3.1.3 COMBINED OPERATION OF BUZA DAM WITH KIZINGA RIVER

The possibility of the Buza dam supplementing intake from the Kizinga river is simulated. The water from the dam is taken only when flow in the Kizinga river is below 2 mgd. The assumptions used are:
- calculation is done on monthly basis;
- maximum storage volume is 247,000 m^3
- water is taken from the Kizinga river when flow is more than 2 mgd
- when the flow in the Kizinga river is less than 2 mgd, only the deficit is supplemented from the dam.

The simulation results are listed in Table C.3.6 and the fluctuation in the amount of total water intaken, intake from the dam and dam volume are illustrated in Figure C.3.8. The combined system would fail to provide sufficient water for an intake of 2 mgd water in drought conditions, even if the dam is constructed. However, dam operation will improve the low intake possible presently during the dry season to some extent, as shown in Figure C.3.9.

The effect of the Buza Dam in combination with the existing water intake are summarized in Table C.3.7. Occurrences of intake falling short of the 2 mgd mark would decrease considerably, from 26% to 11.5%, and the average water intake quantity in the dry season, which is presently 1.1 mgd, would increase by 50 percent. Therefore, water intake for Mtoni is expected to improve considerably.

However, it should be stressed that rehabilitation of the Buza dam cannot be evaluated by its effect on Mtoni operation alone. It should be viewed from the overall scenario of increasing the total water supply for Dar-es-Salaam. Despite any rehabilitation on the Mtoni plant, its contribution to the water supply of DSM at its rated capacity of 2 mgd is only 3 %. Therefore, the feasibility of the Mtoni plant rehabilitation as well as the Buza dam should be determined from this overall context.

3.1.4 INFILTRATION GALLERY

The possible intake from infiltration galleries is difficult to gauge, since no information is available. Therefore, groundwater pumping tests should be performed. However, it may not be worthwhile conducting such a survey because a) the planned water intake failed soon after installation in the past,b) the catchment area is so small that high yield is not expected and c) use of groundwater in and near the area has already been discounted in previous studies.

3.2 ALTERNATIVE WATER SOURCES

Several studies have been conducted for expansion of the DSM water supply system to meet the expanding demand since the completion of the Mtoni system. Alternative water sources were investigated for the Mtoni plant as shown in Table C.3.8 These were not necessarily aimed at supplementing the supply shortage. Rather, they were aimed at expanding the treatment capacity. Each alternative, however, is reviewed in this study from the viewpoint of its feasibility in supplementing the supply shortage in the existing intake.

3.2.1 GROUNDWATER

As was mentioned in the "History of DSM Water Supply System", groundwater suffered from high salinity and hardness, both increasing with the quantity of water withdrawn. In fact, availability of groundwater is reported to be extremely low inside a radius of 50 to 80 kms from Dar-es-Salaam, and within a depth of 3,000 to 4,000 feet.

Considering this and that there is a history of abandoning shallow wells, groundwater cannot be expected to supplement intake water for Mtoni.

3.2.2 DIVERSION FROM MSIMBAZI RIVER TO KIZINGA

The report in 1967 mentioned the idea of pumping a certain portion of water in the Msimbazi river, located next to the Kizinga river, through the City, to supplement dry season flow of the Kizinga. The report, however, discounted the possibility of this because of the following reasons:
- silting of the aqueduct
- opposition from cultivators downstream in the Msimbazi
- worsening the foul condition in the Msimbazi.

3.2.3 DAM CONSTRUCTION ON KIZINGA AND MZINGA RIVERS

Both dams were studied as water sources for the new water works planned at Mbagala. One study concluded that it was a feasible idea. The study also conducted topographical survey and boring tests.

-Kizinga Dam (see Figure C.3.10)

Location	: 5 km upstream of the existing intake
Type	: Earth-fill dam
Storage	: 15,900,000 m^3 (3,500 million gallon)
Planned Supply	: 21,600 m^3/day (4.75 mgd)
Initial Cost	: Pound Sterling 941,000 (1967 price)

-Mzinga Dam (see Figure C.3.11)

Location	: 6 km upstream of the Mbagala bridge

Type	: Earth-fill dam
Storage	: 33,600,000 m³ (7,400 million gallon)
Planned Supply	: 45,500 m³/day (10 mgd)
Initial Cost	: Pound Sterling 2,422,000 (1967 price)

The other study followed up and reviewed the above study with additional hydrological data, and the modifications made on the Mzinga dam to increase storage and planned supply as follows:

-Mzinga Dam

Location	: 6 km upstream of the Mbagala bridge
Type	: Earth-fill dam
Storage	: 43,200,000 m³ (9,500 million gallon)
Planned Supply	: 77,300 m³/day (17 mgd)
Initial Cost	: Shs.48,440,000 (1970 price)

In conclusion, when constructed, both dams individually has more than sufficient water available for the existing Mtoni plant. However, construction of the dam(s) is not recommended at the present time, unless it proves attractive in comparison with other alternatives such as the Ruvu river or Wami river development. The construction costs are particularly high, if it is only to supplement the existing operation at Mtoni. The construction should be considered in relation to other expansion schemes of the water supply system.

