideally conventional treatment processes should achieve a higher level of BOD removal than waste stabilisation ponds. However, the survey shows that both treatment processes have similar effluent BOD removal. This can be attributed to mechanical equipment failures, lack of process control and organic overloading at older conventional treatment works. High BOD removals at Naivasha and Kitale whose mechanical equipment has been out of operation for sometime can be attributed to low sewage flows. High removal efficiencies at some waste stabilisation ponds like Bungoma and Muranga can be explained by low sewage flows.

Type of sewerage works	% BOD removal	Urban centres	Number in group
Waste stabilisation ponds	< 60	Busia, Isiolo	2
	60-70	Webuye, Meru, Nakuru-Njoro, Nyeri	4
	71-80	Embu, Kisumu, Nanyuki, Eldoret, Nairobi	5
	81-90	Kakamega, Kitale, Machakos, Nakuru-town,	4
	> 90	Bungoma, Thika, Muranga, Kapsabet	4
Conventional	< 60	Limuru, Kiambu	2
	60-70	Eldoret	1
	71-80	Kisumu, Nairobi, Nyeri	3
	81-90	Nyahururu, Homa Bay, Kitale	3
	> 90	Naivasha, Kericho	2
		Total	30

Only two treatment works, Bungoma and Kapsabet, meet the required national standard of 20 mg/ℓ BOD. There are many possible explanations for high effluent BOD results:

1) Organic overload
2) Mechanical failures or incorrect operation of conventional works
3) High quantity of algae in effluent of WSP contributing to high BOD
4) No control on the discharge of industrial wastes
5) Poor maintenance practices, e.g. sludge accumulation in ponds

It is also possible that unusual wet weather experienced in the weeks before the sampling may have upset the effectiveness of the process at several treatment works where storm water intrusion is a prominent

COD values range from medium to strong indicating that there is potentially a large component of industrial or toxic liquid waste being discharged into public sewers. Effluent COD's in all cases exceed effluent standards.

Statistics on Sampling of Effluent Parameters

	TN	SS	BOD	COD
Maximum	197	1170	460	633
Minimum	5.2	20	12.5	80
Average	22	351	99	223

Note: All values in mg/ℓ

(4) Performance of the treatment works – pathogen removal

The level of faecal coliform is an indicator of the amount of pathogenic organisms in the wastewater. The level of faecal coliform in the national effluent standard is restricted to 5000 per 100 mℓ. For agricultural irrigation the level recommended by FAO is 1000 per 100 mℓ. The results of the survey ranged between 0 to 1275 per 100 mℓ of sample indicating that most treatment works are effective at reducing coliform counts to less than 1000 per 100 mℓ. The only two treatment works that exceed the 1000 per 100 mℓ limits are Homa Bay and Kariobangi (Nairobi). In Kariobangi's case there are no maturation ponds and the high faecal counts are expected. In Homa Bay, the treatment works have maturation ponds; however, the extremely high result of 25,600 per 100 mℓ indicates that the facility is hydraulically overloaded probably because of high storm water flows and accumulation of sludge.

(5) Receiving Streams

Samples were taken at 20 treatment facilities, upstream and downstream about 200 meters of the discharge point in order to gain a very crude measure of the potential impact of sewage treatment effluents on receiving streams. The results also provide a perspective on water quality issues in receiving streams and put into question the relevance of strict effluent limits.

In 9 cases, the BOD of the receiving watercourse upstream of the treatment plant is higher than the effluent standard of 20 mg/ℓ indicating a serious surface water quality problem from other sources of pollution. Samples of the Nairobi river taken upstream of the Dandora treatment works show BOD values that are similar to those of weak to strong sewage. At 10 treatment works, the BOD downstream of the treatment plant is lower than the BOD upstream. This result is difficult explain and seems to indicate that the effluent is contributing a significant amount of flow and in effect diluting the natural watercourse. However, this explanation is contradicted by BOD values downstream of the treatment works which are in every case less than the treatment plant effluent in every case indicating good dilution by the watercourse within a relatively short distance.