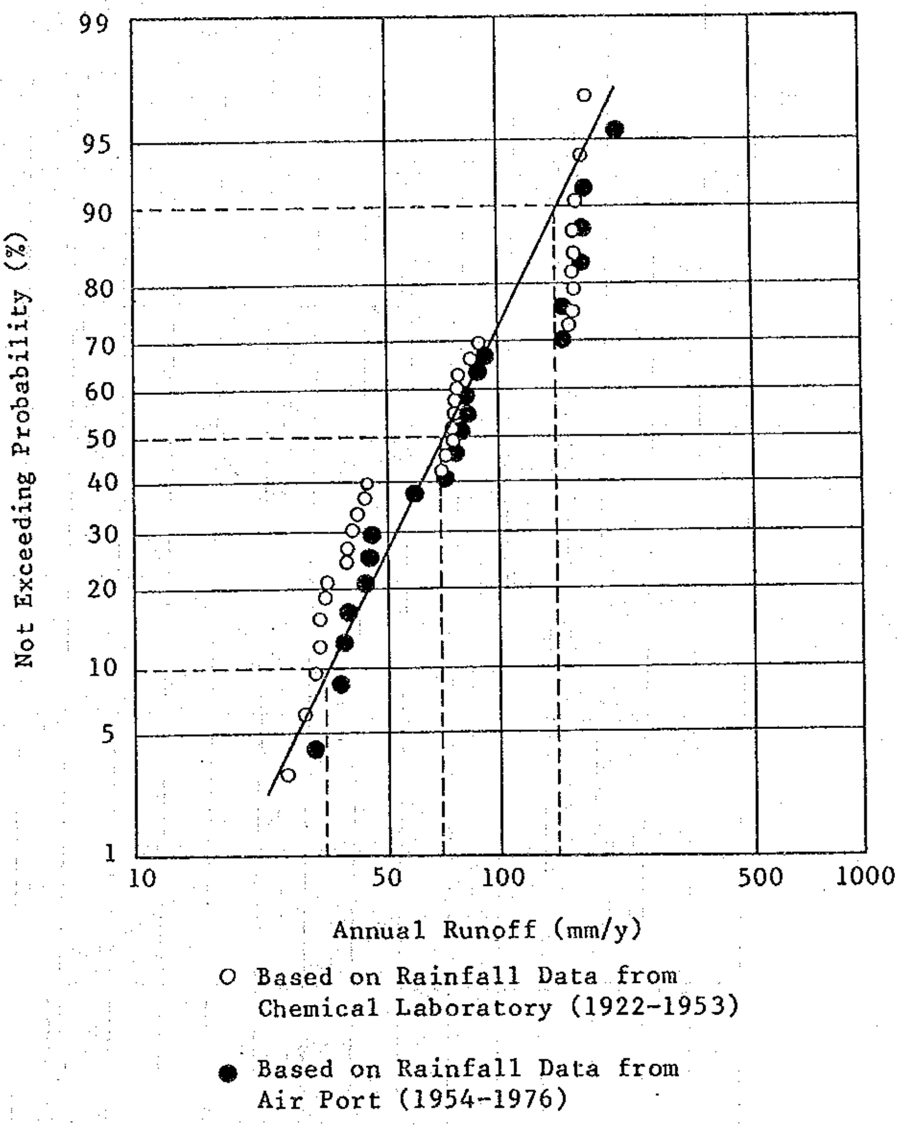

FIG. C.3.1	PROBABILITY OF ANNUAL RUNOFF

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

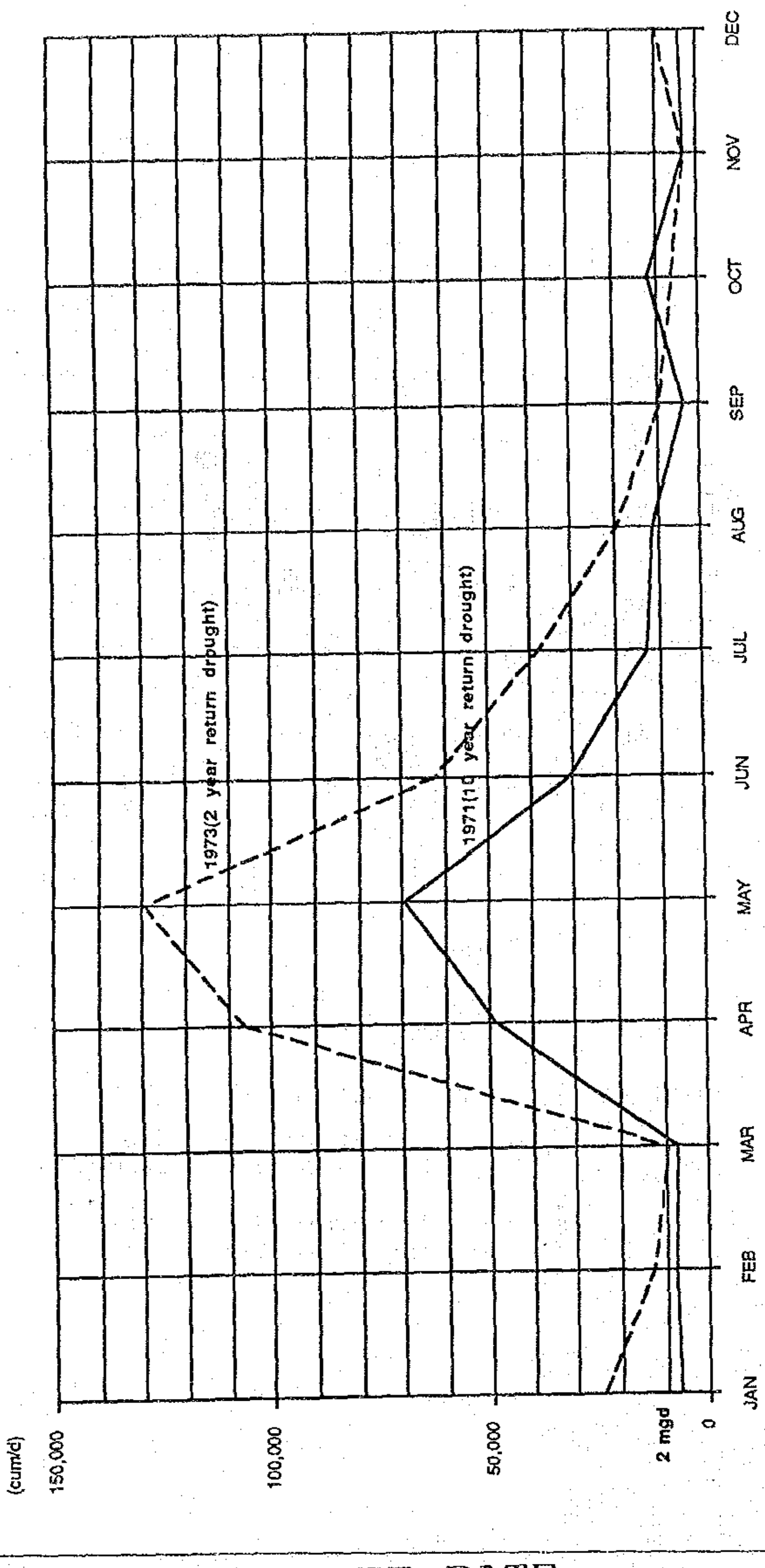

FIG. C.3.2	MONTHLY RUNOFF RATE OF KIZINGA RIVER

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

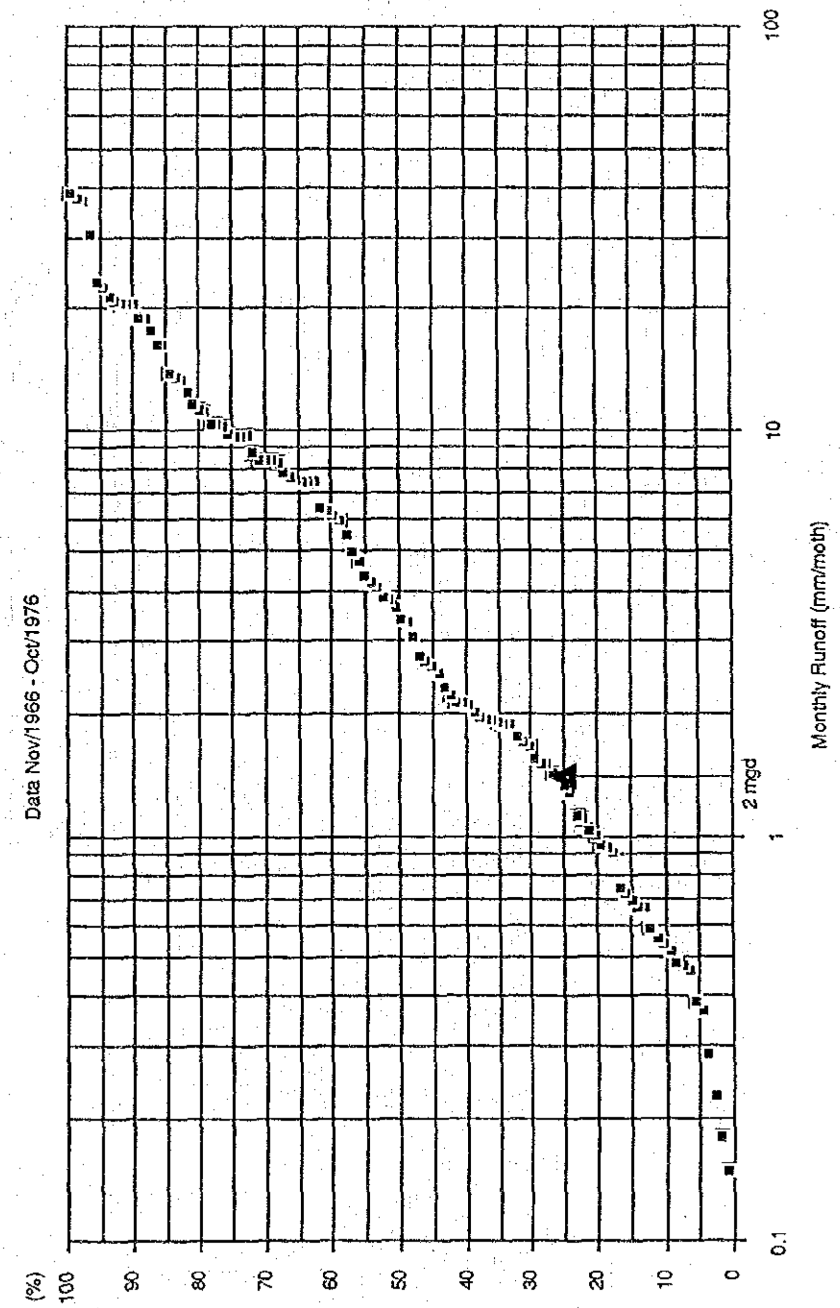

FIG. C.3.3 CUMULATIVE PROBABILITY FOR KIZINGA RIVER MONTHLY RUNOFF

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

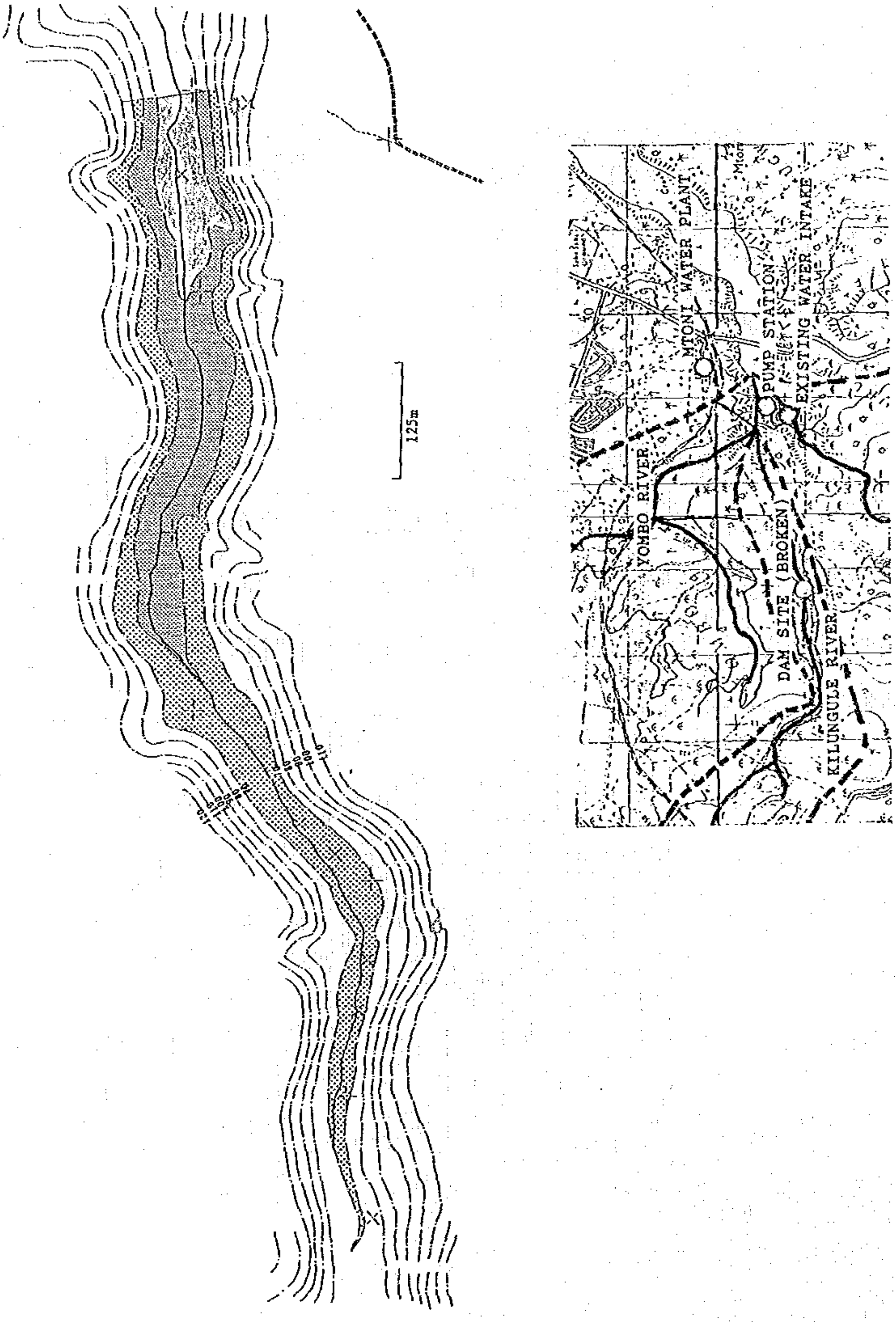

FIG. C.3.4	KILUNGULE DAM FLOOD AREA

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

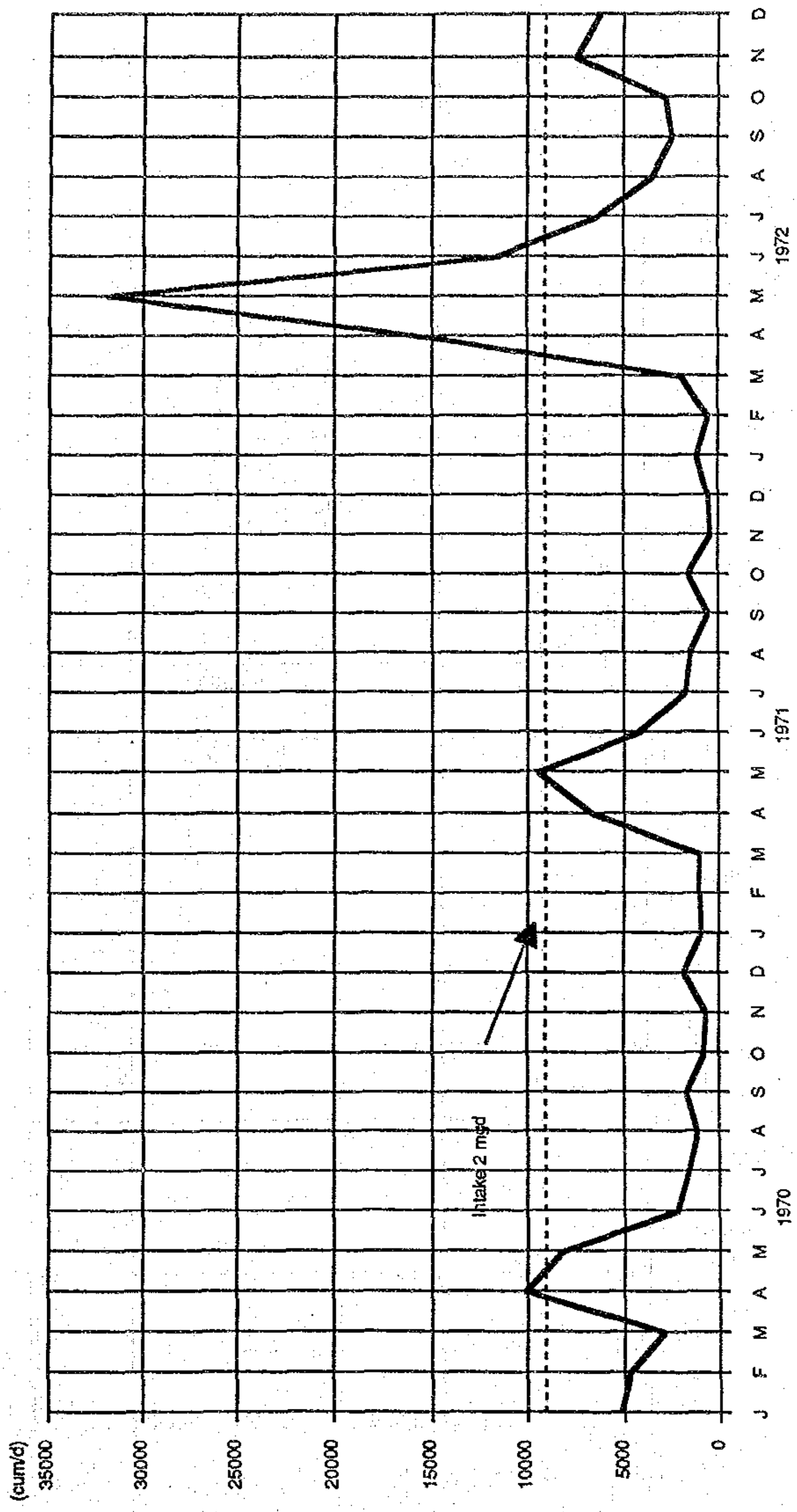

FIG. C.3.5	FLOW RATE OF KILUNGULE RIVER

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

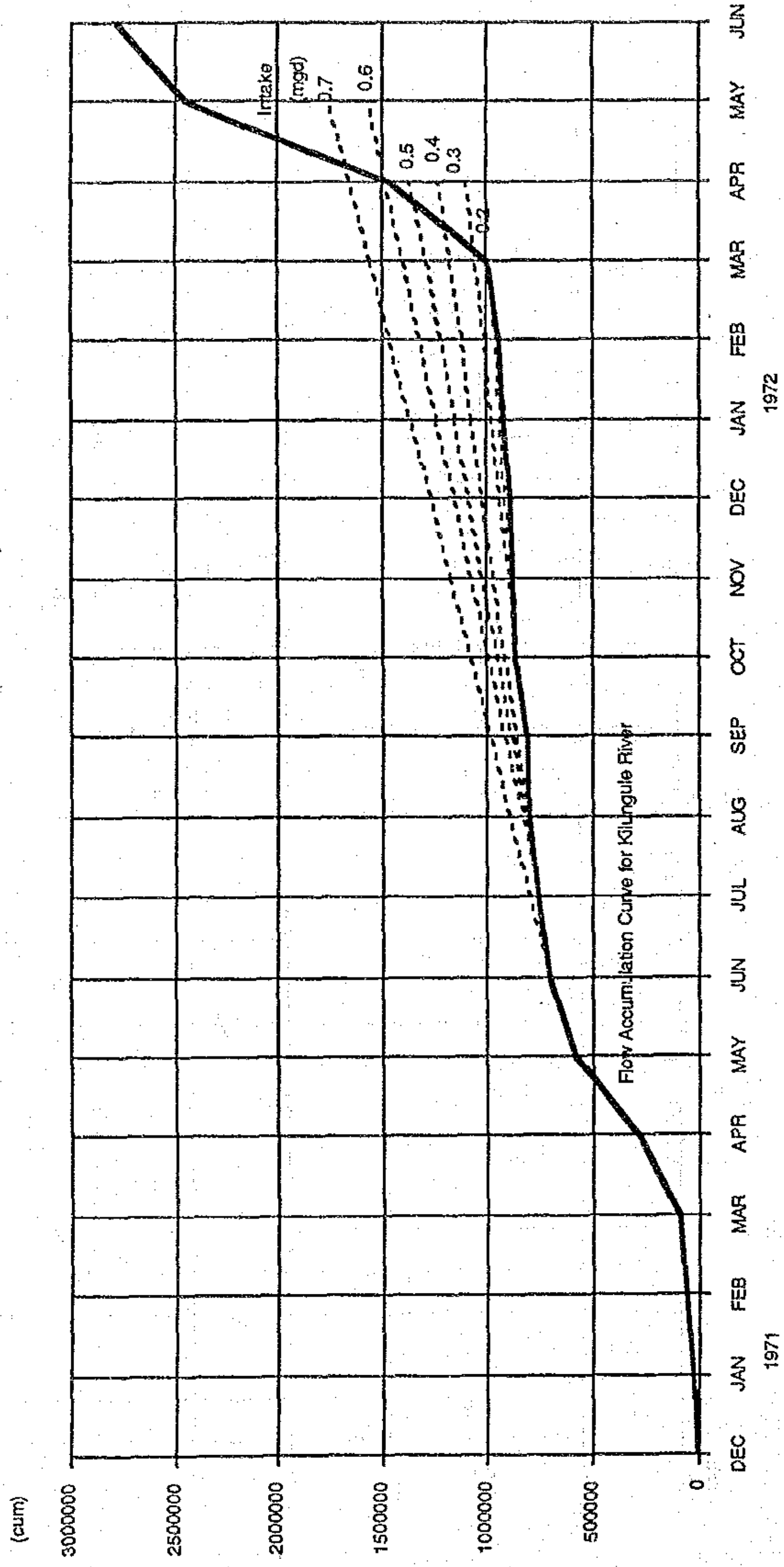

FIG. C.3.6 FLOW ACCUMULATION DIAGRAM FOR KILUNGULE DAM

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

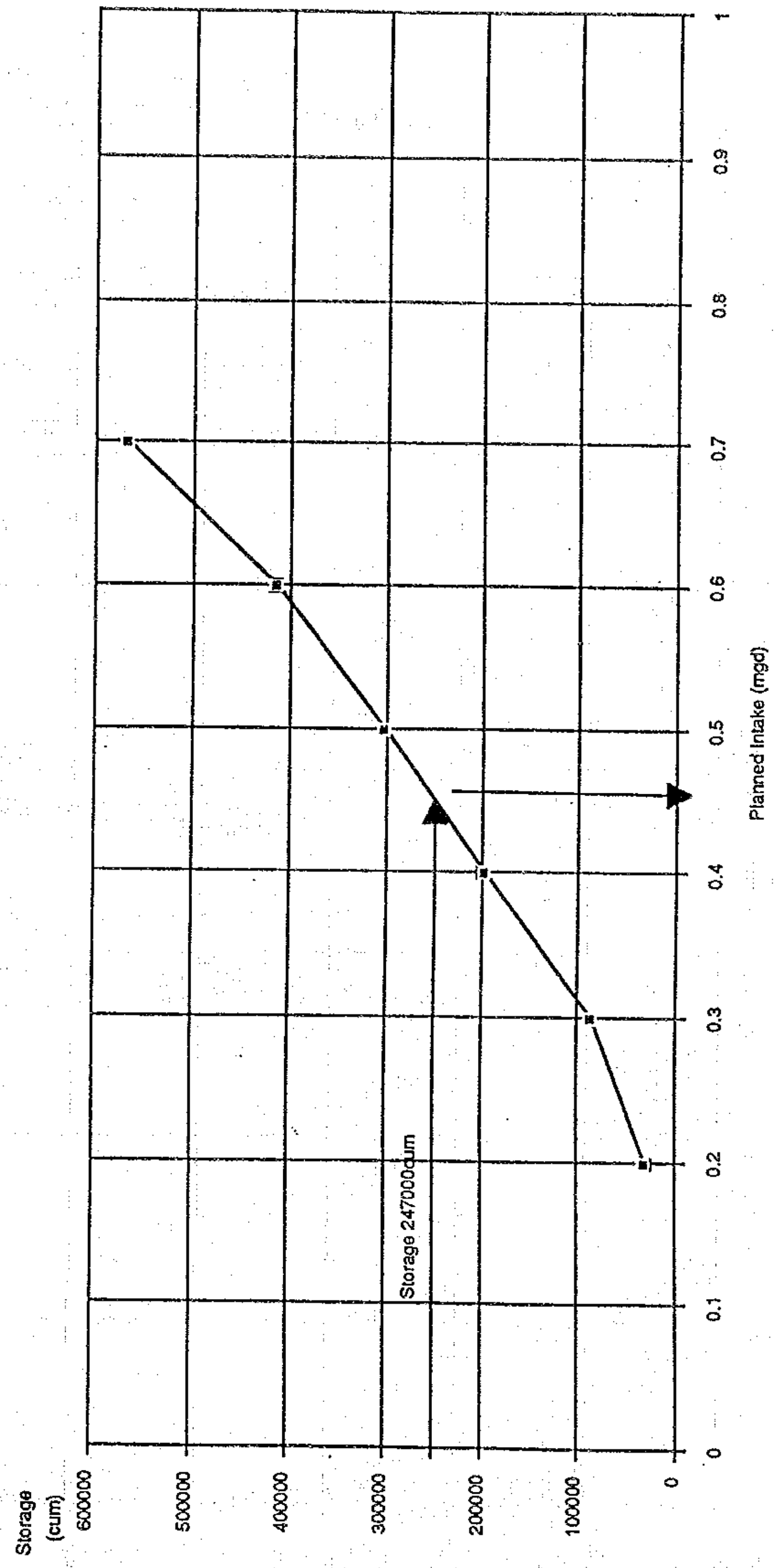

FIG. C.3.7	PLANNED INTAKE AND STORAGE VOLUME FOR KILUNGULE DAM

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

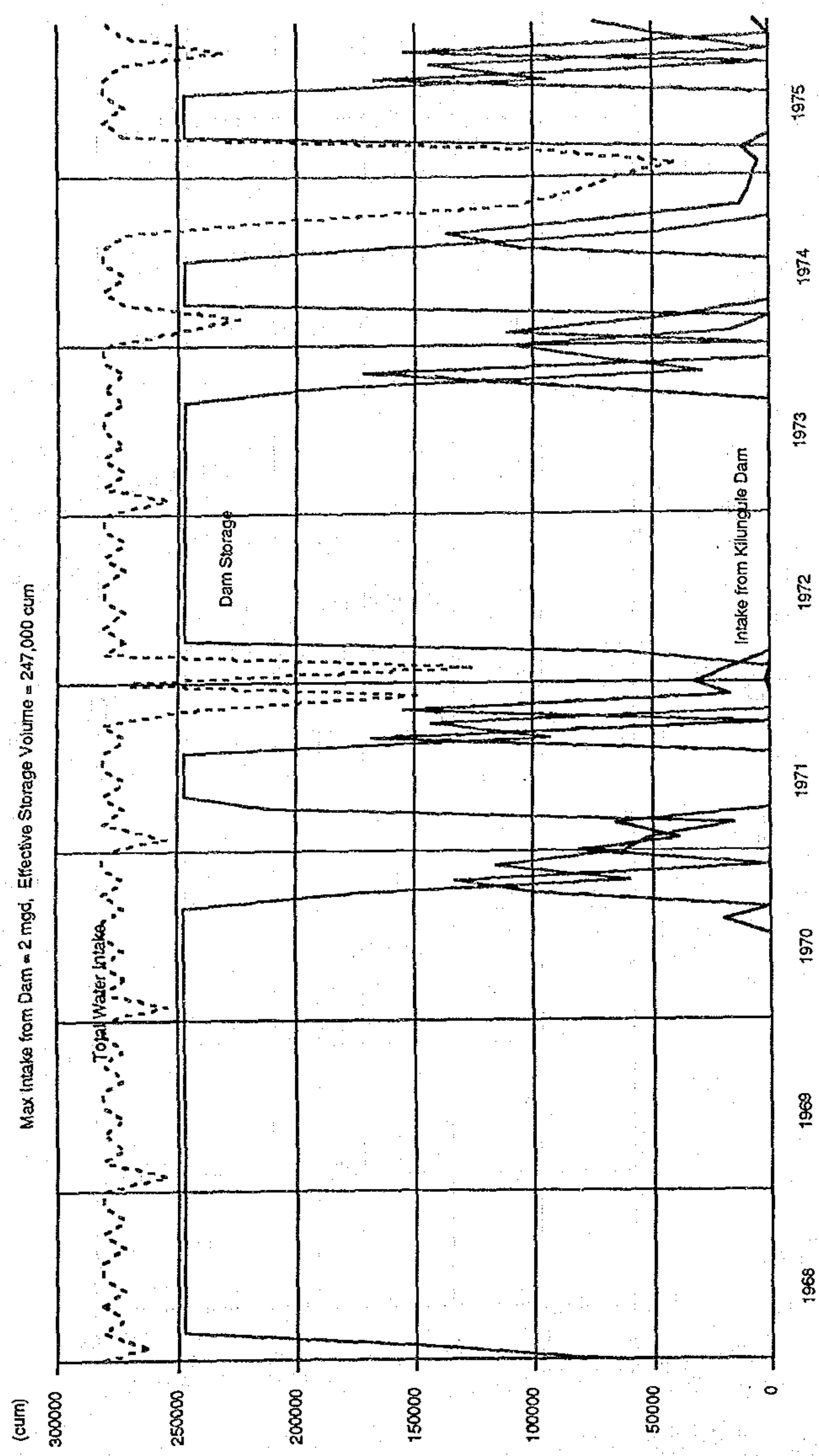

FIG. C.3.8	SIMULATION OF WATER INTAKE AND STORAGE OF DAM

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

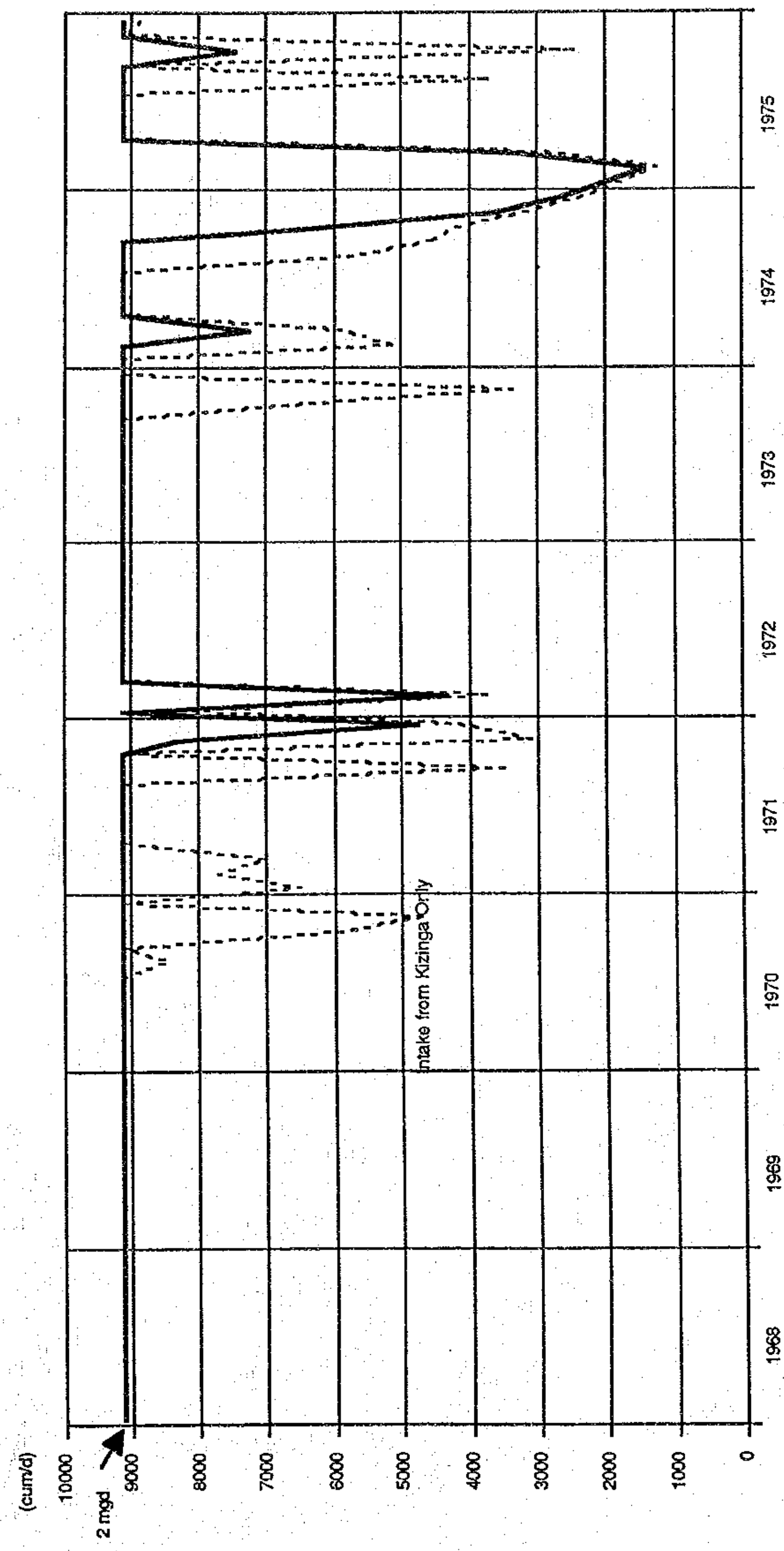

FIG. C.3.9	POSSIBLE MONTHLY WATER INTAKE BY DAM OPERATION

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

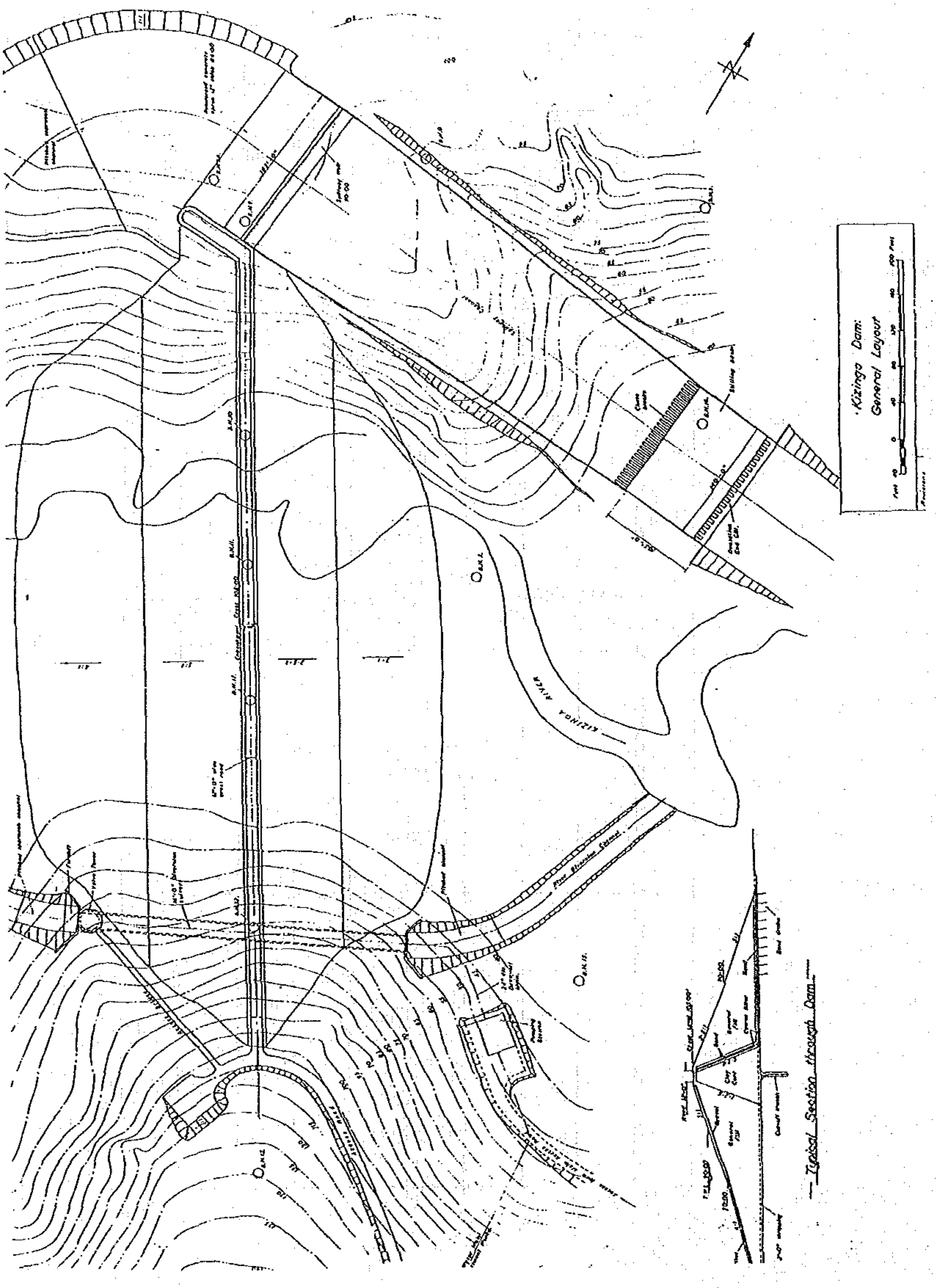

FIG. C.3.10 KIZINGA DAM GENERAL LAYOUT

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

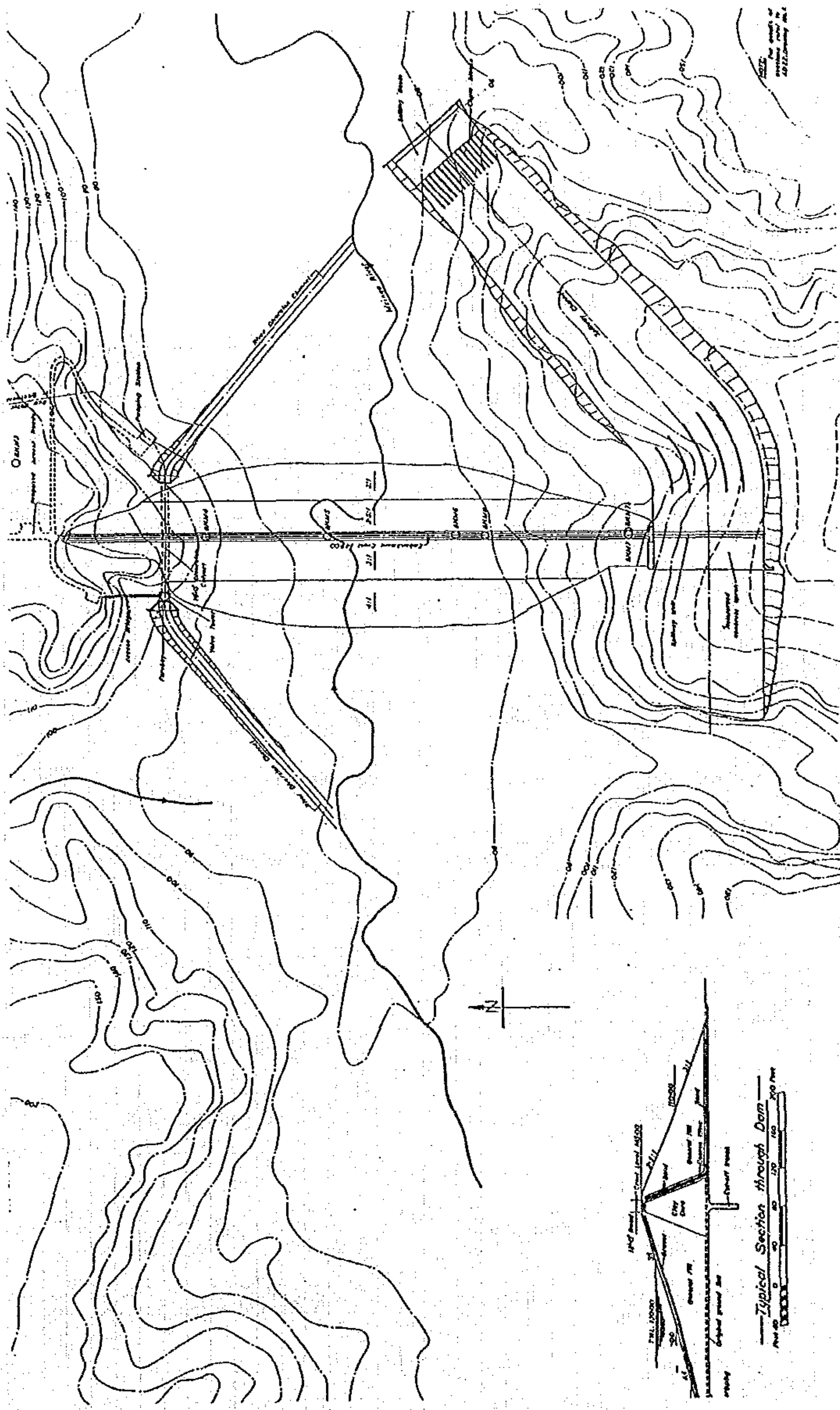

FIG. C.3.11 MZINGA DAM GENERAL LAYOUT

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

TABLE- C.3.1 RAINFALL AND RUNOFF DATA FOR KIZINGA RIVER by REPORT 5)

(mm/month)

Year	1967/1968			1968/1969			1969/1970			1970/1971			1971/1972		
Month	Rainfall	Actual Runoff	Generated Runoff	Rainfall	Actual Runoff	Generated Runoff	Rainfall	Actual Runoff	Generated Runoff	Rainfall	Actual Runoff	Generated Runoff	Rainfall	Actual Runoff	Generated Runoff
NOV	183	8.79	14.60	307	19.11	17.56	156	7.71	7.71	13	0.72	0.00	8	0.48	0.00
DEC	155	13.42	18.23	119	21.01	24.03	56	7.54	7.54	175	2.12	2.61	77	0.67	0.42
JAN	11	2.77	9.10	59	8.48	9.25	77	6.14	6.14	60	1.04	4.33	63	1.29	2.80
FEB	104	2.63	5.96	108	8.34	9.08	28	5.05	5.05	49	1.11	1.37	51	0.56	2.90
MAR	257	23.38	20.15	177	16.40	16.48	109	3.44	3.44	129	1.12	3.37	122	2.32	5.84
APR	337	38.81	35.48	274	20.53	27.51	176	11.55	11.55	149	7.52	7.04	328	17.86	17.83
MAY	156	30.92	33.35	185	37.36	30.93	70	9.71	9.71	139	11.15	8.22	366	37.92	30.12
JUN	49	21.51	16.91	16	19.08	17.06	1	2.52	2.52	54	4.76	5.92	0	13.25	18.21
JUL	2	10.35	8.68	22	12.37	7.65	18	1.94	1.94	17	2.03	2.96	31	7.47	2.97
AUG	9	6.37	4.78	47	9.76	7.87	2	1.35	1.35	13	1.77	1.19	8	4.07	2.51
SEP	19	4.18	3.81	18	6.44	6.08	72	1.95	1.95	6	0.54	0.04	37	2.72	1.10
OCT	51	3.81	4.15	13	4.36	2.23	22	0.95	0.95	32	1.91	0.00	98	3.35	3.30
Total	1333	166.94	175.20	1345	183.24	175.73	787	59.85	59.85	836	35.79	37.05	1189	91.96	88.00

Year	1972/1973			1973/1974			1974/1975			1975/1976		
Month	Rainfall	Actual Runoff	Generated Runoff	Rainfall	Actual Runoff	Generated Runoff	Rainfall	Actual Runoff	Generated Runoff	Rainfall	Actual Runoff	Generated Runoff
NOV	149	8.47	7.18	10	0.52	0.00	5	0.49	0.25	55	1.67	0.00
DEC	109	7.45	8.09	114	1.56	0.00	11	0.37	3.47	101	1.42	1.12
JAN	66	3.86	4.38	115	1.52	0.00	46	0.29	3.46	51	0.23	3.89
FEB	43	1.89	2.38	3	0.74	0.19	15	0.18	1.95	50	0.15	1.85
MAR	122	1.52	5.01	119	0.94	3.18	162	0.47	7.77	194	5.51	1.85
APR	382	16.42	19.83	282	9.77	12.06	327	11.28	17.78	237	13.95	9.82
MAY	64	20.73	21.43	97	10.36	16.31	274	20.62	18.65	169	22.59	10.98
JUN	65	9.67	6.72	24	2.15	8.78	14	7.91	11.89	74	10.30	4.05
JUL	9	6.02	5.15	52	2.22	1.63	8	1.72	8.00	75	8.40	2.93
AUG	45	3.11	2.87	1	0.92	0.85	9	0.59	4.42	5	3.66	1.90
SEP	3	1.44	1.54	13	0.70	1.50	74	1.90	0.00	6	1.97	0.00
OCT	23	1.01	0.00	37	0.67	1.29	23	0.39	0.00	19	2.15	0.00
Total	1080	81.59	84.58	867	32.07	45.79	968	46.21	77.64	1036	72.00	38.39

Table- C.3.2 Annual Runoff

Based on the generated monthly runoff data for the Kizinga River between 1923 to 1976 by Report (5).

Year	Generated Runoff (mm/y)
1922	44.19
1923	26.42
1924	34.02
1925	33.50
1926	164.47
1927	38.18
1928	168.34
1929	41.28
1930	89.18
1931	79.83
1932	162.87
1933	31.91
1934	75.37
1935	85.57
1936	172.17
1937	75.42
1938	78.81
1939	160.44
1940	161.05
1941	32.33
1942	163.86
1943	163.03
1944	78.72
1945	71.98
1946	39.46
1947	175.75
1948	76.45
1949	29.04
1950	38.55
1951	42.87
1952	32.19
1953	71.71
1954	174.14
1955	44.86
1956	43.81
1957	75.79
1958	82.45
1959	37.91
1960	154.03
1961	70.22
1962	216.64
1963	92.59
1964	167.93
1965	31.12
1966	151.94
1967	51.97
1968	175.20
1969	175.73
1970	59.85
1971	37.05
1972	88.00
1973	84.58
1974	45.79
1975	77.64
1976	38.39

Table- C.3.3 Monthly Runoff for Kizinga

Month	RUNOFF (mm/month)							
	1968	1969	1970	1971	1972	1973	1974	1975
JAN	2.77	8.48	6.14	1.04	1.29	3.86	1.52	0.29
FEB	2.63	8.34	5.05	1.11	0.56	1.89	0.74	0.18
MAR	23.38	16.40	3.44	1.12	2.32	1.52	0.94	0.47
APR	38.81	20.53	11.55	7.52	17.86	16.42	9.77	11.28
MAY	30.92	37.36	9.71	11.15	37.92	20.73	10.36	20.62
JUN	21.51	19.08	2.52	4.76	13.25	9.67	2.15	7.91
JUL	10.35	12.37	1.94	2.03	7.47	6.02	2.22	1.72
AUG	6.37	9.76	1.35	1.77	4.07	3.11	0.92	0.59
SEP	4.18	6.44	1.95	0.54	2.72	1.44	0.70	1.90
OCT	3.81	4.36	0.95	1.91	3.35	1.01	0.67	0.39
NOV	19.11	7.71	0.72	0.48	8.47	0.52	0.49	1.67
DEC	21.01	7.54	2.12	0.67	7.45	1.56	0.37	1.42
Total	184.85	158.37	47.44	34.10	106.73	67.75	30.85	48.44
Max	38.81	37.36	11.55	11.15	37.92	20.73	10.36	20.62
Min	2.63	4.36	0.72	0.48	0.56	0.52	0.37	0.18
Ave	15.40	13.20	3.95	2.84	8.89	5.65	2.57	4.04

Table- C.3.4 Monthly Flow Rate of Kizinga River

Catchment Area = 194 sqkm

Month	Flow Rate (cum/day)							
	1968	1969	1970	1971	1972	1973	1974	1975
JAN	17,335	53,068	38,425	6,508	8,073	24,156	9,512	1,815
FEB	17,594	57,784	34,989	7,691	3,746	13,095	5,127	1,247
MAR	146,314	102,632	21,528	7,009	14,519	9,512	5,883	2,941
APR	250,971	132,761	74,690	48,629	115,495	106,183	63,179	72,944
MAY	193,499	233,801	60,766	69,777	237,306	129,730	64,834	129,041
JUN	139,098	123,384	16,296	30,781	85,683	62,533	13,903	51,151
JUL	64,771	77,412	12,141	12,704	46,748	37,674	13,893	10,764
AUG	39,864	61,079	8,448	11,077	25,470	19,463	5,757	3,692
SEP	27,031	41,645	12,610	3,492	17,589	9,312	4,527	12,287
OCT	23,843	27,285	5,945	11,959	20,965	6,321	4,193	2,441
NOV	123,578	49,858	4,656	3,104	54,773	3,363	3,169	10,799
DEC	131,482	47,186	13,267	4,193	46,623	9,763	2,315	8,886
Total	1,175,380	1,007,896	303,761	216,919	676,989	431,102	196,292	308,009
Max	250,971	233,801	74,690	69,777	237,306	129,730	64,834	129,041
Min	17,335	27,285	4,656	3,104	3,746	3,363	2,315	1,247
Ave	97,948	83,991	25,313	18,077	56,416	35,925	16,358	25,667

TABLE C.3.5 Monthly Flow Rate for Kilungule River

Assuming same runoff pattern as Kizinga's . Catchment area at dam site = 26 sqkm

Month	RUNOFF (cum/month)							
	1968	1969	1970	1971	1972	1973	1974	1975
JAN	72,020	220,480	159,640	27,040	33,540	100,360	39,520	7,540
FEB	68,380	216,840	131,300	28,860	14,560	49,140	19,240	4,680
MAR	607,880	426,400	89,440	29,120	60,320	39,520	24,440	12,220
APR	1,009,060	533,780	300,300	195,520	464,360	426,920	254,020	293,280
MAY	803,920	971,360	252,460	289,900	985,920	538,980	269,360	536,120
JUN	559,260	496,080	65,520	123,760	344,500	251,420	55,900	205,660
JUL	269,100	321,620	50,440	52,780	194,220	156,520	57,720	44,720
AUG	165,620	253,760	35,100	46,020	105,820	80,860	23,920	15,340
SEP	108,680	167,440	50,700	14,040	70,720	37,440	18,200	49,400
OCT	99,060	113,360	24,700	49,660	87,100	26,260	17,420	10,140
NOV	496,860	200,460	18,720	12,480	220,220	13,520	12,740	43,420
DEC	546,260	196,040	55,120	17,420	193,700	40,560	9,620	36,920
Total	4,806,100	4,117,620	1,233,440	886,600	2,774,980	1,761,500	802,100	1,259,440
Max	1,009,060	971,360	300,300	289,900	985,920	538,980	269,360	536,120
Min	68,380	113,360	18,720	12,480	14,560	13,520	9,620	4,680
Ave	400,508	343,135	102,787	73,883	231,248	146,792	66,842	104,953

Table- C.3.6 Simulation of Water Intake and Kilugule Dam Storage

planned intake = 2.00 mgd (9092 cum)

Year	Mon	Required Intake(2mgd)	Monthly River Runoff(cum/m)			Water Intake (cum/m)			Dam Storage Volume (cum)
			Kizinga	Kilungule	Total	Kizinga	Kilungule Dam	Total	
1968	JAN	281,852	537,380	72,020	609,400	281,852	0	281,852	72,020
	FEB	263,668	510,220	68,380	578,600	263,668	0	263,668	140,400
	MAR	281,852	4,535,720	607,880	5,143,600	281,852	0	281,852	247,000
	APR	272,760	7,529,140	1,009,060	8,538,200	272,760	0	272,760	247,000
	MAY	281,852	5,998,480	803,920	6,802,400	281,852	0	281,852	247,000
	JUN	272,760	4,172,940	559,260	4,732,200	272,760	0	272,760	247,000
	JUL	281,852	2,007,900	269,100	2,277,000	281,852	0	281,852	247,000
	AUG	281,852	1,235,780	165,620	1,401,400	281,852	0	281,852	247,000
	SEP	272,760	810,920	108,680	919,600	272,760	0	272,760	247,000
	OCT	281,852	739,140	99,060	838,200	281,852	0	281,852	247,000
	NOV	272,760	3,707,340	496,860	4,204,200	272,760	0	272,760	247,000
	DEC	281,852	4,075,940	546,260	4,622,200	281,852	0	281,852	247,000
1969	JAN	281,852	1,645,120	220,480	1,865,600	281,852	0	281,852	247,000
	FEB	254,576	1,617,960	216,840	1,834,800	254,576	0	254,576	247,000
	MAR	281,852	3,181,600	426,400	3,608,000	281,852	0	281,852	247,000
	APR	272,760	3,982,820	533,780	4,516,600	272,760	0	272,760	247,000
	MAY	281,852	7,247,840	971,360	8,219,200	281,852	0	281,852	247,000
	JUN	272,760	3,701,520	496,080	4,197,600	272,760	0	272,760	247,000
	JUL	281,852	2,399,780	321,620	2,721,400	281,852	0	281,852	247,000
	AUG	281,852	1,893,440	253,760	2,147,200	281,852	0	281,852	247,000
	SEP	272,760	1,249,360	167,440	1,416,800	272,760	0	272,760	247,000
	OCT	281,852	845,840	113,360	959,200	281,852	0	281,852	247,000
	NOV	272,760	1,495,740	200,460	1,696,200	272,760	0	272,760	247,000
	DEC	281,852	1,462,760	196,040	1,658,800	281,852	0	281,852	247,000
1970	JAN	281,852	1,191,160	159,640	1,350,800	281,852	0	281,852	247,000
	FEB	254,576	979,700	131,300	1,111,000	254,576	0	254,576	247,000
	MAR	281,852	667,360	89,440	756,800	281,852	0	281,852	247,000
	APR	272,760	2,240,700	300,300	2,541,000	272,760	0	272,760	247,000
	MAY	281,852	1,883,740	252,460	2,136,200	281,852	0	281,852	247,000
	JUN	272,760	488,880	65,520	554,400	272,760	0	272,760	247,000
	JUL	281,852	376,360	50,440	426,800	281,852	0	281,852	247,000
	AUG	281,852	261,900	35,100	297,000	261,900	19,952	281,852	247,000
	SEP	272,760	378,300	50,700	429,000	272,760	0	272,760	247,000
	OCT	281,852	184,300	24,700	209,000	184,300	97,552	281,852	174,148
	NOV	272,760	139,680	18,720	158,400	139,680	133,080	272,760	59,788
	DEC	281,852	411,280	55,120	466,400	281,852	0	281,852	114,908

(Continued)

Year	Mon	Required Intake(2mgd)	Monthly River Runoff(cum/m)			Water Intake (cum/m)			Dam Storage Volume (cum)
			Kizinga	Kilungule	Total	Kizinga	Kilungule Dam	Total	
1971	JAN	281,852	201,760	27,040	228,800	201,760	80,092	281,852	61,856
	FEB	254,576	215,340	28,860	244,200	215,340	39,236	254,576	51,480
	MAR	281,852	217,280	29,120	246,400	217,280	64,572	281,852	16,028
	APR	272,760	1,458,880	195,520	1,654,400	272,760	0	272,760	211,548
	MAY	281,852	2,163,100	289,900	2,453,000	281,852	0	281,852	247,000
	JUN	272,760	923,440	123,760	1,047,200	272,760	0	272,760	247,000
	JUL	281,852	393,820	52,780	446,600	281,852	0	281,852	247,000
	AUG	281,852	343,380	46,020	389,400	281,852	0	281,852	247,000
	SEP	272,760	104,760	14,040	118,800	104,760	168,000	272,760	93,040
	OCT	281,852	370,540	49,660	420,200	281,852	0	281,852	142,700
	NOV	272,760	93,120	12,480	105,600	93,120	155,180	248,300	0
	DEC	281,852	129,980	17,420	147,400	129,980	17,420	147,400	0
1972	JAN	281,852	250,260	33,540	283,800	250,260	31,592	281,852	1,948
	FEB	263,668	108,640	14,560	123,200	108,640	16,508	125,148	0
	MAR	281,852	450,080	60,320	510,400	281,852	0	281,852	60,320
	APR	272,760	3,464,840	464,360	3,929,200	272,760	0	272,760	247,000
	MAY	281,852	7,356,480	985,920	8,342,400	281,852	0	281,852	247,000
	JUN	272,760	2,570,500	344,500	2,915,000	272,760	0	272,760	247,000
	JUL	281,852	1,449,180	194,220	1,643,400	281,852	0	281,852	247,000
	AUG	281,852	789,580	105,820	895,400	281,852	0	281,852	247,000
	SEP	272,760	527,680	70,720	598,400	272,760	0	272,760	247,000
	OCT	281,852	649,900	87,100	737,000	281,852	0	281,852	247,000
	NOV	272,760	1,643,180	220,220	1,863,400	272,760	0	272,760	247,000
	DEC	281,852	1,445,300	193,700	1,639,000	281,852	0	281,852	247,000
1973	JAN	281,852	748,840	100,360	849,200	281,852	0	281,852	247,000
	FEB	254,576	366,660	49,140	415,800	254,576	0	254,576	247,000
	MAR	281,852	294,880	39,520	334,400	281,852	0	281,852	247,000
	APR	272,760	3,185,480	426,920	3,612,400	272,760	0	272,760	247,000
	MAY	281,852	4,021,620	538,980	4,560,600	281,852	0	281,852	247,000
	JUN	272,760	1,875,980	251,420	2,127,400	272,760	0	272,760	247,000
	JUL	281,852	1,167,880	156,520	1,324,400	281,852	0	281,852	247,000
	AUG	281,852	603,340	80,860	684,200	281,852	0	281,852	247,000
	SEP	272,760	279,360	37,440	316,800	272,760	0	272,760	247,000
	OCT	281,852	195,940	26,260	222,200	195,940	85,912	281,852	187,348
	NOV	272,760	100,880	13,520	114,400	100,880	171,880	272,760	28,988
	DEC	281,852	302,640	40,560	343,200	281,852	0	281,852	69,548

(Continued)

Year	Mon	Required Intake(2mgd)	Monthly River Runoff(cum/m)			Water Intake (cum/m)			Dam Storage Volume (cum)
			Kizinga	Kilungule	Total	Kizinga	Kilungule Dam	Total	
1974	JAN	281,852	294,880	39,520	334,400	281,852	0	281,852	109,068
	FEB	254,576	143,560	19,240	162,800	143,560	111,016	254,576	17,292
	MAR	281,852	182,360	24,440	206,800	182,360	41,732	224,092	0
	APR	272,760	1,895,380	254,020	2,149,400	272,760	0	272,760	247,000
	MAY	281,852	2,009,840	269,360	2,279,200	281,852	0	281,852	247,000
	JUN	272,760	417,100	55,900	473,000	272,760	0	272,760	247,000
	JUL	281,852	430,680	57,720	488,400	281,852	0	281,852	247,000
	AUG	281,852	178,480	23,920	202,400	178,480	103,372	281,852	167,548
	SEP	272,760	135,800	18,200	154,000	135,800	136,960	272,760	48,788
	OCT	281,852	129,980	17,420	147,400	129,980	66,208	196,188	0
	NOV	272,760	95,060	12,740	107,800	95,060	12,740	107,800	0
	DEC	281,852	71,780	9,620	81,400	71,780	9,620	81,400	0
1975	JAN	281,852	56,260	7,540	63,800	56,260	7,540	63,800	0
	FEB	254,576	34,920	4,680	39,600	34,920	4,680	39,600	0
	MAR	281,852	91,180	12,220	103,400	91,180	12,220	103,400	0
	APR	272,760	2,188,320	293,280	2,481,600	272,760	0	272,760	247,000
	MAY	281,852	4,000,280	536,120	4,536,400	281,852	0	281,852	247,000
	JUN	272,760	1,534,540	205,660	1,740,200	272,760	0	272,760	247,000
	JUL	281,852	333,680	44,720	378,400	281,852	0	281,852	247,000
	AUG	281,852	114,460	15,340	129,800	114,460	167,392	281,852	94,948
	SEP	272,760	368,600	49,400	418,000	272,760	0	272,760	144,348
	OCT	281,852	75,660	10,140	85,800	75,660	154,488	230,148	0
	NOV	272,760	323,980	43,420	367,400	272,760	0	272,760	43,420
	DEC	281,852	275,480	36,920	312,400	275,480	6,372	281,852	73,968

Table- C.3.7 Expected Effects of Kilungule dam

Based on the simulation from 1968 to 1975.

Effect	Existing Intake (only from Kizinga)	Intake from Kilungule Combination with the existing Intake
No. of months to fail to intake 2 mgd. (Probability)	25 (26.0 %)	11 (11.5 %)
Average intake whole period	7927 cum/d (1.74 mgd)	8585 cum/d (1.89 mgd)
Average intake in month to fail to intake 2mgd	4962 cum/d (1.10 mgd)	7509 cum/d (1.65 mgd)

TABLE C.3.8 ALTERNATIVE WATER SOURCES FOR MTONI TREATMENT PLANT

Source	Description	Conclusion
Underground Water	Deep well, Shallow well, Infiltration	Not available within a radius of 50 - 80 km from Dar es salaam and within depth of 3,000 - 4,000 feet
Diversion of Msimbasi water to Kizinga	A certain portion of water of Msimbasi is pumped to Kizinga to increase its flow in dry season.	Details of the idea is unknown, but diversion is concluded as not feasible because of a) silting of aqueduct b) possible opposition from cultivators c) worsen the foul condition of the river.
Kizinga Dam	New earth-fill dam construction on Kizinga river	Storage;3,500 mg (15,900,000 m^3) Possible water supply; 4.75mgd (21,600 m^3/day) Initial dam cost; 941,000 UK pounds (1967)
Mzinga Dam	New earth-fill dam construction on Mzinga river	- PLAN A - Storage;7,400 mg (33,600,000 m^3) Possible water supply; 10mgd (45,500 m^3/day) Initial dam cost; 2,422,000 UK pounds(1967) - PLAN B - Storage;9,500 mg (43,200,000 m^3) Possible water supply; 17mgd (77,300 m^3/day) Initial dam cost; 48,440,000 UK pounds(1970)

4. FIELD WORK UNDERTAKEN

4.1 GENERAL

4.1.1 PURPOSE

Before beginning any rehabilitation work, in order to get a better idea of the water system and to propose an optimum development plan, the following should be available:

- proper and correct inventory of pipes, valves, hydrants and interconnections.
- present condition of installed pipes and valves.
- proper estimation of water losses, right up to the consumer premises.
- regular and systematic field studies of flows and pressures at convenient points in the primary, secondary and tertiary distribution network.

Hence, the following field works were undertaken and are presented in the order shown below.

1. Water Pressure Measurement in order to grasp water service conditions throughout the city.
2. External condition of pipes, which has helped formulate the distribution pipe network rehabilitation plan
3. Internal condition of pipes, which has helped formulate the distribution pipe network rehabilitation plan
4. Leakage Measurement in Model Areas (including surface-level leakage) has become the basis for evaluation of the effectiveness of various leakage prevention measures and their financial feasibility.
5. Inventory of Distribution Pipe
6 Flow Measurement in Treatment Plants and Reservoirs in order to estimate
   1) the demand and leakage along the transmission pipes and
   2) net supply to the city.
7. Leakage Measurement in Transmission Pipe to estimate the amount of water removed (offtaken or leaked out) in the transmission pipeline
8. Flow Measurement in Distribution Pipe
9. Determination of Roughness Coefficient

Besides the following observations were made and presented in other section:

1. Consumer meter installation,
2. Per capita consumption in full-house connection, yard connection and kiosk,
3. Effect of meter installation on water conservation.