(6) Sludge treatment and disposal

For waste stabilisation ponds the need for sludge treatment occurs only when the ponds are de-sludged. Most of the sludge is produces in anaerobic ponds and although the volume is reduced thorough the natural digestion process these facilities usually have to be de-sludged at 4 to 5 year intervals in order to maintain treatment efficiencies. Sludge accumulation in facultative ponds should normally be very slow and de-sludging would normally occur at 15 to 20 year intervals. However, in Kenya most primary ponds and facultative ponds suffer the heavy inflow of sand and grit since grit removal and storm water by-pass facilities are not provided or often inadequate. In Kenya de-sludging of ponds is rarely done and as observed during the surveys most ponds are in desperate need of relief. Municipal and town councils have indicated that they do not have the required equipment such as sludge pumps. Where ponds are de-sludged, the sludge is normally dumped on the ground within the site and left to dry. During the investigation period the older ponds at Nairobi's Dundora treatment works were being de-sludged.

Conventional treatment works generate much larger volumes of sludge. Primary settling basins must be de-sludged regularly and the sludge produced by the secondary biological treatment process must be wasted in order to maintain the appropriate mixed liquor concentrations. Sludge from conventional treatment works is normally not stable and therefore needs to be treated before disposal. The conventional work surveyed had digester facilities although some are not operating properly because of mechanical equipment failures. After it has been treated the sludge is usually sent to drying beds and then sold to farmers for agricultural use.

2.3 Operation and Maintenance

2.3.1 General Observations

Sewerage systems are generally working well below capacity due to water rationing and this results in blocking of sewers and poor performance of treatment facilities. Maintenance standards are generally poor, in many cases non-existent.

With the exception of newer facilities, most sewage treatment facilities have either fallen into serious disrepair or are non-operational and beyond repair. Clearly, it is only a matter of time before most new facilities suffer the same fate. The following problems were noted during visits made to facilities in 24 urban centres:

(1) Most municipalities are not well equipped and do not have the revenue required to support operations, maintenance, and renewal of sewerage infrastructure.

(2) Mechanised treatment processes are not maintained and most are inoperative due to a lack of skilled trades people for maintenance or lack of funds to replace broken equipment.

(3) In many cases, mechanical and electrical equipment has been vandalised and never replaced.

(4) There are few trained operators, as a result conventional treatment processes are not monitored or adjusted to provide efficient treatment.

(5) Most of the older treatment ponds (15 to 20 years) need to be de-sludged in order to restore hydraulic retention times required for effective treatment.

(6) The grass at most ponds are not cut and in several cases embankments have been allowed to deteriorate.

(7) Most sewers receive a minimum of maintenance and most were installed more than 20 years ago. Although little is known about the condition of sewers in most urban centres the survey has established that most sewer reticulation is in need of maintenance:

(8) Most sewer reticulation systems are not cleaned or flushed routinely resulting in the heavy build up of silt, frequent blockages and conditions leading to septic sewage. Most municipalities lack the basic equipment and tools for sewer maintenance.
The inspection of sewers in Kenya is not carried out. Without inspection it is difficult to assess with any certainty what the condition of sewer infrastructure might be.

(9) In Kenya it is common to use stones or corncobs for anal cleansing. These materials lead to frequent blockages especially in areas where sewers are only 150 mm in diameter. The use of sand for washing kitchen utensils also leads to excessive deposits of silt.

(10) Several trunk sewers have collapsed or have become permanently blocked resulting in sewage overflows into the environment. Pitch fibre sewers, which were widely used in the 50's and 60's, have collapsed due to age and quality of materials.

(11) In several urban centres, the amount of water consumed per capita is so severely restricted by a poorly performing water supply system that the sewer reticulation systems are frequently blocked; in some cases permanently.

(12) Infiltration is high in most urban centres and the flow into most treatment plants doubles or triples during wet weather. If infiltration is high then leakage of sewage into the ground and thus the ground water is inevitable and probably a significant source of contamination in areas with shallow wells.