4.1.2 EQUIPMENT AND MATERIAL USED

Equipment used for field measurement, which is prepared by JICA, is listed below. Upon completion of the field measurement programme, all equipment might be handed over to NUWA. Counterpart project personnel from NUWA like engineers, technicians and laborers have become quite familiar with the operation of the equipment involved because all flow and pressure measurements were taken jointly by the JICA Study Team and the above-mentioned counterpart personnel from NUWA.

1. Pressure Gauges
   (0-10 bar) NUWA property, (0- 6 bar) NUWA property, (0- 2.5 bar) NUWA property
   (0-10 kg/cm2 x 60mm) 5 sets
2. 7-day Recording Pressure Gauge (water pressure recorder)
   Model:FJN-24, 5 sets
3. Ultrasonic Portable Flowmeter (PORTA FLOW) 4 sets
   220V, 50Hz, Single-phase
   with 1 set Thickness Meter (Model: T) and 2 sets Large Sensor
4. DC Battery for PORTA FLOW 4 pieces
5. DC Battery Liquid 8 pieces
   2.5 liters/piece
6. AC Generator 2 sets
   Model: BLG-10-FSSY 10 KVA, 200 V, 50 Hz, 3-phase
7. Water Pump 2 sets
   Model: HK2-15 200 V, 50 Hz, 3-phase
8. Pick Hammer 2 sets
   Model: Pionjar 121A, with 3 kinds of Blade, each 2
9. Sounding Rod or Stethoscope or Listening stick (1 meter) 3 pieces
10. Sounding Rod or Stethoscope or Listening stick (1.5 meter) 3 pieces
11. Sound Wave Type Pipeline Detector 3 sets
    Model: PL-130
    Accessories :
    - 1Shoulder Belt 1 piece
    - Cord(Electric) 1 piece
    - Cord(Frequency) 1 piece
    - Frequency Tools 1 piece
    - Fixed Board 1 piece
    - Sensor Spare 1 piece
12. Iron Pipe & Live Cable Locator 3 sets
    Model: BL-801GXII
13. Corrosion Meter 3 sets
    Model: RS-1611
14. Measuring Wheel 2 sets
    Model: F-20
15. Scale Checker with Printer (Model: SP-500) 1 set
    Model: Type-D
16. Portable Magnetic Flow Meter 1 set
    Model: TK-105DH for open channel
17. Magnetic Flow Meter 1 set
    Model : KM-FB [NEW ROD FLOW]
18. Accessories for Flow Meter[PORTA FLOW]
    Thickness Meter (Model : T) 1 set
    Extension Cable 1 set

19. Water Meter
Model: PXA 1/2" 50 pieces
PAA 3/4" 250 pieces
20. 16.Water Meter Tester 3 sets
Model: TR-1
21. Computer 1 set
Model: J-3100GX-041
22. Printer 1 set
Model: PWS5269A
23. Walkie Talkie (Transceiver) 8 sets
Model : C-150
24. Conductivimeter 1 set
Model : CM-1
25. Water Quality Meter [LOVIBOND] 2 sets
Model : 3/40J-set
Accessories :
Colorimetric Plate 3pieces
Reagent
26. Turbidimeter 2 sets
Model : WA-PT-4T
27. Land Cruisers - 2 vehicles
28. Copy Machine 1 set
Model : NP-1215
Accessories :
Sorter 1 piece
Tray 1 piece
Stand 1 piece
29. Pipe Wrench
Model: P250 2 sets
P300 2 sets
P450 2 sets
30. Pipe Cutter
Model: 42-A 3 sets
44-S 3 sets
with 4 spare blades
31. Concrete Cutter 2 sets
Model: K-650MARK II
with 4 spare blades
32. Pipe Threader 2sets
33. Tapping Machine with Drill 4 pieces
* Drill for Cast Iron Pipe
1/2" 1 piece
3/4" 3 pieces
1" 1 piece
* Hallsaw for P.V.C.
1/2" 1 piece
3/4" 1 pieces
1" 1 piece
* Saddle for Cast Iron Pipe
3" 1/2" 10 pieces
3" 3/4" 20 pieces
3" 1" 10 pieces
4" 1/2" 10 pieces
4" 3/4" 20 pieces
4" 1" 10 pieces

* Saddle for P.V.C.
  - 3" 1/2" 10 pieces
  - 3" 3/4" 10 pieces
  - 3" 1" 10 pieces
  - 4" 1/2" 10 pieces
  - 4" 3/4" 10 pieces
  - 4" 1" 10 pieces

34. Socket
    - 1/2" 48 pieces
    - 3/4" 248 pieces
35. Reducer
    - 3/4" x 1/2" 50 pieces
36. Connector for Polyethylene Pipe
    - 1/2" 10 pieces
    - 3/4" 10 pieces
37. Galvanized Steel Pipe
    - 1/2" x 5.5m 48 pieces
    - 3/4" x 5.5m 248 pieces
38. 90 Degree Steel Elbow
    - 1/2" 300 pieces
    - 3/4" 1500 pieces
39. Steel Nipple
    - 1/2" 200 pieces
    - 3/4" 1000 pieces
40. Bronze Cast Iron Gate Valve
    - 1/2" 55 pieces
    - 3/4" 275 pieces
41. Bronze Cast Iron Check Valve
    - 1/2" 55 pieces
    - 3/4" 275 pieces

4.2 WATER PRESSURE MEASUREMENT*

4.2.1 PURPOSE

Pressure readings were taken at as many points as possible throughout the distribution system, in order to assess the condition of water supply in each area of the city. This data was also used for calibration of the network analysis model. Readings were taken at 3 different times on two days - January 17, 1990 and August 3, 1990.

4.2.2 PROCEDURE

Before pressures was measured, confirmation of pressure recording points and preparation for measurement were conducted, which required approximately one week. The location of the 72 pressure

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* The contents of this section is summarized in section 4.3.2 "low pressure areas", Main Report.

tapping points of NUWA are shown in Figure C.4.1 and their characteristics are given in Table C.4.1. Measurements were conducted by 6 groups, with 1 group stationed at the office for coordination. Three pick-up trucks of NUWA with drivers were provided. The average number of points per group was 12, and readings were generally finished within an hour. Readings were recorded at three time periods, with each period starting at 6:00 am, 10:00 am and 4:00 pm. These times were intended to measure the morning peak period, average and evening peak period, respectively. The pressures, however, did not significantly differ during the three times, except in areas along the Pugu road to the city center, where pressure drops ranging between 5 and 10 m were recorded in the evening.

At certain points in the city, a 7-day pressure recording gauge was installed, either at the pressure tapping location or at consumer taps. Continuous pressure readings were obtained at these locations over periods varying from 2 to 4 days.

4.2.3 EQUIPMENT USED

- pressure gauge
- 7-day pressure recording gauge

Pressure tapings consist of a three-way stop valve, an extended pipe and its fittings, and a saddle clamp.

4.2.4 RESULT

Pressure measurements were conducted at the following periods;
- morning peak hours (06:00 - 08:00)
- afternoon (14:00 - 16:00)
- evening peak hours (18:00 - 20:00)

Results are shown in Tables C.4.2 to C.4.3. From the readings, pressure contour lines are obtained, as shown in Figures C.4.2 (1) to C.4.2 (4).

It should be noted that the above-mentioned contours are based on the pressures measured on January 17, 1990 for various locations within the secondary pipe distribution system and do not necessarily take into account the additional head losses that generally occur within the smaller distribution mains and, in particular, through the long service pipes in the so-called unplanned areas.

4.2.5 ANALYSIS

Based on a review of the field pressure readings, certain conclusions can be reached regarding the nature of the distribution system.

(1) LOWER ZONE

Fairly adequate pressure was only available in belt areas along Bagamoyo road (from Kijitonyama to Kinondoni street), Morogoro road (from Manzese to UWT street) and Pugu road (from the Industrial area to UWT street). This is due to the low elevation of these areas and the existence of large distribution pipes.

Large areas of the system other than those mentioned above do not have adequate water supply. The most severely affected areas are Kinondoni/Mwananyamala, Msasani Peninsula, Ubungo, Mabibo, Kigogo, Tandika, Mtoni, Kurasini and Kigamboni.

Many of these deficiencies are considered to be the result of incorrect operation of valves, or inadequate connection of distribution mains within the system. Other deficiencies are due to capacity restrictions in certain distribution mains or to difficulties involved in supplying certain areas of the city, which are located at marginal elevations.

The low pressure in the system throughout the city is due to the University reservoir never filling up, a condition persisting since the early 1980s. Consequently, upstream distribution pipes have never been flowing full. This is either due to insufficient supply or excess consumption, as well as leakage.

The probable causes for supply deficiencies in the above-mentioned areas are detailed below.

The low pressures experienced in the Kinondoni/Mwananyamala and Kigogo areas are due primarily to the overloaded 8" pipes along Morocco road, resulting from its disconnection from the 48" distribution main. The low pressures experienced in Msasani Peninsula are due to high head losses occurring in the 8" and 6" pipes.

Ubungo and Mabibo are located at elevations of over 40 m and therefore cannot be adequately supplied from the University reservoir. The low water pressures experienced in these areas are not, therefore, due to deficiencies in the distribution mains. In fact, there are many large diameter pipes in these areas.

The low pressures experienced in Tandika and Mtoni are largely due to these areas being located at high elevations (between 35 and 40 m).
Low pressures in the Kurasini and Kigamboni areas result largely from the inadequacy of the distribution pipes along Kilwa road and piping connections.

(2) UPPER ZONE

Field pressure readings were not conducted for the Upper zone due to the fact that only intermittent supply is available, starting at about 5 a.m. and stopping when the Kimara reservoir dries up, usually between 9 and 10 a.m. After that, water in Kimara reservoir is stored for the next day's supply.

The existing distribution system, however, is considered to be more than adequate to supply existing demand in the Ubungo, Tabata, Kipawa, Ukonga and airport areas.

(3) MODIFICATIONS TO THE DISTRIBUTION SYSTEM

In the course of field investigations, it became apparent that there were a number of modifications that could be made to the system which were likely to improve the distribution system.

An earlier report on the distribution system highlighted a number of suspected operational difficulties and, if the recommendations therein have not already been acted upon, then action should be taken to implement them. This may involve trial pitting to determine pipework details.

NUWA should also institute an immediate programme to investigate and properly maintain all valves within the system.

Each valve should be temporarily excavated, its operation checked and the direction of rotation of its operating stem noted. The size and location of each valve should be recorded and valve marker posts replaced as necessary. Valve boxes should be cleaned out regularly and all valves should be left fully open.

In the past, valves within the system have often been throttled or closed due to attempts to reduce demand in particular areas or to prevent pipe bursts. Locations of throttled valves are soon forgotten and generally result in severe deficiencies occurring within the system at a later date.

It should be noted that these modifications are relatively minor in nature, involving the opening or the removal of a valve, or the interconnections of pipes on two sides of a street, and can readily be undertaken by NUWA in Dar-es-Salaam using existing resources.

The performance of the modified distribution system will improve considerably, in comparison to the existing distribution system.

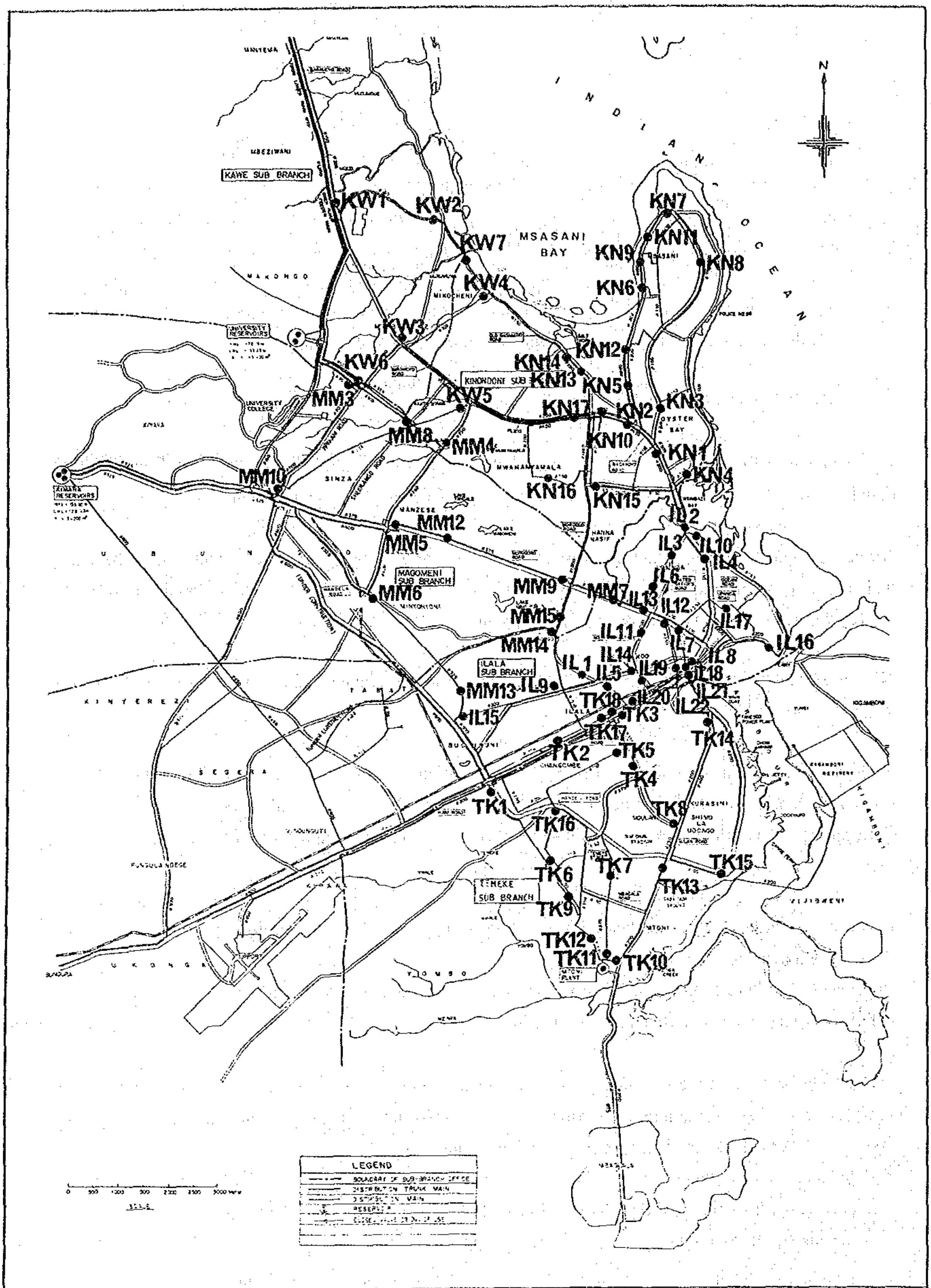

FIG. C.4.1 LOCATION OF WATER PRESSURE MEASUREMENT

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

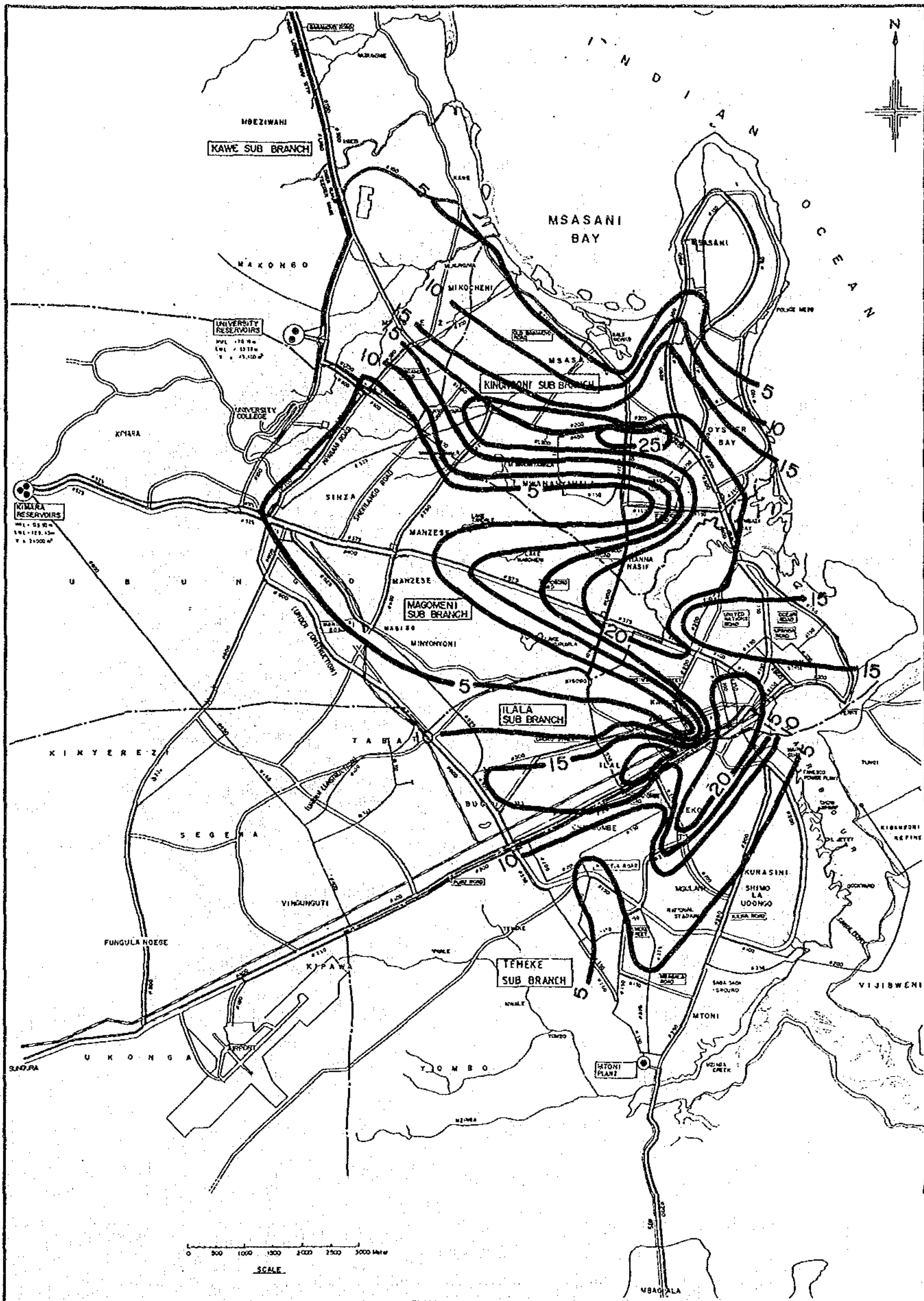

FIG. C.4.2 (1)	EFFECTIVE PRESSURE CONTOUR LINES, MORNING ON JAN. 17th 1990

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

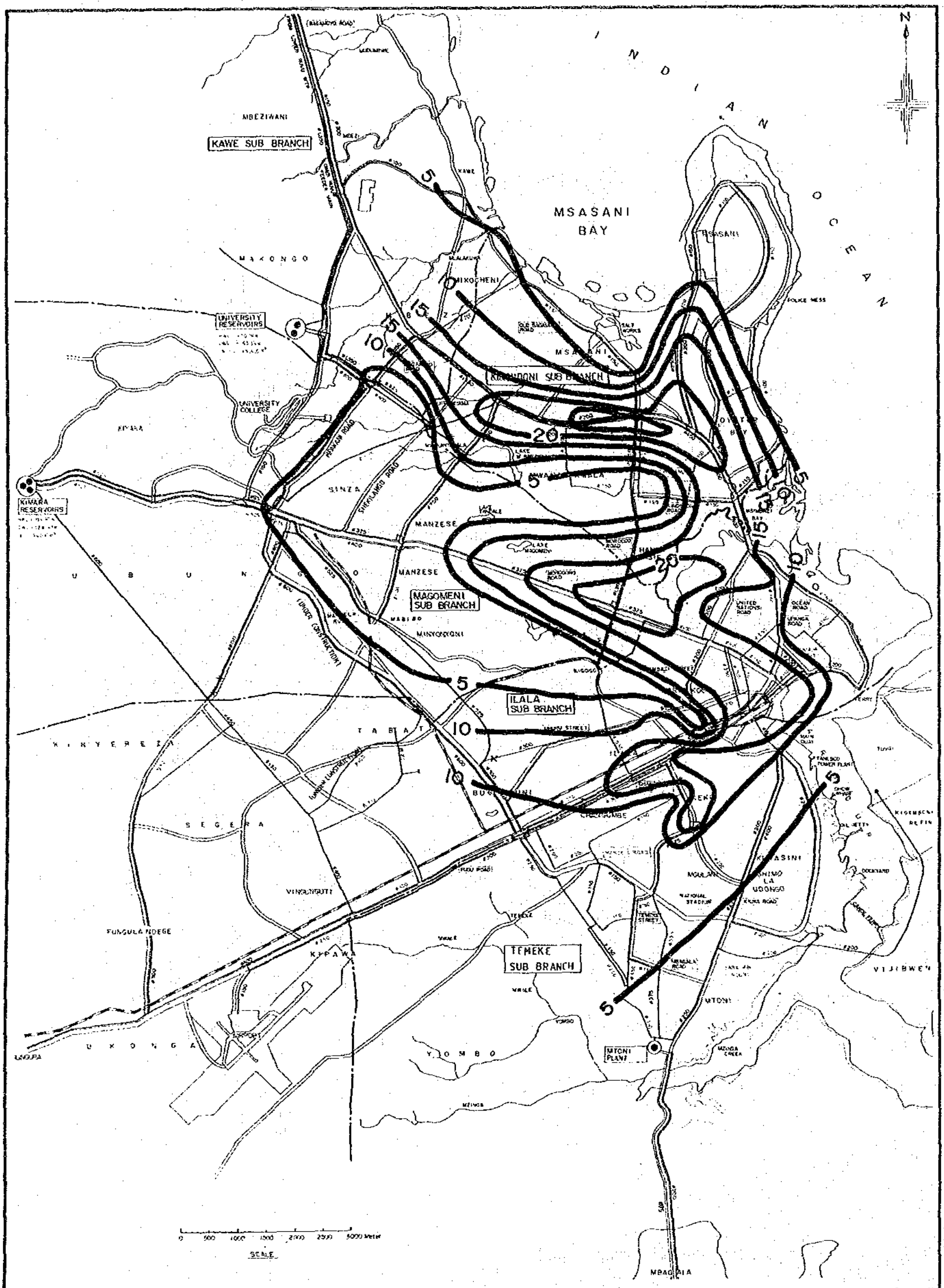

FIG. C.4.2 (2)	EFFECTIVE PRESSURE CONTOUR LINES, EVENING ON JAN. 17th 1990

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

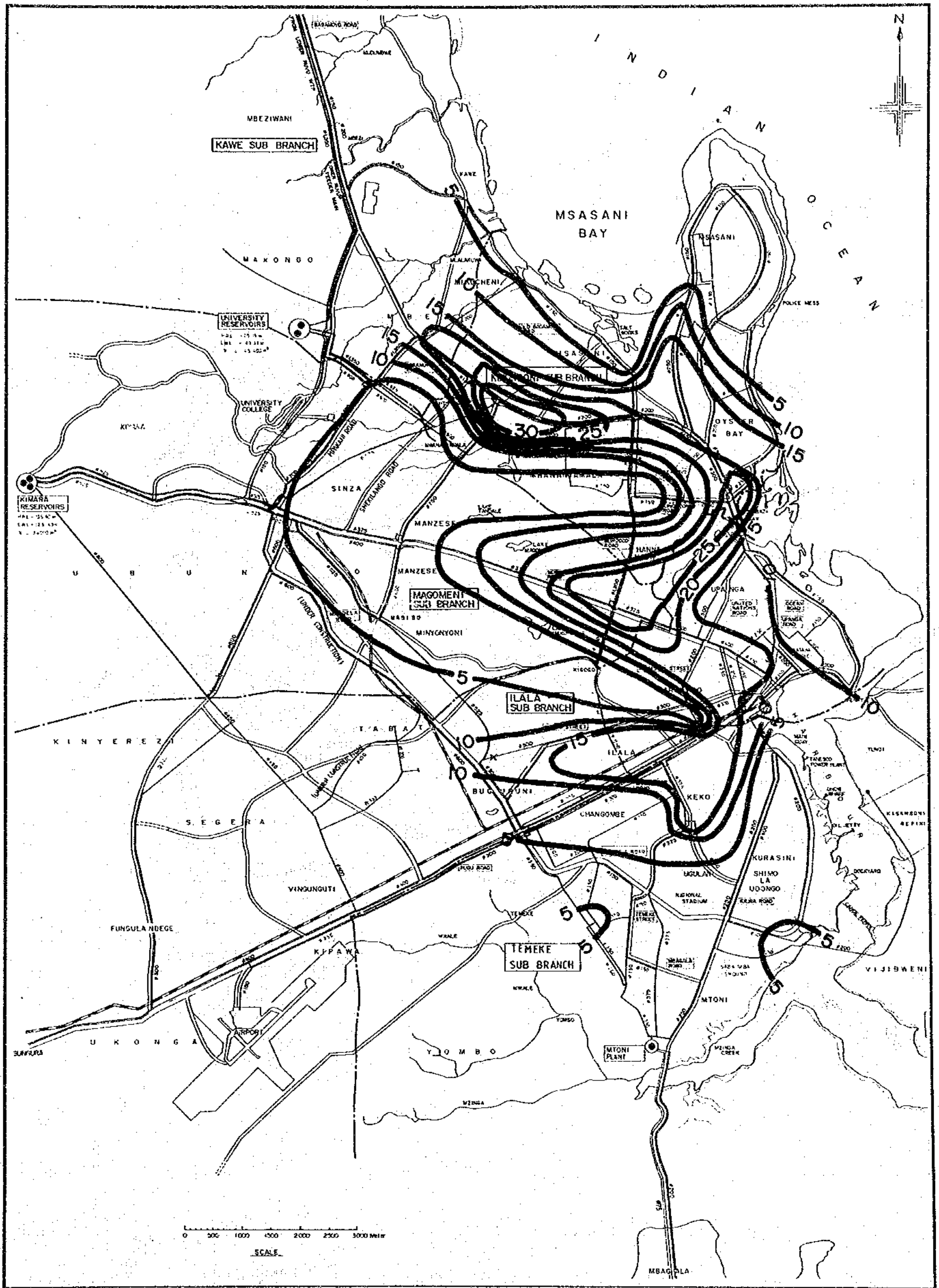

FIG. C.4.2 (3) EFFECTIVE PRESSURE CONTOUR LINES, MORNING ON AUG. 3rd 1990

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

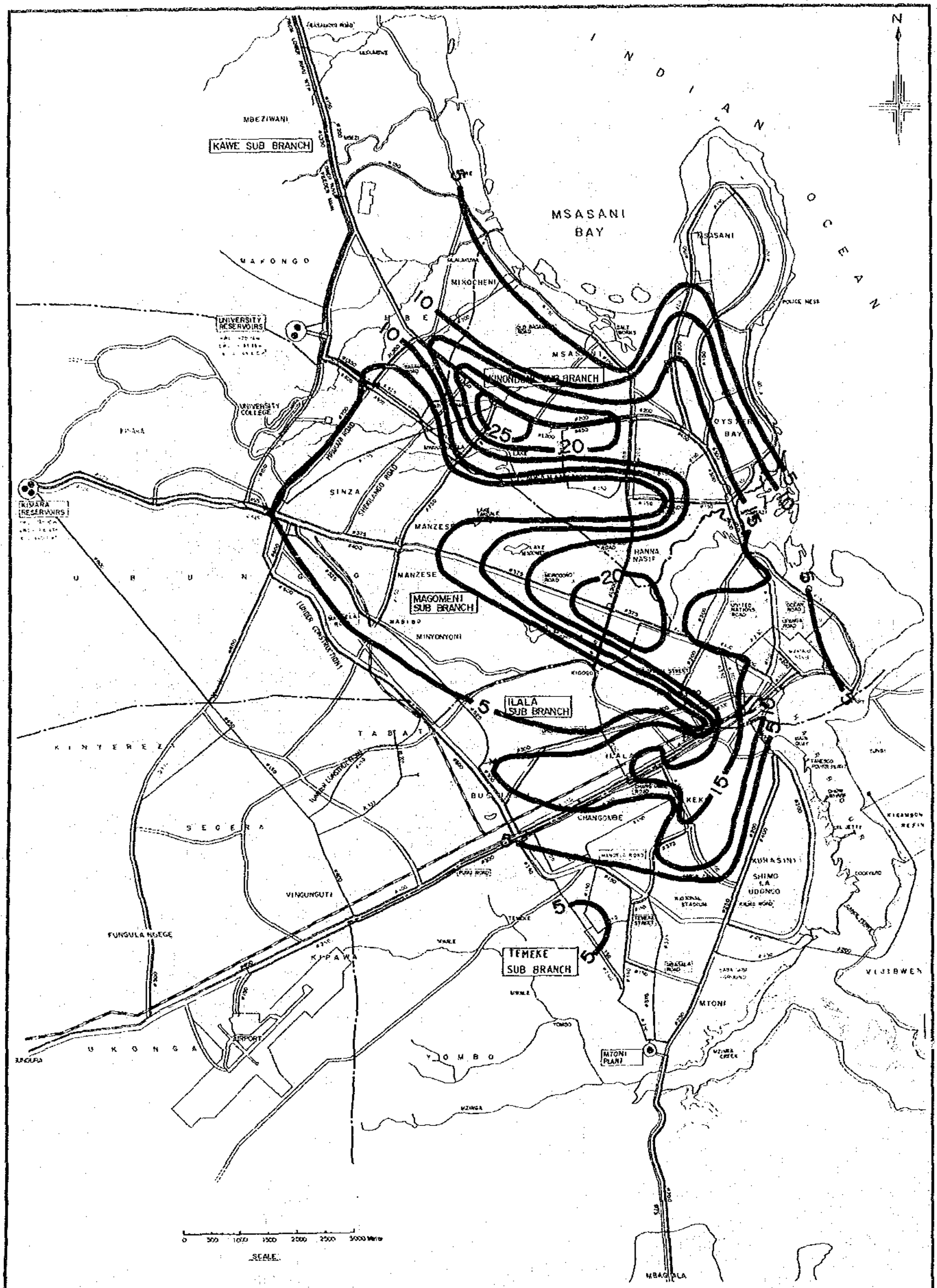

FIG. C.4.2 (4)	EFFECTIVE PRESSURE CONTOUR LINES, EVENING ON AUG. 3rd 1990

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

TABLE C.4.1 CHARACTERISTICS OF PRESSURE MEASURING POINTS

(1)	(2)	(3)	(4) (5)	(6)
TEMEKE Sub branch				
TK 1	34.--	3.57	14"(350)	DIP
TK 2	22.5-	4.71	10"(250)	DIP
TK 3	19.--	5.05	12"(300)	DIP
TK 4	18.--	5.15	15"(375)	CIP
TK 5	18.--	5.15	6"(150)	CIP
TK 6	34.--	3.57	6"(150)	DIP
TK 7	33.--	3.67	15"(375)	CIP
TK 8	17.--	5.25	8"(200)	CIP
TK 9	40.--	2.97	8"(200)	CIP
TK10	32.--	3.77	10"(250)	CIP
TK11	32.--	3.77	15"(375)	CIP
TK12	40.--	2.97	14"(350)	DIP
TK13	24.--	4.56	10"(250)	CIP
TK14	14.--	5.55	8"(200)	CIP
TK15	------	-----	----------	----
TK16	26.--	4.36	6"(150)	CIP
TK17	19.--	5.05	12"(300)	DIP
TK18	19.--	5.05	12"(300)	DIP
MAGOMENI Sub branch				
MM 3	38.--	3.17	32"(800)	SP
MM 4	30.--	3.96	30"(750)	DIP
MM 5	38.--	3.17	15"(375)	CIP
MM 6	30.--	3.96	21"(525)	SP
MM 7	6.--	6.34	15"(375)	CIP
MM 8	34.--	3.56	32"(800)	SP
MM 9	18.--	5.15	15"(375)	CIP
MM10	50.--	1.98	21"(525)	SP
MM12	26.--	4.36	15"(375)	CIP
MM13	19.--	5.05	21"(525)	SP
MM14	8.5-	6.09	6"(150)	CIP
MM15	10.--	5.95	6"(150)	CIP
ILALA Sub branch				
IL 1	18.--	5.15	6"(150)	CIP
IL 2	6.--	6.34	16"(400)	DIP
IL 3	6.5-	6.29	12"(300)	CIP
IL 4	7.--	6.24	6"(150)	CIP
IL 5	18.--	5.15	8"(200)	CIP
IL 6	7.--	6.24	12"(300)	CIP
IL 7	7.--	6.24	10"(250)	CIP
IL 8	8.5-	6.09	22"(550)	SP
IL 9	24.--	4.56	6"(150)	CIP
ILALA Sub branch (continued)				
IL10	6.--	6.34	6"(150)	CIP
IL11	10.--	5.95	8"(200)	CIP
IL12	11.--	5.85	10"(250)	CIP
IL13	10.--	5.95	16"(400)	DIP
IL14	16.--	5.35	12"(300)	CIP
IL15	34.--	3.57	12"(300)	CIP
IL16	4.5-	6.50	8"(200)	CIP
IL17	9.--	6.04	8"(200)	CIP
IL18	8.5-	6.09	22"(550)	SP
IL19	17.5-	5.20	8"(200)	CIP
IL20	16.--	5.35	10"(250)	DIP
IL21	8.5-	6.09	12"(300)	CIP
IL22	10.--	5.95	10"(250)	CIP
IL23	16.--	5.35	6"(150)	CIP
IL24	10??	5.95	6"(150)	???
KAWE Sub branch				
KW1	36.--	3.37	6"(150)	CIP
KW2	10.--	5.95	6"(150)	CIP
KW3	24.--	4.56	8"(200)	PVC
KW4	4.--	6.54	4"(100)	PVC
KW5	20.--	4.95	21"(525)	SP
KW6	38.--	3.17	54"(350)	SP
KW7	20.--	4.95	6"(150)	CIP
KINONDONI Sub branch				
KN1	12.--	5.75	12"(300)	CIP
KN2	14.--	5.55	18"(450)	CIP
KN3	7.5-	6.19	6"(150)	CIP
KN4	7.--	6.24	10"(250)	CIP
KN5	12.5-	5.70	10"(250)	CIP
KN6	------			
KN7	8.--	6.14	6"(150)	CIP
KN8	10.0-	5.95	6"(150)	CIP
KN9	10.--	5.95	6"(150)	CIP
KN10	14.--	5.55	8"(200)	CIP
KN11	------			
KN12	6.5-	6.29	10"(250)	CIP
KN13	8.--	6.14	6"(150)	CIP
KN14	8.--	6.14	6"(150)	CIP
KN15	10.5-	5.90	6"(150)	CIP
KN16	8.--	6.14	6"(150)	CIP
KN17	13.5-	5.60	18"(450)	CIP

NOTE: (1) Name of pressure measured point(refer to Figure C.4.1)
(2) Ground elevation in meter (3) Static pressure in meter
(4) Pipe diameter in inch (5) Pipe diameter in cm
(6) Pipe material: CIP - cast iron pipe; SP - steel pipe;
DIP - ductile iron pipe; PVC-polyvinyl pipe

TABLE C.4.2 PRESSURE IN THE DISTRIBUTION SYSTEM (ON JANUARY 17,1990)

(Unit:meter)

Point No.	Ground Level	Effective pressure (Time)	Absolute pressure	Effective pressure (Time)	Absolute pressure	Effective pressure(Time)	Absolute pressure
KW1	36.0	31 (7:35)	67	30 (9:55)	66	31 (16:16)	67
KW2	10.0	0 (7:40)	10	1 (10:05)	11	1 (16:20)	11
KW3	24.0	16.5 (7:15)	40.5	15.5 (9:50)	39.5	16 (15:58)	40
KW4	4.0	5.5 (7:50)	9.5	5.5 (10:15)	9.5	5.5 (16:35)	9.5
KW5	20.0	22 (7:10)	42	20 (9:45)	40	21 (15:52)	41
KW6	38.0	4 (7:20)	42	3.5 (9:45)	41.5	4 (16:05)	42
KW7	20.0	5.5 (7:45)	25.5	6 (10:10)	26	6.5 (16:25)	26.5
KN1	12.0	21.5 (6:42)	33.5	20.5 (10:25)	32.5	21.0 (16:34)	33
KN2	14.0	25.0 (6:45)	39	24.0 (10:28)	38	24.0 (16:48)	38
KN3	7.5	16.5 (6:38)	24	15.5 (10:22)	23	16.0 (16:30)	23.5
KN4	7.0	21.0 (5:58)	28	15.0 (9:49)	22	16.2 (15:56)	23.2
KN5	12.5	19.2 (7:07)	31.7	19.0 (10:46)	31.5	20.0 (16:54)	32.5
KN6	----	---- (----)	----	---- (-----)	----	---- (-----)	----
KN7	8.0	1.0 (6:14)	9	1.0 (10:03)	9	1.0 (16:10)	9
KN8	10.0	0.0 (6:08)	10?	0 (9:57)	10?	0 (16:05)	10?
KN9	10.0	3.5 (6:20)	13.5	3.0 (10:08)	17	2.7 (16:15)	16.7
KN10	14.0	19.0 (6:57)	33	19.0 (10:38)	33	19.9 (16:47)	33.9
KN11	----	---- (----)	----	---- (-----)	--	---- (-----)	----
KN12	6.5	16.0 (6:31)	22.5	15.5 (10:17)	22	15.5 (16:25)	22
KN13	8.0	5.0 (6:51)	13	4.0 (10:33)	12	4.3 (16:42)	12.3
KN14	8.0	---- (----)	8	---- (-----)	--	---- (-----)	----
KN15	10.5	1.0 (7:28)	11.5	1.0 (11:02)	11.5	1.0 (17:09)	11.5
KN16	8.0	1.0 (7:19)	9	1.5 (10:56)	9.5	2.0 (17:01)	10.0
KN17	13.5	27.5 (7:01)	41	27.3 (10:42)	40.8	28.0 (16:49)	41.5
TK 1	34.0	10 (5:55)	44	6 (9:57)	40	6 (15:43)	40
TK 2	22.5	18 (6:10)	40.5	12 (10:05)	34.5	14 (15:52)	36.5
TK 3	19.0	12 (6:26)	31	10 (10:22)	29	11 (16:07)	30
TK 4	18.0	20 (7:10)	38	19 (10:50)	37	19 (16:18)	37
TK 5	18.0	7 (6:55)	25	7 (12:43)	25	7 (16:12)	25
TK 6	34.0	8 (7:57)	42	9 (11:41)	43	8 (17:11)	42
TK 7	33.0	high (7:45)	--	-- (-----)	--	high (17:04)	--
TK 8	17.0	5 (7:15)	22	5 (11:04)	22	6 (16:23)	23
TK 9	40.0	0 (7:50)	40?	0 (11:37)	40?	high (17:09)	--
TK10	32.0	4 (7:33)	36	6 (11:19)	38	1 (16:42)	33
TK11	32.0	5 (7:35)	37	7 (11:20)	39	2 (16:44)	34
TK12	40.0	0 (7:39)	40?	0 (11:32)	40?	0 (16:48)	40?
TK13	24.0	0 (7:27)	24?	0 (11:14)	24?	1 (16:35)	25
TK14	14.0	8 (7:20)	22	8 (11:08)	22	9 (16:30)	23
TK15	-	-- (----)	--	-- (-----)	--	-- (-----)	--
TK16	26.0	3 (8:23)	29	-- (-----)	--	8 (17:18)	34
TK17	19.0	21 (6:20)	40	19 (10:16)	38	19 (16:00)	38
TK18	19.0	22 (6:13)	41	19 (10:13)	38	20 (15:57)	39

NOTE: Effective pressure = Absolute pressure - Ground level

TABLE C.4.2 CONTINUED

(Unit:meter)

Point No.	Ground Level	Effective pressure	(Time)	Absolute pressure	Effective pressure	(Time)	Absolute pressure	Effective pressure	(Time)	Absolute pressure
MM 3	38.0	16	(6:01)	54	17	(10:01)	55	15	(15:52)	53
MM 4	30.0	14	(6:53)	44	14	(10:16)	44	13	(16:08)	43
MM 5	38.0	2	(6:34)	40	1	(10:27)	39	1	(16:19)	39
MM 6	30.0	2	(7:06)	32	2	(10:33)	32	2	(16:25)	32
MM 7	6.0	21	(7:48)	27	22	(11:12)	28	22	(17:05)	28
MM 8	34.0	4	(6:45)	38	3	(10:09)	37	3	(16:00)	37
MM 9	18.0	21	(7:43)	39	22	(11:05)	40	22	(16:58)	40
MM10	50.0	0	(6:16)	50?	0	(9:53)	50?	0	(15:45)	50?
MM12	26.0	9	(6:25)	35	8	(10:41)	34	10	(16:32)	36
MM13	19.0	--	(----)	----	--	(-----)	--	--	(-----)	----
MM14	8.5	1	(7:25)	9.5	1	(10:51)	9.5	1	(16:42)	9.5
MM15	10.0	8.5	(7:33)	18.5	95	(11:00)	19	105	(16:51)	20
IL 1	18.0	10	(6:07)	28	8	(10:12)	26	8	(16:00)	26
IL 2	----	--	(----)	----	--	(-----)	--	--	(-----)	--
IL 3	6.5	21	(6:25)	27.5	18	(10:08)	24.5	19	(16:18)	25.5
IL 4	7.0	18	(6:20)	25	14	(10:05)	21	15	(16:16)	22
IL 5	18.0	17	(6:00)	35	13	(9:50)	31	12	(15:55)	30
IL 6	7.0	13	(6:35)	20	11	(10:10)	18	12	(16:24)	19
IL 7	7.0	20	(6:53)	27	17	(10:30)	24	18	(16:40)	25
IL 8	8.5	24	(7:08)	32.5	23	(10:35)	31.5	24	(16:55)	32.5
IL 9	24.0	8	(6:30)	32	2	(9:50)	26	9	(16:26)	33
IL10	6.0	18	(6:10)	24	12	(9:55)	18	14	(16:05)	20
IL11	10.0	--	(----)	----	--	(-----)	----	--	(-----)	--
IL12	11.0	18	(6:45)	29	17	(10:17)	28	17	(16:35)	28
IL13	10.0	20	(6:40)	30	18	(10:13)	28	19	(16:28)	29
IL14	16.0	2	(6:45)	18	2	(10:18)	18	2	(16:42)	18
IL15	34.0	15	(6:20)	49	12	(10:03)	46	12	(16:13)	46
IL16	4.5	18	(6:00)	22.5	9	(9:40)	13.5	8	(15:52)	12.5
IL17	9.0	13	(6:05)	22	8	(9:48)	17	8	(16:00)	17
IL18	8.5	24	(7:09)	32.5	23	(10:36)	31.5	22	(17:00)	30.5
IL19	17.5	2	(6:58)	19.5	2	(10:24)	19.5	2	(16:50)	19.5
IL20	16.0	20	(5:55)	36	13	(9:45)	29	15	(15:50)	31
IL21	8.5	22	(7:15)	30.5	22	(10:38)	30.5	22	(17:06)	30.5
IL22	10.0	--	(----)	----	--	(-----)	----	--	(-----)	----
IL23	16.0	15	(6:50)	31	15	(10:20)	31	16	(16:46)	32
IL24	10.0	20	(6:15)	30	15	(10:00)	25	16	(16:13)	26

NOTE: Effective pressure = Absolute pressure - Ground level

TABLE C.4.3 PRESSURE IN THE DISTRIBUTION SYSTEM (ON AUGUST 3, 1990)

(Unit:meter)

Point No.	Ground Level	Effective pressure	(Time)	Absolute pressure	Effective pressure	(Time)	Absolute pressure	Effective pressure	(Time)	Absolute pressure
KW1	36.0	17	(5:50)	53.0	20	(13:53)	55.5	17	(18:03)	53.0
KW2	10.0	5	(6:47)	15.0	5	(14:34)	15.0	6	(18:44)	16.0
KW3	24.0	19	(5:54)	43.0	15	(14:00)	38.5	13	(18:10)	37.0
KW4	4.0	6	(6:54)	10.0	6	(14:40)	10.0	4	(18:50)	8.0
KW5	20.0	31	(6:32)	51.0	30	(14:20)	49.5	28	(18:30)	47.5
KW6	38.0	6	(6:20)	44.0	3	(14:08)	40.5	0	(18:15)	38.0
KW7	20.0	2	(6:42)	22.0	1	(14:28)	21.0	0	(18:37)	20.0
KN1	12.0	21	(6:42)	33.0	18	(14:37)	30.0	17	(18:34)	29.0
KN3	7.5	16	(6:38)	23.5	14	(14:34)	21.5	13	(18:31)	20.5
KN4	7.0	29	(6:00)	36.0	13	(14:00)	20.0	14	(18:00)	21.0
KN5	12.5	18	(7:02)	30.5	18	(14:57)	30.5	17	(18:54)	29.5
KN7	8.0	1	(6:16)	9.0	1	(14:12)	9.0	1	(18:13)	9.0
KN8	10.0	0	(6:10)	10.0	0	(14:08)	10.0	0	(18:09)	10.0
KN9	10.0	1	(6:22)	11.0	1	(14:18)	11.0	1	(18:18)	11.0
KN10	14.0	19	(6:48)	33.0	18	(14:41)	32.0	16	(18:38)	30.0
KN12	6.5	16	(6:33)	22.5	14	(14:28)	20.5	14	(18:27)	20.5
KN13	8.0	4	(6:52)	12.0	4	(14:45)	12.0	4	(18:43)	12.0
KN15	10.5	1	(7:18)	11.5	1	(15:13)	11.5	1	(19:10)	11.5
KN16	8.0	1	(7:11)	9.0	1	(15:06)	9.0	1	(19:02)	9.0
KN17	13.5	24	(6:57)	37.5	23	(14:50)	36.5	21	(18:48)	34.5
TK1	34.0	4	(8:15)	38.0	5	(15:05)	39.0	4	(18:55)	38.0
TK2	22.5		-		13	(14:15)	35.0	12	(18:05)	34.0
TK3	19.0	17	(6:00)	36.0	4	(14:00)	23.0	14	(17:50)	33.0
TK4	18.0	18	(6:20)	36.0	16	(14:08)	34.0	16	(18:05)	34.0
TK5	18.0	10	(6:08)	27.5	7	(14:05)	25.0	8	(18:00)	26.0
TK6	34.0	8	(7:55)	41.5	8	(14:55)	42.0	8	(18:45)	42.0
TK8	33.0	1	(7:05)	18.0	2	(14:10)	19.0	2	(18:10)	19.0
TK9	40.0	0	(7:50)	40.0	1	(14:50)	40.5	0	(18:40)	40.0
TK10	32.0	2	(7:25)	34.0	4	(14:20)	36.0	4	(18:20)	36.0
TK11	32.0	4	(7:30)	35.5	4	(14:20)	36.0	4	(18:20)	35.5
TK12	40.0	0	(7:40)	40.0	2	(14:30)	42.0	2	(18:30)	42.0
TK13	24.0	2	(7:15)	26.0	4	(14:15)	28.0	4	(18:15)	28.0
TK14	14.0	2	(7:20)	16.0	3	(15:45)	17.0	3	(19:40)	17.0
TK15	-	6	(7:25)	6.0	5	(14:00)	5.0	5	(19:35)	5.0
TK16	26.0	2	(8:00)	28.0	2	(15:00)	27.5	2	(18:50)	28.0
TK17	19.0	21	(6:25)	40.0	16	(14:20)	35.0	19	(19:15)	38.0
TK18	19.0	20	(6:30)	39.0	19	(14:25)	37.5	18	(19:10)	37.0
TK		2	(8:30)		2	(15:35)	-	3	(19:30)	-