(13) Leakage of sewage is also a serious threat to the safety of piped water supply systems. The widespread and frequent shortages of water can create negative pressures in water distribution networks leading to the suction of air and also contaminated groundwater (i.e. sewage) through leaks in the distribution mains. Since residual chlorinating is often inadequate there is a serious potential health risk.

(14) Pumping stations are a vital part of many sewage networks but in most cases these are inoperative. Frequently pumps do not operate because attendants are unreliable or because they lack mechanical knowledge. In many cases the electrical services have

been stolen and never replaced; as a result sewage overflows into storm water drains or watercourses can be observed at most pumping stations.

2.3.2 Typical Organisation

Organisational charts showing the number of skilled and unskilled workers for each urban centre surveyed are shown in the sewer inventory data book. Unfortunately, Mombasa and Nairobi did not provide the information requested.

There is a wide variety of organisational structures from one urban centre to the next. The number of workers and the organisational structure depends to a large extent on the complexity and number of treatment facilities, and to the size of the sewerage system.

Generally speaking, operations and maintenance is usually organised in one department under the direction of the town or municipal engineer. A superintendent reporting to the engineer usually oversees actual day to day operation of the treatment works and sewer system. Where there is more than one treatment works then each treatment works will have its own maintenance staff and one foreman or superintendent in charge of operations at each treatment works. Sewer maintenance is organised under the treatment works superintendent and work crews are responsible for the sewers in the drainage areas that flow to the treatment works. Depending on the size of the operation, one or more foremen are involved in direct supervision of the maintenance work crews. A typical organisational structure is shown in **Figure - 2.3.1.**

2.3.3 Staffing Levels

Staffing levels also vary widely from one urban centre to the next. The number of staff varies from 0.2 to 3.1 workers per 1000 persons served. The average is 1.1. In general, smaller facilities tend to have higher ratio because they require a minimum of six to seven workers for maintenance regardless of how small the population is.

Staffing levels in general appear to be adequate in most cases for waste stabilisation ponds. Municipalities with waste stabilisation ponds tend to have less skilled workers and more labourers for grounds keeping. Staffing levels at large conventional treatment works and in larger systems where pump stations are operated appear inadequate, especially in the numbers of skilled operators, mechanics and electricians.

In all cases there appears to be insufficient number of labourers involved in sewer maintenance. There is little if any preventative maintenance and most sewer maintenance consist of unblocking sewers. This is especially the case in smaller systems were there are many small diameter (150 mm) mains.

Eldoret is the only municipality that practice sewer use bylaw enforcement. Eldoret has 3 inspectors, 3 lab staff, and 1 labourer dedicated to this task. The lab also monitors BOD and other parameters at the conventional treatment plant. Nakuru was supposed to start a new bylaw enforcement programme with the completion of the new treatment works. A total of 8 positions were proposed but information on the actual status of this programme is unavailable.

2.3.4 Human Resources and Skills

Although most facilities have good caretakers there is sadly a lack of trained operators at most treatment works. Controlling what is happening throughout the process is particularly important at conventional treatment works because they require constant monitoring of process parameters to and adjustments to obtain improved efficiencies. Process monitoring, control and flow measurement is non-existent in most locations. Only the lab in Nakuru is well equipped and adequately staffed by well-trained people. The lab in Eldoret is in poor condition and lacks the equipment required for basic sampling and analysis.

No information is available on the level of workmanship practised by skilled trades such as mechanics and electricians. As a general observation it can be said that most mechanical and electrical equipment is in serious disrepair. A lack of skilled staff in most municipalities rather than poor workmanship is the more likely cause. In many cases equipment is just too old to maintain and spare parts are difficult to locate. In most municipalities inadequate funding creates a problem in shortages of spare parts and supplies for maintaining operations.

2.3.5 Operation and Maintenance Practices

There is very little information available on operation and maintenance (O&M) practices. O&M practices vary widely from one urban centre to the next depending on the level of funding available, management, and staffing. From the survey of various treatment works and discussions with maintenance staff it is possible to make the following general observations:

(1) Sewer blockages are frequent especially since many sewers seem to be too small to handle the flow. Blockages tend to be addressed as quickly as possible when they inconvenience the public. Sewers are usually unblocked using rodding machines and cutting tools. Sewer inspection and preventive maintenance such as regular cleaning is to our knowledge never carried out so the general condition of sewers is unknown to the operators. Most municipalities are not well equipped for sewer maintenance and lack the basic equipment for cleaning and flushing sewers, removing silt and grease.