NOTE: Effective pressure = Absolute pressure - Ground level

TABLE C.4.3 CONTINUED

(Unit:meter)

Point No.	Ground Level	Effective pressure	(Time)	Absolute pressure	Effective pressure	(Time)	Absolute pressure	Effective pressure	(Time)	Absolute pressure
IL1	18.0	5	(6:32)	23.0	5	(14:41)	23.0	5	(18:17)	23.0
IL3	6.5	14	(6:25)	20.5	17	(14:20)	23.5	18	(18:00)	24.5
IL4	7.0	10	(6:20)	17.0	15	(14:17)	22.0	15	(18:17)	22.0
IL5	18.0	15	(6:03)	33.0	10	(14:45)	28.0	11	(17:45)	33.0
IL6	7.0	11	(7:05)	18.0	10	(14:25)	17.0	11	(18:20)	18.0
IL7	7.0	19	(6:45)	26.0	16	(14:55)	23.0	17	(18:38)	24.0
IL8	8.5	14	(6:51)	22.5	13	(15:13)	21.5	14	(18:30)	22.5
IL9	24.0	10	(6:28)	34.0	5	(14:35)	29.0	4	(18:15)	28.0
IL10	6.0	11	(6:10)	17.0	11	(14:10)	17.0	11	(18:05)	17.0
IL12	11.0	16	(6:40)	27.0	15	(14:50)	26.0	15	(18:35)	26.0
IL13	10.0	16	(6:35)	26.0	15	(14:45)	25.0	15	(18:25)	25.0
IL14	16.0	2	(6:37)	18.0	2	(14:51)	18.0	2	(18:21)	18.0
IL15	34.0	12	(6:15)	46.0	10	(14:00)	44.0	9	(18:00)	43.0
IL16	4.5	10	(6:00)	14.5	0	(14:00)	4.5	5	(18:00)	9.5
IL17	9.0	8	(6:48)	17.0	6	(15:00)	15.0	7	(18:45)	16.0
IL18	8.5	14	(6:56)	22.5	13	(15:14)	21.5	14	(18:31)	22.5
IL19	17.5	2	(6:44)	19.5	2	(14:55)	19.5	2	(18:25)	19.5
IL20	16.0	18	(6:00)	34.0	14	(14:48)	30.0	13	(17:40)	29.0
IL21	8.5	14	(6:58)	22.5	13	(15:15)	21.5	14	(18:33)	22.5
IL23	16.0	2	(6:40)	18.0	2	(14:53)	18.0	2	(18:23)	18.0
IL24	10.0	12	(6:15)	12.0	15	(14:15)	15.0	15	(18:10)	15.0
MM3	38.0	23	(6:50)	61.0	22	(15:10)	60.2	19	(18:30)	57.0
MM4	30.0	13	(6:23)	42.5	14	(14:45)	44.0	13	(18:05)	43.0
MM5	38.0	1	(7:14)	38.9	1	(15:32)	39.1	0	(18:48)	38.2
MM6	30.0	0	(7:20)	30.0	0	(15:40)	30.1	0	(18:55)	30.0
MM7	6.0	24	(5:45)	30.0	22	(13:55)	28.0	20	(19:40)	26.0
MM8	34.0	0	(6:32)	34.0	0	(14:55)	34.0	0	(18:13)	34.0
MM9	18.0	29	(5:52)	47.0	24	(14:05)	41.5	23	(19:35)	40.5
MM10	50.0	6	(7:02)	56.0	5	(15:25)	55.0	5	(18:40)	55.0
MM12	26.0	9	(6:10)	35.0	10	(14:35)	36.0	9	(19:03)	35.0
MM14	8.5	1	(6:02)	9.5	1	(14:23)	9.7	0	(19:14)	8.8
MM15	10.0	10	(8:05)	20.0	11	(14:12)	21.0	10	(19:25)	20.0

NOTE: Effective pressure = Absolute pressure - Ground level

4.3 PIPE EXTERNAL CONDITION *

4.3.1 PURPOSE

The purpose of this study was to evaluate the external condition of pipes.

4.3.2 POINTS INVESTIGATED

Eighty one points (see Figure C.4.3) were investigated during the first on-site study. Concrete pipes, constituting the primary distribution network, with diameters ranging from 1,000 mm to 1,350 mm, were not investigated because they are corrosion resistant. All sections, except 3 ductile iron pipes, were cast iron pipes.

4.3.3 EQUIPMENT USED

- corrosion meter
- thickness meter

4.3.4 PROCEDURE

The procedure used is as follows :

1) Selection of points from NUWA pipe drawings to cover at least one point in each section of the main distribution pipes.
2) Location of pipe at each point with the guidance of a technician from NUWA and pipe locator.
3) Excavation of the point, and
4) Measurement of thickness and corrosion.

Since only the general location of pipes/valves are shown on NUWA drawings, the pipe locator proved to be of great value during the study. The pipes and valves were then excavated manually. However, it was extremely difficult to find valves.

Valve marker posts were missing and valve boxes were completely covered with dirt and refuse. When valve boxes were located in their correct positions, it was invariably found that boxes were filled with dirt, rubbish, stagnant water and, in some instances, concrete. Gaining access to the valves required a considerable amount of time and effort in cleaning out the boxes, which, in many cases, were several

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* The contents of this section is summarized in section 4.3.5 "silt and encrustation", Main Report.

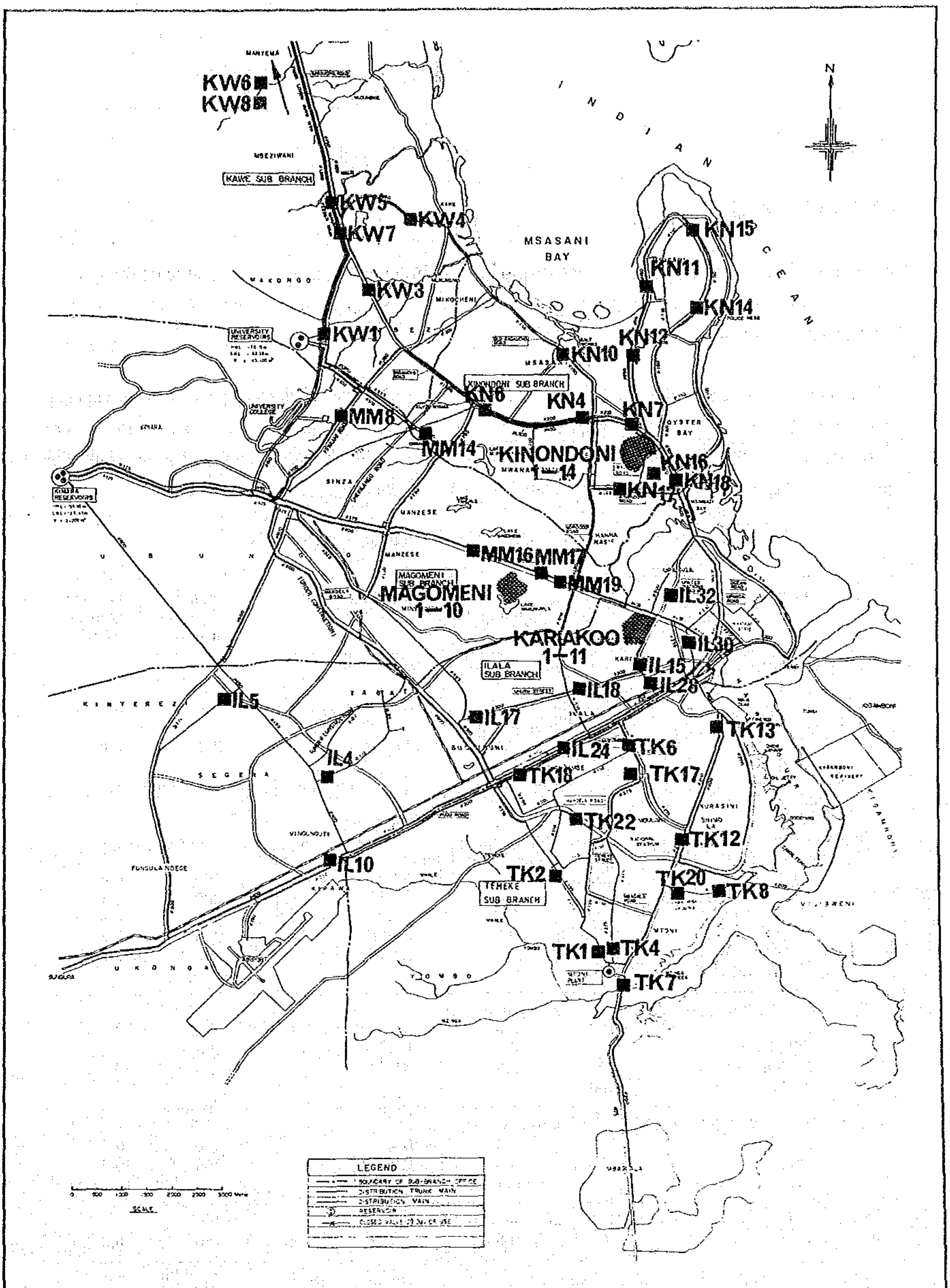

FIG. C.4.3	LOCATION OF PIPE EXTERNAL CONDITION OBSERVATION

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

feet deep.

4.3.5 RESULT

When the valves were exposed and opened, it was often the case that either the valve or the flanges were leaking considerably. Valves opening clockwise as well as those opening anti-clockwise exist throughout the system.

It was observed during day-to-day inspections that the external condition of the pipe surface was similar in most pipes, i.e., they were in good condition, and corrosion was mostly less than 1 mm. Pipes were also inspected in the three model areas. The results confirm the above. Table C.4.4 gives results in terms of pipe age. Three points were measured in each pipe; the crown and the two sides.

TABLE C.4.4 (1) PIPE EXTERNAL CONDITION

pipe sample no. (mm)	pipe diameter (mm)	external corrosion	pipe sample no.	pipe diameter (mm)	external corrosion (mm)
1. "LAID IN 1985, 5-YEARS OLD"		average = 0.25 mm			
MM8	750	0.2	MM14	750	0.3
2. "LAID IN 1980, 10-YEARS OLD"		average = 0.67 mm			
KINO5	100	0.5	MM16	375	0.8
MM17	200	0.7			
3. "LAID IN 1979, 11-YEARS OLD"		average = 0.40 mm			
IL30	250	0.4			
4. "LAID IN 1970, 20-YEARS OLD"		average = 0.53 mm			
KINONDONI2	100	0.3	KN4	200	0.6
KINONDONI3	100	0.3	KN12	200	1.1
KINONDONI6	100	0.4	IL17	300*	0.9
KINONDONI7	100	0.3	MM19	375*	0.7
KINONDONI1	100	0.4	KN18	400	0.3
KINONDONI4	100	0.5			
5. "LAID IN 1968, 22-YEARS OLD"		average = 0.61 mm			
KINONDONI11	100	0.4	KINONDONI12	100	0.3
KINONDONI13	100	0.3	KINONDONI10	100	1.2
KINONDONI9	100	1.2	KN15	150	0.7
KINONDONI8	100	0.2			
6. "LAID IN 1967, 23-YEARS OLD"		average = 0.42 mm			
KN14	150	0.3	IL4	300	0.3
KN6	150	0.4	IL5	300	0.4
KN11	200	0.7			
7. "LAID IN 1966, 24-YEARS OLD"		average = 0.40 mm			
KN16	100	0.5	KN17	150	0.3

* ductile iron pipe.

TABLE C.4.4 (2) PIPE EXTERNAL CONDITION

pipe sample no. (mm)	pipe diameter (mm)	external corrosion	pipe sample no.	pipe diameter (mm)	external corrosion (mm)
8. "LAID IN 1965, 25-YEARS OLD" average = 0.99 mm					
KARIAKOO 9	100	0.7	KARIAKOO8	150	0.8
KARIAKOO 6	100	1.4	KARIAKOO3	150	0.9
KARIAKOO 5	100	1.1	IL28	200	0.7
KARIAKOO 7	100	0.7	KW1	200	1.0
KARIAKOO 10	100	0.5	IL15	200	0.8
KARIAKOO 1	100	0.3	KINONDONI14	200	0.4
KARIAKOO 2	100	0.7	KW7	250	0.7
KARIAKOO 4	100	1.4	IL18	300	2.1
KARIAKOO 11	100	0.7	IL10	400	3.4
IL24	150	0.5			
9. "LAID IN 1960, 30-YEARS OLD" average = 0.68 mm					
TK17	150	1.0	IL32	250	1.0
KN10	150	0.7	TK20	250	0.9
KW5	150	0.4	TK18	300	0.5
KW4	200	0.5	TK1	350*	0.4
10. "LAID IN 1959, 31-YEARS OLD" average = 0.37 mm					
MAGOMENI2	100	0.2	MAGOMENI8	100	1.2
MAGOMENI9	100	0.6	MAGOMENI1	100	0.2
MAGOMENI4	100	0	MAGOMENI6	100	0.1
MAGOMENI5	100	0.1	MAGOMENI10	100	0.3
MAGOMENI3	100	0	MAGOMENI7	150	1.0
11. "LAID IN 1955, 35-YEARS OLD" average = 0 .43 mm					
KW8	200	0.4	TK6	375	0.5
TK7	250	0.4			
12. "LAID IN 1954, 36-YEARS OLD" average = 1 .00 mm					
KW3	150	1			
13. "LAID IN 1953, 37-YEARS OLD" average = 0 .25 mm					
TK13	200	0.3	TK8	250	0.2
14. "LAID IN 1952, 38-YEARS OLD" average = 0 .50 mm					
KN7	200	0.5			
15. "LAID IN 1951, 39-YEARS OLD" average = 0 .43 mm					
TK22	150	0.9	TK2	350	0.2
TK12	250	0.2			
16. "LAID IN 1950, 40-YEARS OLD" average = 1 .45 mm					
KW6	150	1.2	TK4	375	1.7

* ductile iron pipe.

4.3.6 ANALYSIS

The external condition of the pipe look fairly good, with a smooth external surface. The degree of corrosion does not differ significantly with pipe age. Nevertheless, the regression curve to correlate corrosion and pipe age is as follows;

$Y = 0.57 + 0.003X$

where Y: corrosion in mm   X: pipe age in year

Approximately 40 % of pipe samples were 100 mm in diameter, since they were investigated in areas where meters were installed in three model areas - Kariakoo, Magomeni and Kinondoni. Other samples were taken all over Dar es salaam. In order to avoid locational bias, regression curves were also developed that exclude samples taken in these three model areas and this relationship is as follows;

$Y = 0.60 + 0.004x$

where Y: corrosion in mm   X: pipe age in year

The degree of corrosion of, for example, 10-year old pipes is 0.64 mm, while that of a pipe that is 50 years old is 0.80 mm. Pipe wall thicknesses are not clear. But, judging from the fact that most cast iron pipes are made to British Standards, they should be as follows;

	Vertically cast gray iron	Spun gray iron
100 mm	8.5 to 10.5 mm	6.2 to 8.0 mm
150 mm	9.5 to 15.2 mm	7.2 to 11.4 mm
200 mm	10.7 to 17.1 mm	7.8 to 13.0 mm
250 mm	11.8 to 19.3 mm	8.8 to 14.6 mm
300 mm	12.2 to 20.2 mm	9.6 to 15.9 mm

Another factor which affects the degree of corrosion is the subsoil. The subsoil prevailing DSM is fortunately the non-aggressive variety, consisting of fluviatile marine deposits of sand, gravel and silt. These are predominantly sedimentary rocks.

4.4 PIPE INTERNAL CONDITION *

4.4.1 PURPOSE

The purpose of this study is to evaluate the internal, physical condition of pipes and to correlate it with such factors as age and material of pipe and velocity of flow.

4.4.2 POINTS INVESTIGATED

Twenty four points were investigated in DSM as is shown in Figure C.4.4. Every pipe was scanned with a scale checker, while some pipes were also inspected visually. Pipes which were visually inspected were in model areas.

4.4.3 EQUIPMENT USED

- pipe locator
- scale checker
- thickness meter
- "portaflow" flow meter

4.4.4 PROCEDURE

Two procedures were used. One procedure is explained below. The other procedure is explained in section 4, Appendix E because these pipes were also selected and investigated for the effect of meter installation.

1) Selection of points for measurement from NUWA pipe drawings to cover at least one point in each section of the main distribution pipes.
2) The next step was to locate the pipe at each point with the help of a technician from NUWA and a pipe locator.
3) Excavation of the located point.
4) Measurement of encrustation, rust and deposit in the pipe section with a scale checker. Thickness, corrosion and flow in the pipe section were also measured.

In addition, the internal surface of 4-inch cast iron pipe was visually investigated. The pipe was at a depth of 60 cm along the road, one block west from the Morocco road and directly branches off from

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* The contents of this section is summarized in section 4.3.5 "silt and encrustation", Main Report.

the Bagamoyo road main. It was installed around 1960, i.e., it was about 30 years old. Three push rings were loosened from the joints after closing the two adjacent valves and the three pipes were taken out to observe the internal surface.

4.4.5 RESULT

From visual inspection, the external surface looked good; no rust was observed and corrosion was measured to be 0.3 mm in thickness. Some of the push rings were superannuated and the rubber joints had been damaged, though there was no leakage. Severe encrustation between 10 to 35 mm in thickness was observed, with 20 mm being the average value. Reduction of the cross-sectional area is 64 percent. 4-inch pipes effectively became 2.5 inch pipes. Colloidal particles were also found.

Results of encrustation measurements are shown in Table C.4.5 and Figure C.4.5, grouped according to pipe age. Blockage of pipe and reduction in effective internal area was larger in smaller diameter pipes, i.e. less than 150 mm pipe. On the other hand, there was no blockage or area reduction in large diameter pipes, i.e. diameter greater than 200 mm. This is indicative of blockage by tuberculation. When inflow meters were installed, pipes were investigated visually and also measured by scale checker. It showed that even when the scale checker found no blockage, there was much silt in the pipe.

4.4.6 ANALYSIS

The pipes in which there were some blockages mostly consisted of loose deposits of, typically silt, though tuberculation was also observed. Removal of silt, coupled with better treatment to ensure that no flocs and silt escape from the treatment plants, could increase the carrying capacity of the pipes, resulting in an increase in residual pressures in the tertiary system and at consumer premises.

TABLE C.4.5 PIPE INTERNAL CONDITION

No.	material	diameter (mm)	year laid	effective area(%)	No.	material	diameter (mm)	year laid	effective area(%)
BO1	CIP	150	1976	100	KA3	CIP	100	1955	91
KW1	CIP	150	1958	100	KA4	CIP	100	1955	77
KN1	CIP	150	1976	100	MM1	CIP	100	1965	78
KN2	STEEL	250	1983	100	MM2	CIP	100	1965	64
KN3	CIP	200	1952	78	IL2	CIP	100	1960	80
KN4	CIP	400	1963	100	IL1	CIP	100	1960	87
KN5	CIP	100	1965	74	TK1	CIP	250	1979	100
KN6	CIP	150	1966	92	TK2	CIP	300	1955	100
KN7	CIP	200	1965	100	TK3	CIP	200	1956	100
KN8	CIP	200	1952	100	TK4	CIP	200	1956	100
KA1	CIP	100	1955	100	TK5	CIP	200	1956	100
KA2	CIP	100	1955	100	TK6	CIP	200	1956	100
					TK7	CIP	250	1956	100