(2) Basic maintenance at waste stabilisation ponds consists of grass cutting, removing screenings, removing grit, removing floating scum and weeds, and occasionally de-sludging. Although the level of maintenance varies from facility to facility poor maintenance practices were observed in almost every case. Simple grass cutting along the embankments is not practised regularly. Goats and cattle are allowed to trample the embankments. Scum and weeds in facultative ponds are almost never removed. Screens, where they exist are cleaned regularly but the debris is usually not disposed of and remains piled up on the side of the inlet facility. Sedimentation channels that were found at most facilities were inoperative because the grit and sand had not been removed.

2.3.6 Expenditure and Financial Resources for Operation and Maintenance

In most local authorities there is in general a serious lack of revenue to support the on-going operation and maintenance of sewerage infrastructure. At present, 38 schemes in 30 urban centres are operated by LAs under MOLA's supervision. The financial performance of these schemes during 1995, 196 and 1997 was surveyed by the study team. Of the 30 schemes, 15 yielded the necessary data and these results are discussed in section 4.2 of the institutional supporting report. According to the data, only two schemes have given a reasonable contribution to asset management having spent a significant amount on O&M: Athi river and Nyeri.

Generally, the financial performance of sewerage schemes varies considerably depending on the success of the water supply system and the cost of O&M which varies according to the type of technology used for treatment. Some schemes such as Kericho, Nyeri and Athi river appear to more than cover the costs of operation and maintenance; others such as Mombasa are reported to be making large losses with little hope of becoming financially viable under current conditions. Few, if any, are yet financially viable in being able to recover the costs of O&M, depreciation and a contribution to reserves.

The sewerage charge is normally a surcharge on the water supply charge. The sewer surcharge is normally set as a percentage of the water tariff (usually 50%) regardless of the actual cost of providing the services. At present, progressively less revenue is collected to pay for sewerage as more people become dissatisfied with the water supply services in some municipalities. The viability of providing sewerage operations is very largely dependent on the good management of the water supply system and the extent to which water can be delivered to satisfied consumers who will pay their water bills (and therefore sewerage charges). The sewer surcharge is not easy to implement where the water undertaker is under different management. In at least 3 towns, (Meru, Kisii, Muranga) significant amounts of money have not been transferred from the water undertaker (MWR) to the LA. The same is apparently true of NWCPV (GTZ report on 12 towns, 1995, UWASAM) which usually collects the sewer surcharge on behalf of the LA when it is the water undertaker.

This explains why twelve municipalities surveyed by GTZ in 1995 indicated an interest in becoming water undertakers:

1) In order to have sustainable management of sewerage schemes it is imperative that they control the water supply system as well.
2) They were experiencing difficulties in getting the funding for expansion of the sewerage systems because most financiers would like water and sewerage issues to be planned together.

2.4 Summary of the Major Issues

The population is growing at an alarming rate exerting pressure on existing water and sewage infrastructure and the environment. Currently most people living in urban centres (about 85%) have access to potable water supplies but only 28% have the benefit of waterborne sewage disposal. This means many people are discharging wastewater into the environment.

The need for sewerage development is great but development has been very slow over the last decade. Extensive work will be required to extend and develop sewer reticulation to service the growing urban population. Most sewerage facilities have fallen into a serious state of disrepair and a tremendous effort and resources will be required to improve the efficiency and effectiveness of sewage treatment works to prevent health risks and environmental contamination. Major constraints to the sustainable development and operation of sewerage projects include:

(1) Lack of information for planning

Much of the basic information required for proper planning is unavailable. Good records and statistics are required for good planning. Examples of the information required to support sewerage planning and operation are:

1) location, quantity of discharges into water resources
2) regular water quality monitoring, linked to flow records
3) the size and characteristics for urban centres such as population densities and land use
4) the number of contributors
5) the sewage inflow to each public sewage treatment works
6) the operating efficiencies of sewage treatment works
7) an inventory of important industrial effluent discharges and treatment plants
8) the quality and quantity of industrial effluents

Once the data is collected it must be studied to identify trends in pollution for example and to identify potential priority areas. Investigation is required into how the effluent from treatment works and industry affects receiving streams, and to determine appropriate treatment design criteria and standards for effluent discharges.