NOTE: CIP = cast iron pipe DIP = ductile iron pipe

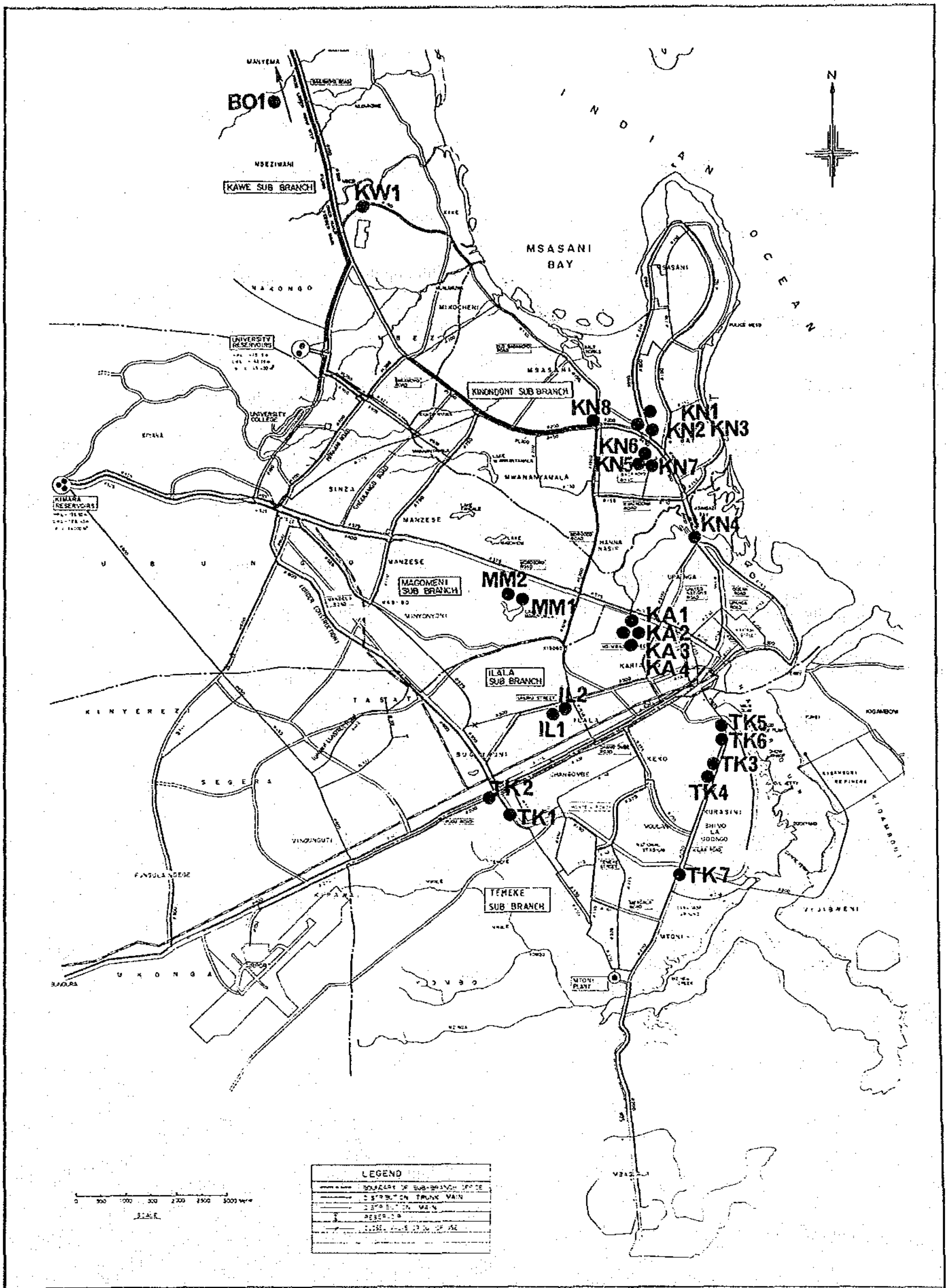

FIG. C.4.4	LOCATION OF PIPE INTERNAL CONDITION OBSERVATION

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

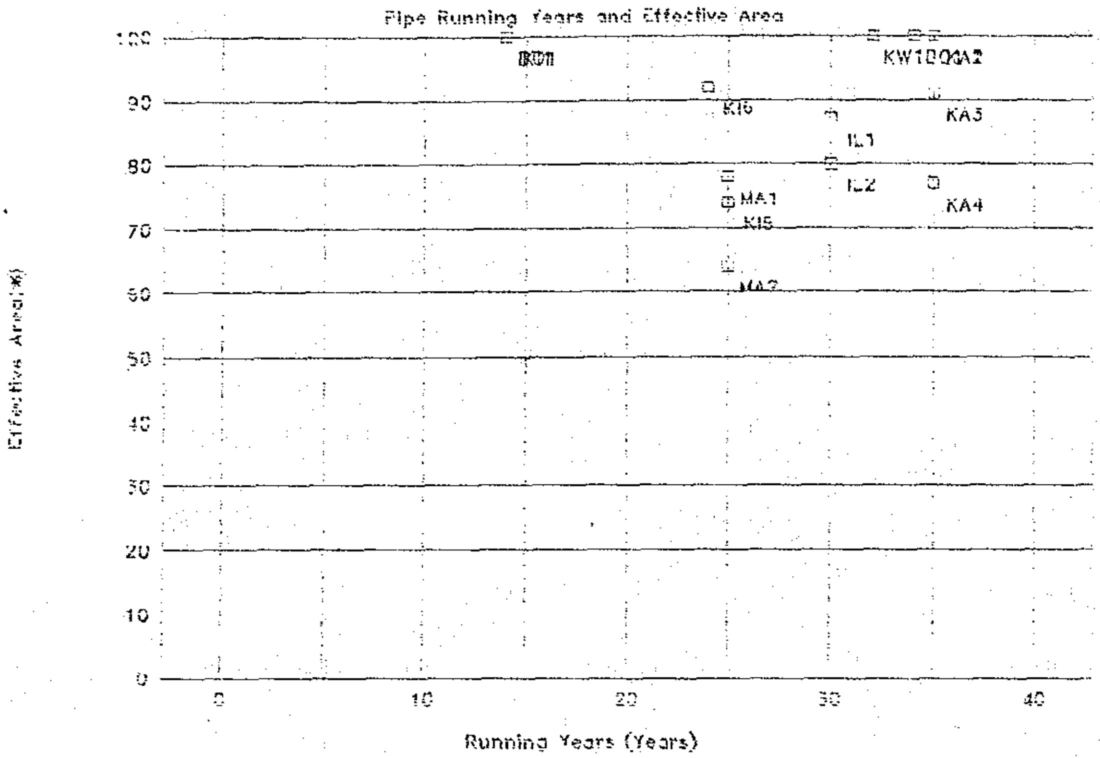

FIG. C.4.5	RELATIONSHIP BETWEEN PIPE INCRUSTATION AND YEAR OF INSTALLATION

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

4.5 LEAKAGE MEASUREMENT IN THE DISTRIBUTION PIPES *

4.5.1 PURPOSE

The purpose of this study was to estimate the leakage in three model areas of Kariakoo, Magomeni and Kinondoni (see Figure C.4.6), and using data in the three model areas measured during the first and second on-site studies, correlate leakage to such factors as areal and pipe characteristics and supply pressure.

4.5.2 PROCEDURE

1) Select an area, which can be hydraulically isolated by means of valves, from NUWA pipe drawings.
2) Confirm that pressure and flow are sufficient in the selected area.
3) Find boundary valves in the area with the help of technicians, and with pipe locator and, confirm that every valve is operational. Further, confirm that flow of water is actually stoppable by use of the valves.
4) Close all boundary valves except the inlet valve and, install a flow meter in the inlet pipe.
5) Measure for at least 24 hours, including minimum night flow.
6) Count the number of properties and inhabitants.

4.5.3 AREAS INVESTIGATED

(1) KARIAKOO MODEL AREA

Kariakoo area (see Figure C.4.7) is located in the city center, and is one of the busiest commercial area. The area consists of shops and residential dwellings, and include the peripheral unplanned residential areas. Unplanned areas have developed on the western side of the model area which slopes down to the Msimbazi creek. The number of families and the population in the model area is 1,272 and 6,270, respectively.

Approximately 80 percent of the houses have service pipes. Most of the service pipes were installed around 1965. Pipe material is either galvanized steel or PVC. Diameters are either 1 or 3/4 inch. About 10 percent of the taps, out of the 1,380 taps, are not working well, with high leakage observed in one-third of these taps.

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* The contents of this section are summarized in section 4.3.4 "water losses in the system", Main report.

(2) MAGOMENI MODEL AREA

The Magomeni model area (see Figure C.4.8) is divided into three kinds of residential areas : planned area(A), planned area(B) and unplanned area.
The distribution network was installed at the time when planned area(A) was being developed in 1965. Service pipes are connected to 89 percent of the houses. At that time, galvanized steel pipes were common for service pipes, and consequently, most service pipes currently used are made of galvanized steel, with the exception of some PVC pipes. Diameters are 1/2, 3/4 or 1 inch and their lengths are relatively short - 2 to 10 m.

The planned area(B) was developed after 1965 without provision of distribution pipes. Hence, only 56 percent houses have service pipes. PVC is more prevalent as compared to galvanized pipes here than in the planned area(A). The diameter used is mostly 3/4 or 1 inch. The service pipes extend along the service road which is approximately 10 m wide, from a 4-inch distribution pipe. The lengths of service pipes are long enough, varying from 20 m to as long as 150 m, which are determined by the respective distances from each house to the distribution pipe. The service pipes have been laid on a "first come, first serve basis" and consequently, the network appears to look like "spaghetti connections".

The unplanned areas have been developed along the periphery of the planned areas. As is the case of the rest of DSM, houses are built on a slope, starting from the flat edge of the planned area and ending in the swampy areas. Here, 26% of the houses have service pipe connections. PVC is more in use than galvanized pipes, reflecting the relative newness of these areas. The diameters are either 3/4 inch or 1 inch. Lengths are also long, from 20 to 150 m. Some service pipes pass under other houses.

All service pipes are buried close to surface. The surface of galvanized pipes have rusted. Leakage is prevalent at service pipe connections to distribution pipe.

Leakage takes place in about 10 percent of the water taps, with half of these leakages being very severe.

(3) KINONDONI MODEL AREA

The Kinondoni model area (see Figure C.4.9) is located to the south of the junction of the old and the new Bagamoyo roads. The area consists of planned and unplanned residential areas, sizes of which are 35 and 7 hectares, respectively. As is typical, distribution pipes exist only in the planned area. Hence, service pipes are rather short in the planned areas, about 30 meters on an average, while service pipes are long in the unplanned area. The service pipes were installed around 1970.

4.5.4 EQUIPMENT USED

- pipe locator
- "portaflow" flow meter
- scale checker

4.5.5 RESULT

Flow observed over two 24 hour periods in Kinondoni model area is shown in Figure C.4.10. Minimum night flow of 4.8 l/sec was observed, at around 2:40 a.m, as expected. This value is as high as 75 percent of average day-time flow. From this, leakage is calculated to be 37% of supply (refer to Table C.4.6). Similarly, leakage levels are calculated to be 22% in Magomeni model area and 48% in Kariakoo model area.

4.5.6 ANALYSIS

All three areas have cast iron pipes that are between 20-30 years old. Testing of areas having uPVC pipes was also attempted, but unfortunately no area could be found with sufficient pressure to produce meaningful results. It is anticipated that leakage levels in uPVC pipe areas will be at least as high as the model areas.

It is interesting to note that about 73 percent of water is accounted for and that only 27 percent is unaccounted-for. Inflow from the 3 sources totals 182,000 m^3/day while the estimated billed amount is 132,000 m^3/day, which is the average for the period July, 1989 to September, 1989.

Following rehabilitation, the supply pressures in all areas will increase. This increased pressure will not only increase the escape of water through existing leaks but will also increase the occurrence of new leakage. By using empirical methods the leakage in the model areas is predicted to increase between 55% and 72% (refer to Table C.4.8).

The conclusion is that the rehabilitation measures recommended will, when implemented, substantially increase system supply pressures which will, in turn, dramatically increase leakage levels. It is imperative therefore that an effective leakage control strategy is established on a priority basis. Tables C.4.9 and C.4.10 indicate target leakage levels and potential savings.

TABLE C.4.6 CURRENT LEAKAGE LEVELS IN 3 MODEL AREAS

	Kariakoo	Magomeni	Kinondoni	REMARKS
(1) Minimum night flow : l/sec	14.0	2.7	4.8	from measurement (refer to Figs. C.4.10 to C.4.12)
(2) Legitimate usage: l/sec	0.4	0.7	0.3	refer to section 4.5.7
(3) Net night flow	13.6	2.0	4.5	(1)-(2)
(4) Pressure variation : meter	16 - 26	5 - 24	5 - 20	
(5) Pressure variation factor	0.746	0.600	0.521	calculated (refer to Table C.4.7)
(6) Leakage: m^3/day	877	104	203	(3)X(5)X86.4
(7) Consumption: m^3/day	946	371	344	(8)-(6)
(8) Demand: m^3/day	1,823	475	547	from measurement (refer to Figs. C.4.10 to C.4.12)
(9) Leakage				
% of demand	48	22	37	(6)/(8)
% of consumption	93	28	59	(6)/(7)
(10) Connection	358	301	221	from survey
(11) Leakage per connection (l/hr)	102	14	38	daily base leakage (6)X1000/24/(10)

TABLE C.4.7 CALCULATION OF PRESSURE VARIATION FACTOR IN MODEL AREA

Model Area	KARIAKOO		MAGOMENI		KINONDONI	
Period (hour)	Average Pressure (meter)	Leakage Index*	Average Pressure (meter)	Leakage Index*	Average Pressure (meter)	Leakage Index*
00 - 02	25	15	23	14	19	11
02 - 04	26	16	24	14	20	12
04 - 06	23	14	23	14	17	10
06 - 08	16	10	7	4	7	4
08 - 10	16	10	5	3	5	3
10 - 12	16	10	11	7	6	4
12 - 14	17	10	11	7	7	4
14 - 16	18	11	11	7	6	4
16 - 18	18	11	13	8	6	4
18 - 20	18	11	10	6	8	5
20 - 22	19	11	11	7	9	5
22 - 24	24	14	16	10	15	9
Σ(leakage indices)		143		101		75
Leakage index for night period		16		14		12
Therefore,	T=143/16*2 =17.9 hours		T=101/14*2 =14.4 hours		T=75/12*2 =12.5 hours	
namely	T=17.9/24 =0.746		T=14.4/24 =0.600		T=12.5/24 =0.521	

(* calculated from a figure of "Leakage control policy and practice", Water Authorities Association, UK, 1985)

TABLE C.4.8 PREDICTED INCREASE IN LEAKAGE

Area	Kariakoo*	Magomeni*	Kinondoni	REMARKS
(1)pressure (average night test): meter	26.0	24.0	20.0	From Fig.C.4.13
(2)pressure after rehabilitation : meter	49.0	45.0	45.0	Estimation
(3)leakage test index	16.0	14.0	12.0	From Fig.C.4.14
(4)index after rehabilitation	36.0	32.0	32.0	From Fig.C.4.14
(5)factor	2.25	2.29	2.67	(4)/(3)
(6)net night flow :liters/second	13.6	2.0	4.5	From Table C.4.6
(7)net night flow after rehabilitation :liters/second	30.6	4.6	12.0	(5) X (6)
(8)predicted** leakage:m^3/day	2,203	331	864	(7)X 0.833 X 86.4
(9)consumption:m^3/day	946	371	344	From Table C.4.6
(10)% of demand after rehabilitation	70	47	72	(8)/((8)+(9))
(11)% Of demand before rehabilitation	48	22	37	From Table C.4.6
(12)% Increase	146	214	195	(10)/(11)

** Assumes 10m pressure variation i.e., factor = 0.8333

TABLE C.4.9 TARGET LEAKAGE LEVELS

Area	Kariakoo*	Magomeni*	Kinondoni	REMARKS
(1)NET NIGHT FLOW:l/s	13.6	2.0	4.5	From Table C.4.6
(2)NO OF CONNECTIONS	358	301	221	From survey
(3)LEAKAGE: l/connect/hr*1	137	24	73	(1)X3600/(2) night flow base
(4)INITIAL TARGET LEVEL: l/connect/hr*	2 20	20	20	
(5)TARGET NET NIGHT FLOW:l/s	2.0	1.7	1.2	(4)X(2)/3600
(6)TARGET % OF DEMAND	13%	25%	20%	*3

*1 Passive leakage control i.e., repair of reported leakage should result in leakage levels of about 18-20 l/connect/hr

- Average leakage for 3 areas
  =(13.6 + 2.0 + 4.5) X 3600/(358 + 301 + 221)
  = 82 l/connect/hr
- Target = 20 l/connect/hr

Reduction of 76% in net night flow

*2 Regular sounding should achieve intrinsic leakage levels of between 8 and 14 l/prop/hr so this is very conservative.

*3 ((5)X86.4Xfactor)/((5)X86.4Xfactor + Consumption), assuming (pressure variation) factor = 0.833

TABLE C.4.10 POTENTIAL SAVINGS

Area	Kariakoo*	Magomeni*	Kinondoni	REMARKS
(1)Net night flow (l/s) *1	14.0	2.7	4.8	From Table C.4.6
(2)Leakage (m^3/day) *1	902	140	216	*2
(3)Target net night flow (l/s)	2.0	1.7	1.2	From Table C.4.9
(4)Target leakage (m^3/day)	144	122	86	(3)X86.4X0.833
(5)Saving (m^3/day)	758	18	130	(2)-(4)
(6)Unit cost water Produced (T.Shs/m^3)	10	10	10	
(7)Saving (million T.Shs./year)	2.8	0.1	0.5	((5)X(6)X365)/1,000,000

*1 including wastage
*2 (1)X(Pressure variation factor in Table C.4.6)X86.4

4.5.7 LEGITIMATE USAGE

Legitimate usage was evaluated using the result of leakage survey through consumer premises, since leakages are considered to constitute the major part of legitimate usage. As a result, legitimate usage is as follows;

- Kariakoo area : 0.4 liters per second
- Magomeni area : 0.7 " " "
- Kinondoni area : 0.3 " " "

The basic data used for leakage level estimation is explained below. During the leakage survey conducted in March, 1990 in the three model areas, the number of connections, taps and leaking taps were enumerated in addition to the number of inhabitants. The ratio of taps leaking range from 9 percent in Kariakoo and Magomeni to 19 percent in Kinondoni, as shown in Table C.4.11.

TABLE C.4.11 LEAKAGE NUMBER WITHIN CONSUMER PREMISES IN 3 AREAS

Area	Kariakoo*	Magomeni*	Kinondoni
(A) Number of Connection	358	301	221
(B) Number of Tap	1,379	1,255	751
(C) Number of Leaking Tap	119	113	140
Ratio (C/A)	33%	38%	63%
Ratio (C/B)	9%	9%	19%

Leakage was measured in approximately 10 % of the taps leaking; 9 out of 119 in Kariakoo, 11 out of 113 in Magomeni and 16 out of 140 in Kinondoni (Some data were measured in October, 1990). Leakage measurements were conducted during the daytime and tap pressures were also measured. The results are shown in the following three tables. The quantity of leakage per connection during the daytime was 258 l/day in Kariakoo, 287 l/day in Magomeni and 133 l/day in Kinondoni (refer to Table C.4.12).

To convert daytime leakage to those during minimum night flow (MNF), 24-hour pressure readings in nearby main pipes (shown in Figure C.4.13) were used. From the readings, MNF pressures were read while daytime pressures were averaged, as shown in Table C.4.13. Above-ground leakage is different from underground leakage and is considered as wastage. Wastage is estimated by the following orifice formula; the quantity is 0.5 the power of pressure. Hence, leakages during MNF were estimated as follows;

Kariakoo : 326 l/day = 258 x $\sqrt{(26.0/16.3)}$
Magomeni : 469 l/day = 287 x $\sqrt{(24.0/9.0)}$
Kinondoni: 243 l/day = 133 x $\sqrt{(20.0/6.0)}$

Since leakages occurred through 119 taps in Kariakoo, the total leakage is 119 x 326 l/day = 0.4 l/sec. Similarly, this value is 0.7 in Magomeni and 0.3 in Kinondoni. These values are put into item (2) of Table C.4.6.and other values are obtained, similar to the original procedure.

TABLE C.4.12 LEAKAGE VOLUME WITHIN CONSUMER PREMISES

Street Name	House Number	Place	Date Measured	Volume (liter)	Leaking Period (min/sec)	Leakage (l/s)
KARIAKOO AREA						
Simba	2	Tap	8/3/90	0.3	7'10"	60
Nyamwezi	46	Tap	8/3/90	0.3	4'02"	107
Jangwani	19	Tap	8/3/90	0.3	8'19"	52
Ndovu	4	Tap	8/3/90	0.3	11'48"	37
Twiga	26	Tap	8/3/90	1.0	3'32"	408
B6,B7	Kiosk	Tap	8/3/90	0.3	1'57"	222
Nyamwezi	36	Tap	16/10/90	0.8	2'00"	576
Swah/Twiga	20	Tap	16/10/90	0.4	1'00"	576
C4,C5	Kiosk	Tap	16/10/90	0.4	2'00"	288
Average						258
MAGOMENI AREA						
Mengo	24	Tap	13/03/90	0.30	2'04"	209
Mengo	12	Tap	13/03/90	0.30	4'16"	101
Mosque	3	Tap	13/03/90	0.30	2'37"	165
Mosque	4	Tap	13/03/90	0.30	2'20"	185
Mosque	14	Tap	13/03/90	0.30	1'52"	231
Mkwawa	176	Tap	15/10/90	0.05	10'00"	7
Mkwawa	212	Tap	15/10/90	0.20	3'42"	78
Kagera	150	Tap	15/10/90	0.33	2'00"	238
Matombo	44	Tap	15/10/90	1.16	1'33"	1078
Mengo	32	Tap	15/10/90	0.76	2'30"	438
Mengo	4	Shower	15/10/90	0.58	1'45"	477
Matombo	8	Valve	15/10/90	0.90	3'00"	432
Chole	2	Tap	15/10/90	0.10	3'50"	38
Mosque	6	Tap	15/10/90	0.45	2'51"	227
Mosque	7	Tap	15/10/90	0.45	2'45"	236
Matombo	38	Valve	15/10/90	0.62	2'00"	446
Average						287
KINONDONI AREA						
Kinondoni	510	Elbow	20/03/90	0.3	1'40"	259
Kinondoni	490	Tap	20/03/90	0.3	4'14"	102
Kinondoni	248	Tap	20/03/90	0.3	5'12"	83
Kinondoni	43	Tap	20/03/90	0.3	2'18"	188
Kinondoni	48	Tap	20/03/90	0.3	5'37"	77
Kinondoni	496	Valve	20/03/90	0.3	3'58"	109
Kinondoni	C	Valve	20/03/90	0.3	3'15"	133
Kinondoni	B	Valve	20/03/90	0.3	7'37"	57
Kinondoni	295A	Tap	20/03/90	0.3	5'00"	35
Kinondoni	502	Tap	20/03/90	0.3	5'00"	37
Kinondoni	23	Tap	20/03/90	0.3	2'57"	386
Average						133

TABLE C.4.13 PRESSURES IN 3 AREAS

	KARIAKOO	MAGOMENI	KINONDONI
minimum nighttime flow	26.0 meter	24.0	20.0
average daytime	16.3	9.0	6.0