(2) Insufficient operating revenue to support operation and maintenance

Low revenue contributes to inadequate budgets for operation and maintenance. Insufficient revenue is the principal cause for the serious state of disrepair in most sewerage systems. Low revenue is the result of: i) unaccounted for water due to unmetered consumption; ii) customers unwilling to pay because service levels are inadequate e.g. water rationing; iii) revenue billing and collection that is not well managed; iv) sewer surcharges that are collected by water undertakers but not remitted to sewerage operating authority; v) revenue collected for sewer services that are used to finance other municipal priorities; and vi) tariffs that are too low and do not represent the true cost of providing services.

(3) Facilities difficult to operate and maintain

There is no national standard for the planning and design of sewerage systems. Since most of the infrastructure is funded through donor agencies, foreign consultants carry out much of the planning and design. This has resulted in a wide variety of methods and designs often leading to the selection of inappropriate technology unsuitable for local conditions, difficult and expensive to operate and maintain.

(4) Insufficient water supply for sewer operations

The separation between the operation of sewerage and water services has lead to a serious lack of cooperation to planning and problem solving. In several cases, conventional sewerage is provided in areas where individual water consumption is too low for proper operation resulting in blocking and in some cases complete failure.

In other cases, water supply systems that were once adequate have deteriorated to the point where water rationing is required. This also results in low wastewater flows and eventually sewage system failures.

(5) Shortage of trained personnel

There is a serious shortage of trained personnel at every level from engineers, to sewerage system operators and sewer maintenance staff and skilled trades people. The implementation of a sewerage development programme will result in many more sewerage treatment plants and kilometres of sewers to be maintained. Without sufficient quantity of qualified people future investments in infrastructure will not provide the intended benefits. Furthermore, without proper operation and maintenance new systems will quickly become dysfunctional and the government will once again be saddled with the financial burden of paying the higher costs of replacing rather than the lower costs of maintaining existing infrastructure.

(6) Lack of tools and equipment

It is not enough to hire and train sufficient quantities of staff. This staff must be given the tools they need to do the job. At the present time, those responsible for sewage disposal services are badly handicapped by lack of transport, poor office facilities, and bad communications.

The situation is the direct result of inadequate operating revenue and can only be corrected by a concentrated effort to improve collection of revenue and subsequently increased spending for sewer operations.

(7) Inadequate preventive maintenance

There are two types of maintenance management: crisis and planned. In crisis management agencies perform repairs and maintenance primarily in response to emergencies. This is common in most systems encountered in Kenya because preventive maintenance is neglected. Crisis management is more costly in the long term because problems tend to get larger with time and eventually facilities must be replaced before their normal life expectancy.

(8) Ineffective control of industrial wastewater discharges

It is anticipated that in the future most industries will discharge their wastewater to public sewer systems instead of directly into the nation's waterways. These discharges may contain significant amounts of toxic pollutants and other substances that can affect the treatment systems and possibly interfere with its performance. Some pollutants may pass unchanged through the treatment process and into receiving streams. The pollutants may enter treatment plant sludge making its disposal difficult and re-use impossible.

If left uncontrolled, industrial pollution of water resources could lead to more costly water supply schemes (more treatment, clean source further away) and health problems with associated costs.

(9) Poor operation of sewerage works

Many treatment works and pumping stations are currently inoperative because mechanical and electrical components have failed or maintenance has been neglected for too long. Other systems are overloaded because the connected population has growth beyond the original design capacity. These two situations result in the disposal of sewage without adequate treatment and many operating problems.

Most other treatment works fail to meet effluent standards because there is a lack of process monitoring and control due largely to the lack of procedures and trained operators.