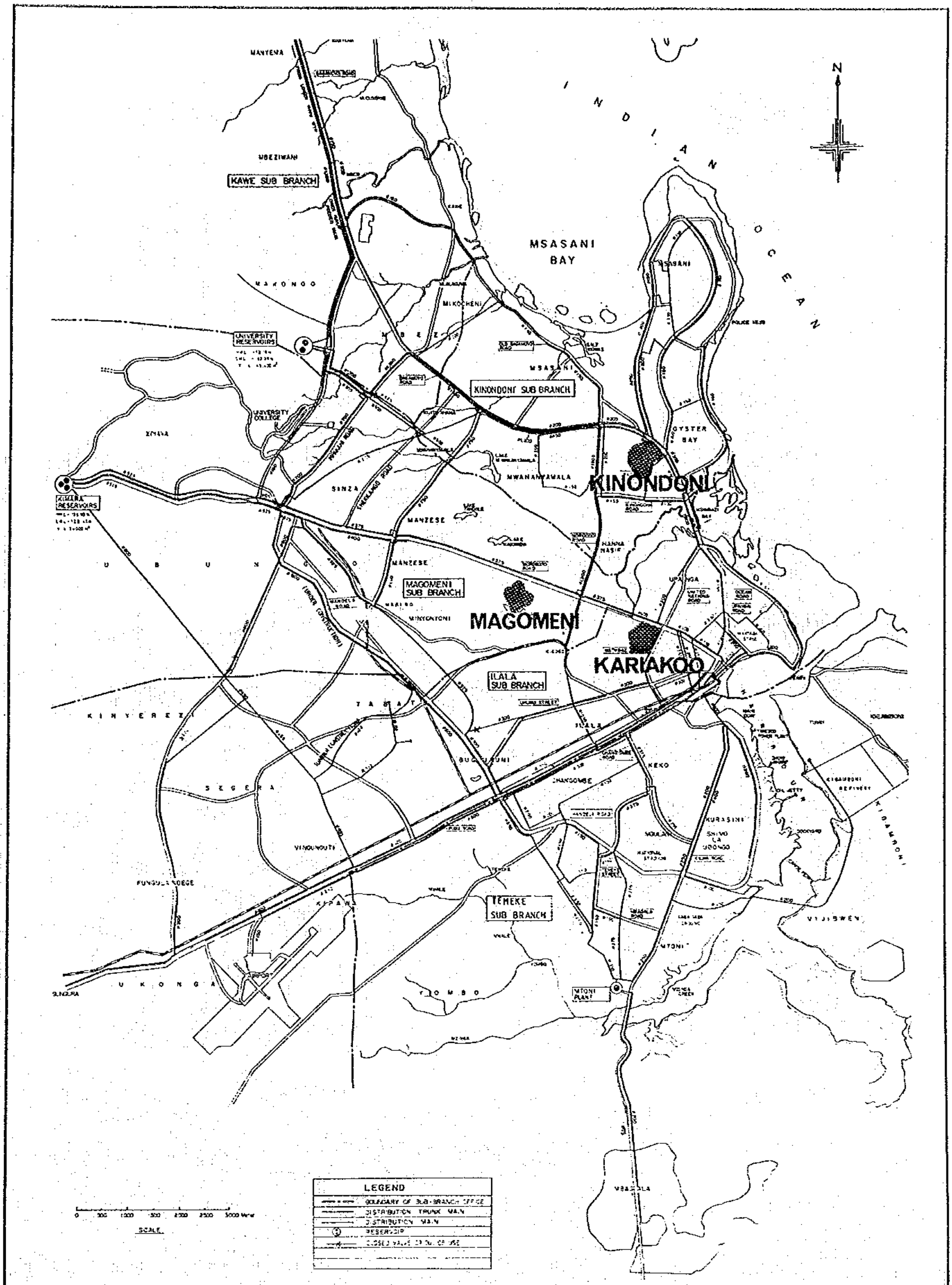


FIG. C.4.6	LOCATION OF LEAKAGE MEASUREMENT

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

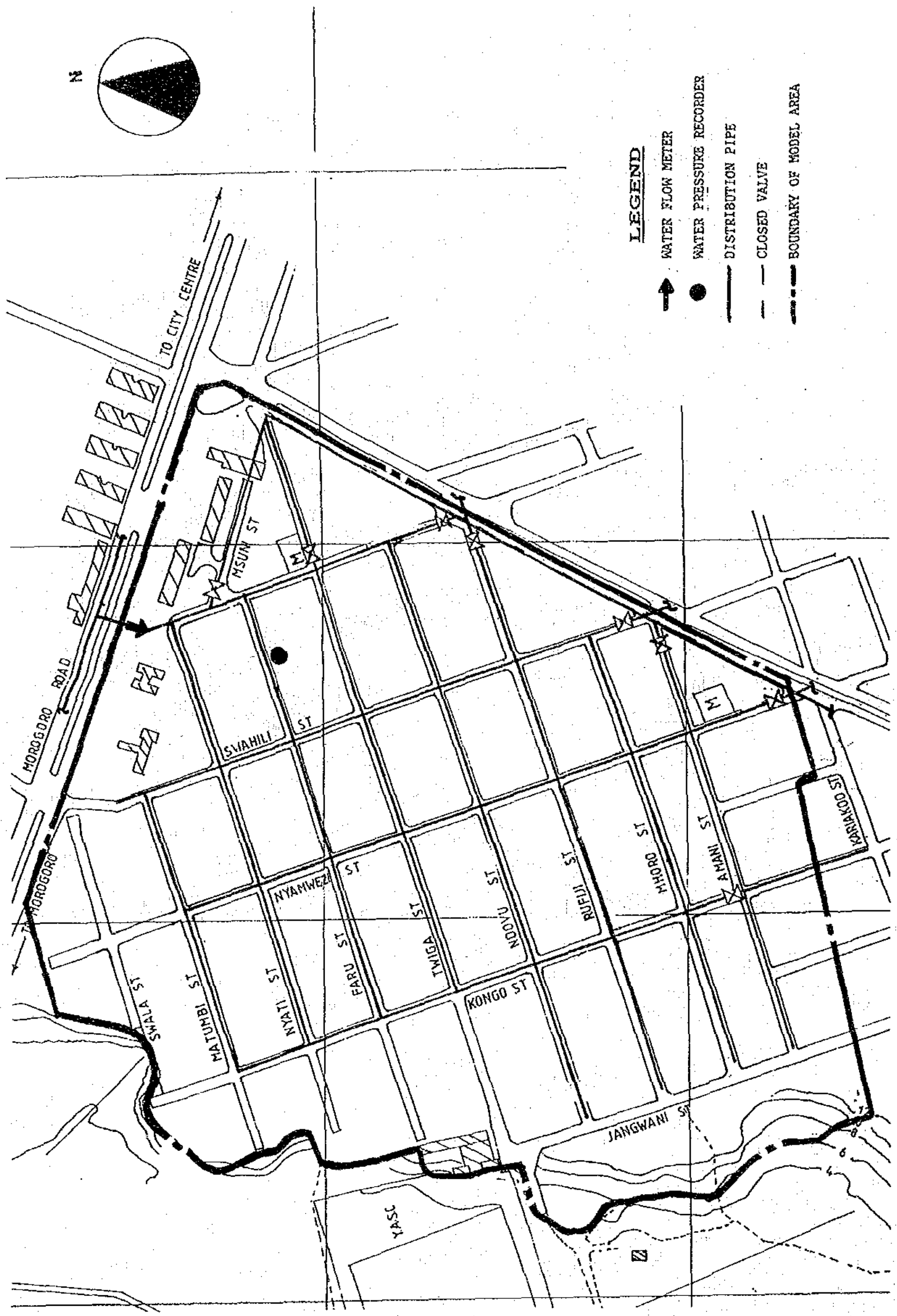


FIG. C.4.7	FLOW AND PRESSURE MEASUREMENT, KARIAKOO MODEL AREA

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

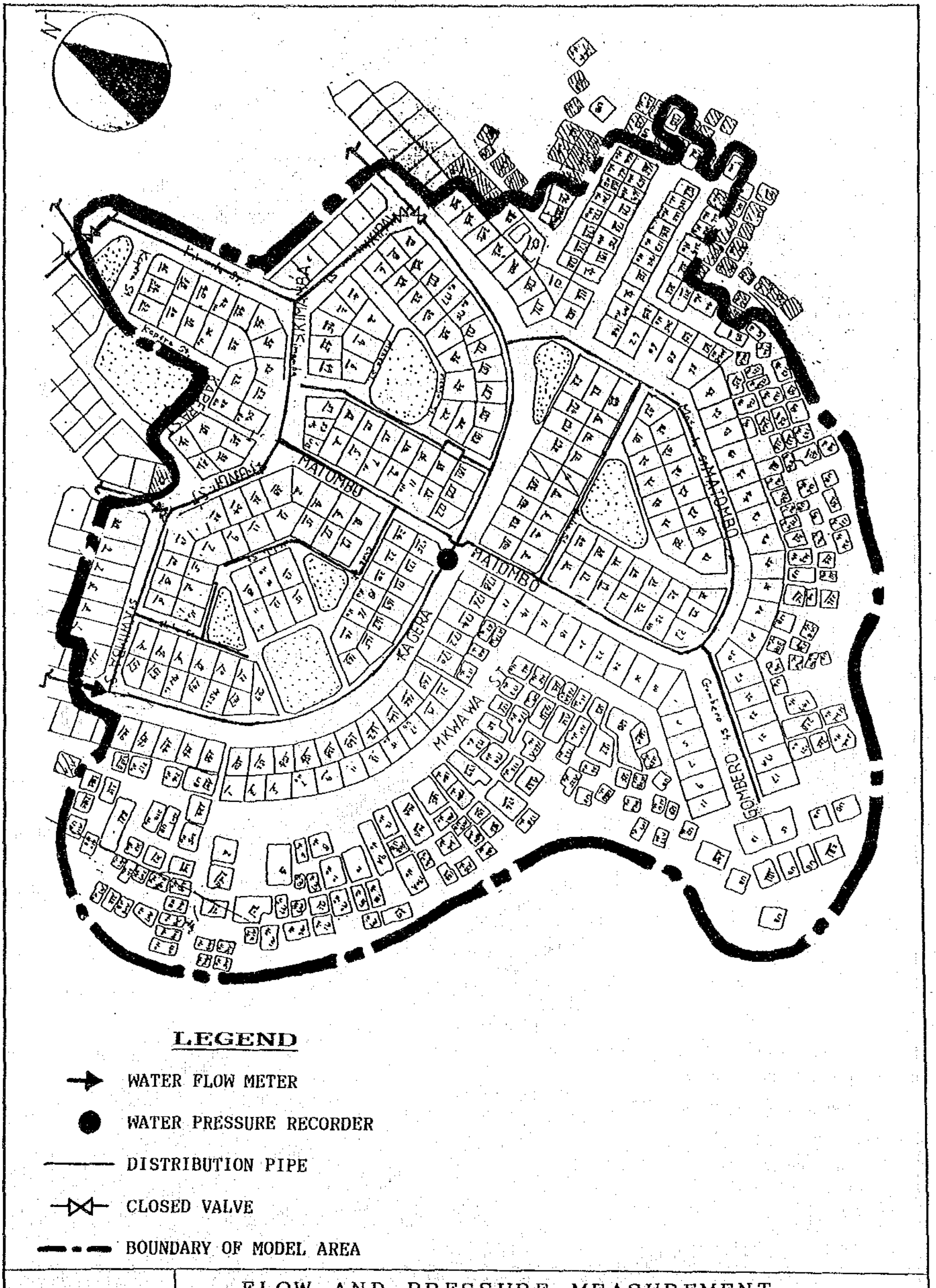


FIG. C.4.8 FLOW AND PRESSURE MEASUREMENT, MAGOMENI MODEL AREA

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

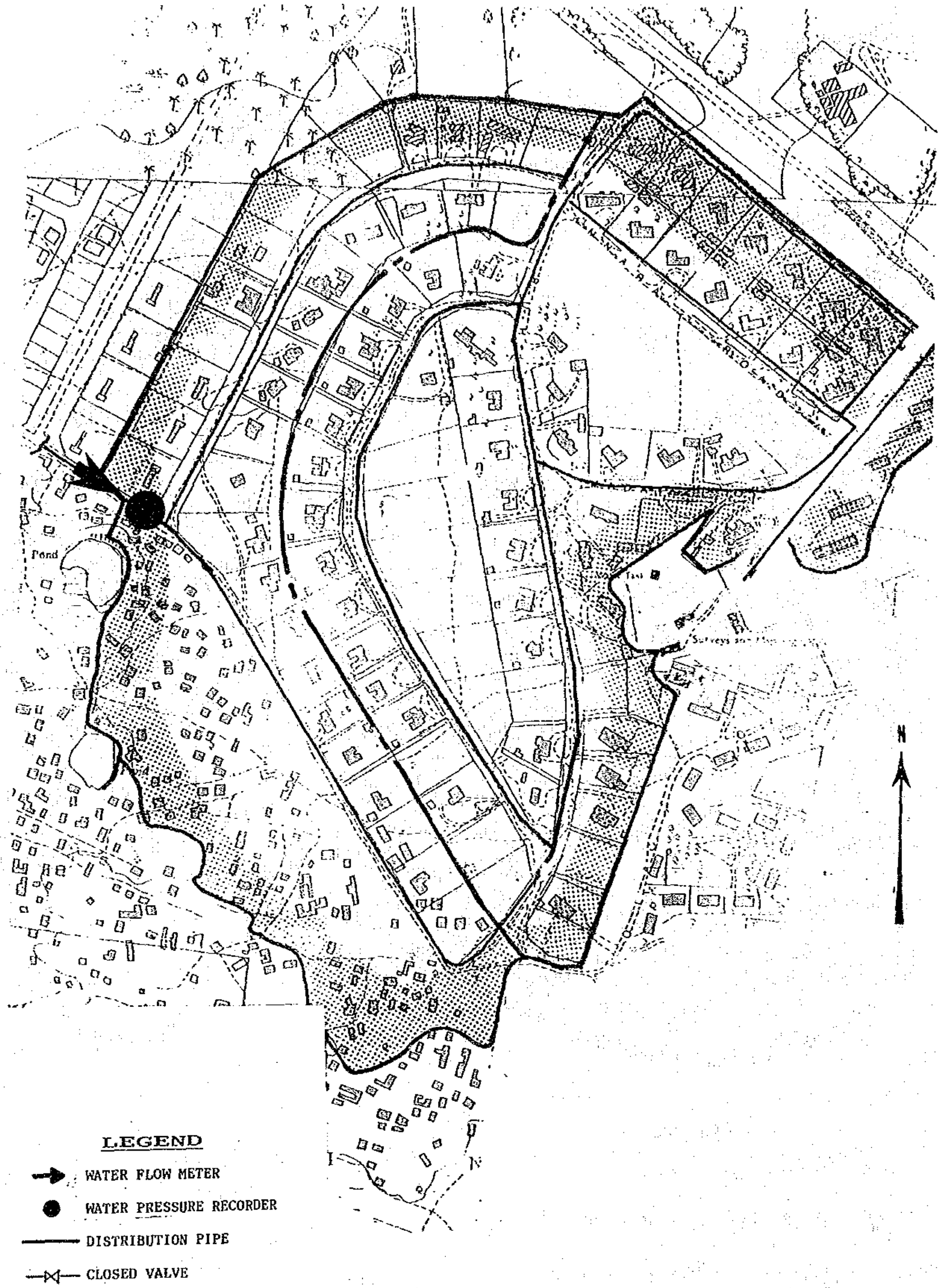


FIG. C.4.9	FLOW AND PRESSURE MEASUREMENT, KINONDONI MODEL AREA

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY

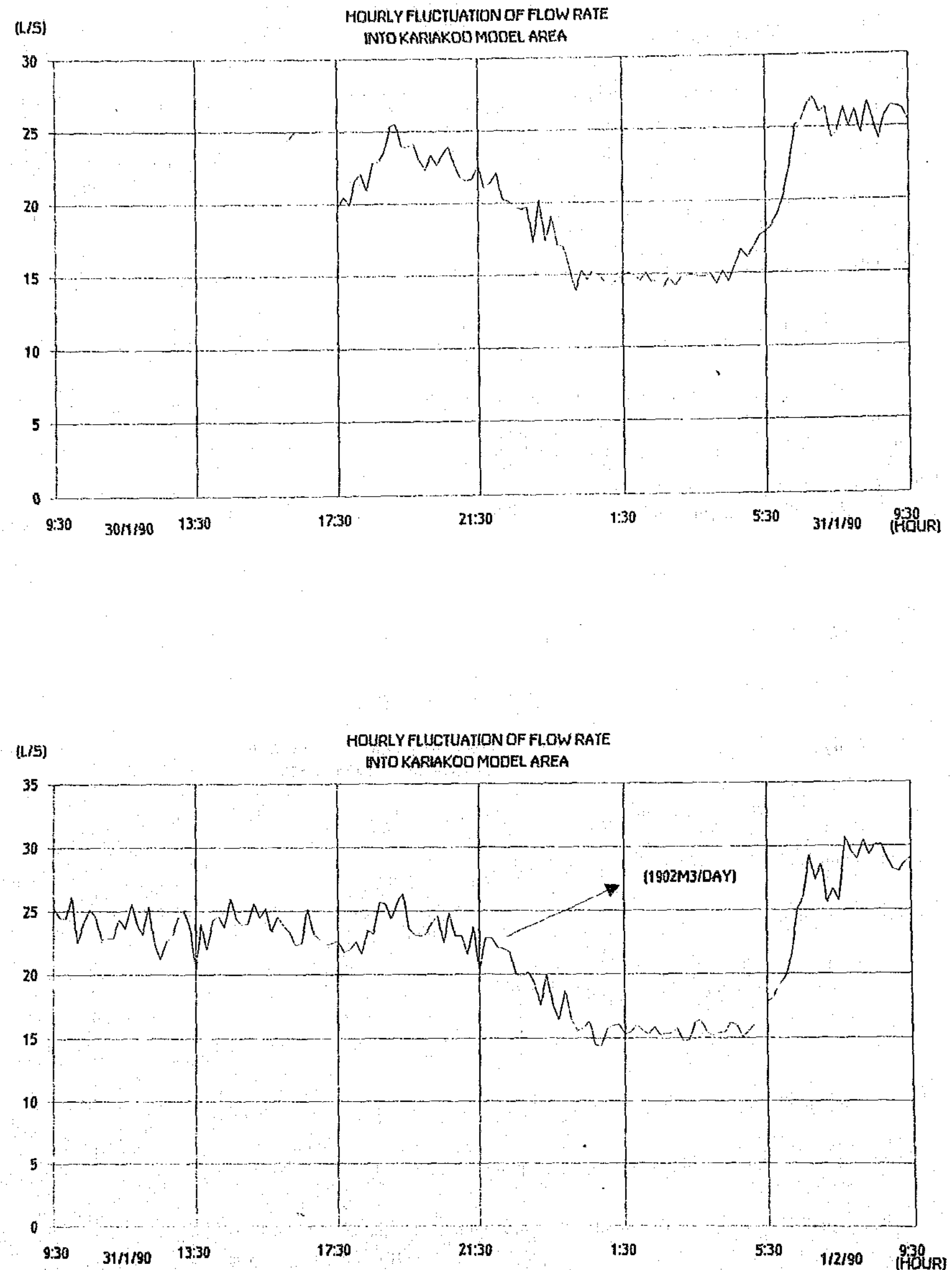
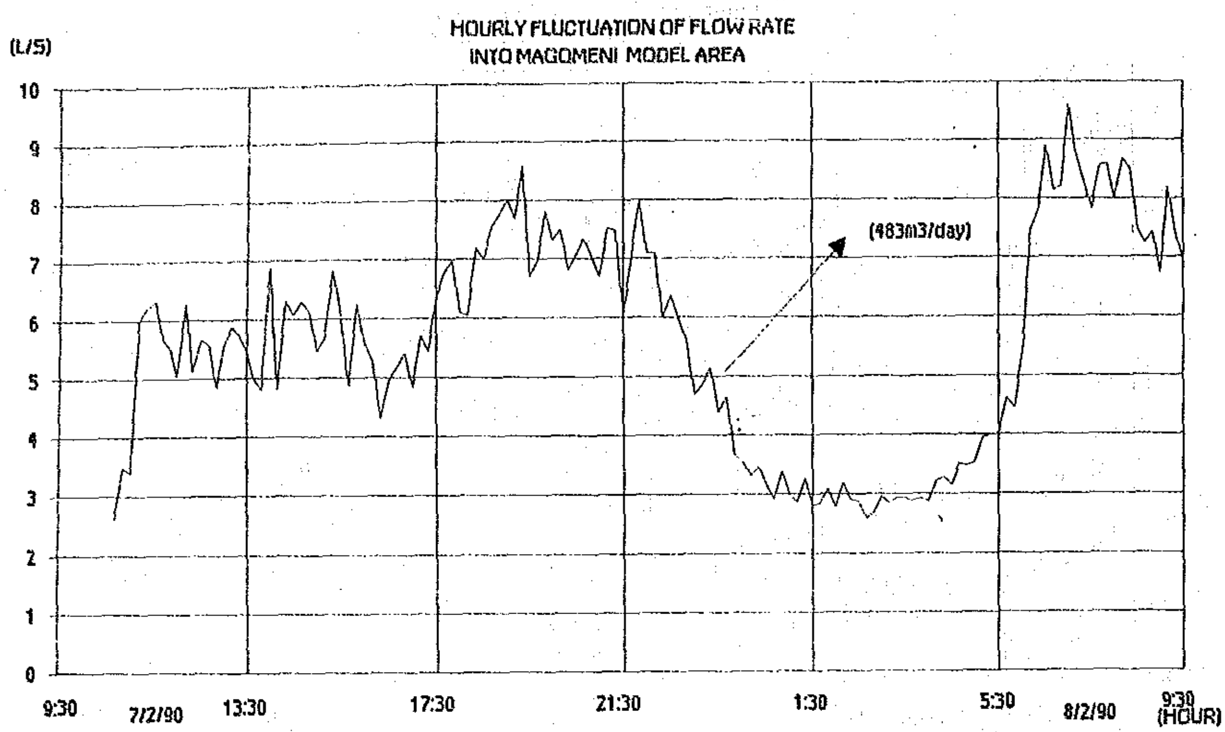


FIGURE C.4.10 INFLOW INTO KARIAKOO AREA



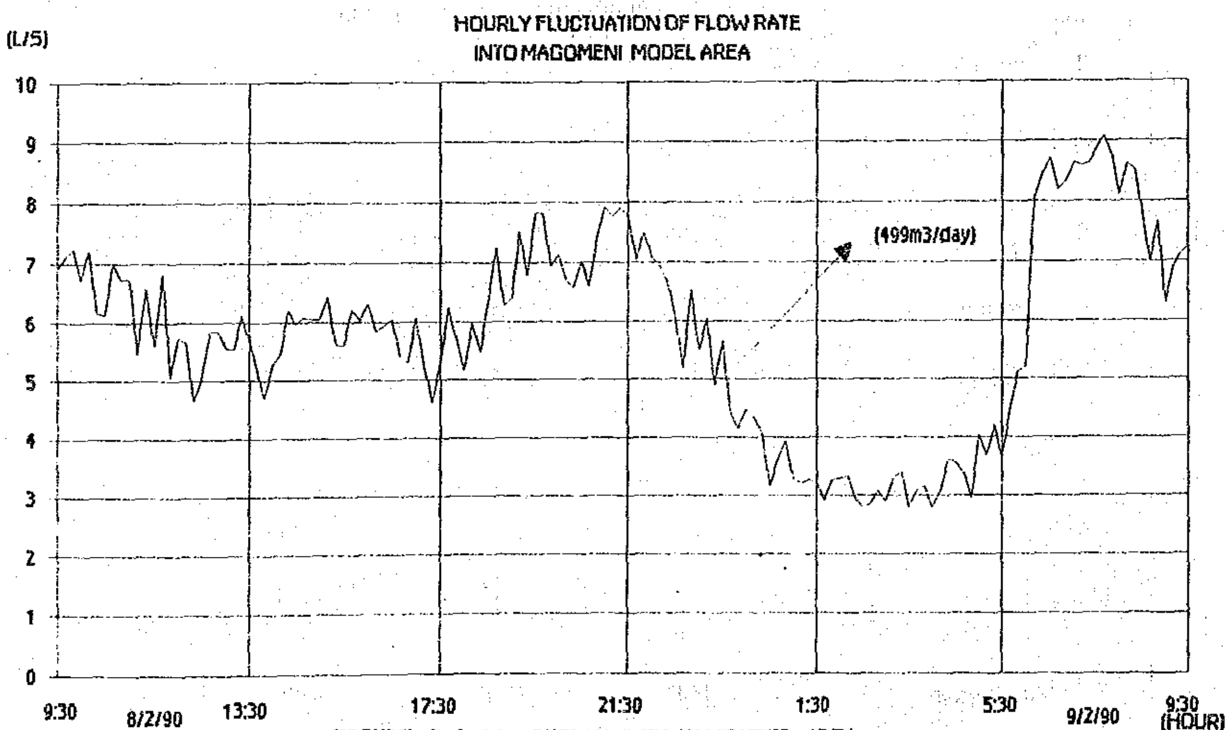


FIGURE C.4.11 INFLOW INTO MAGOMENI AREA

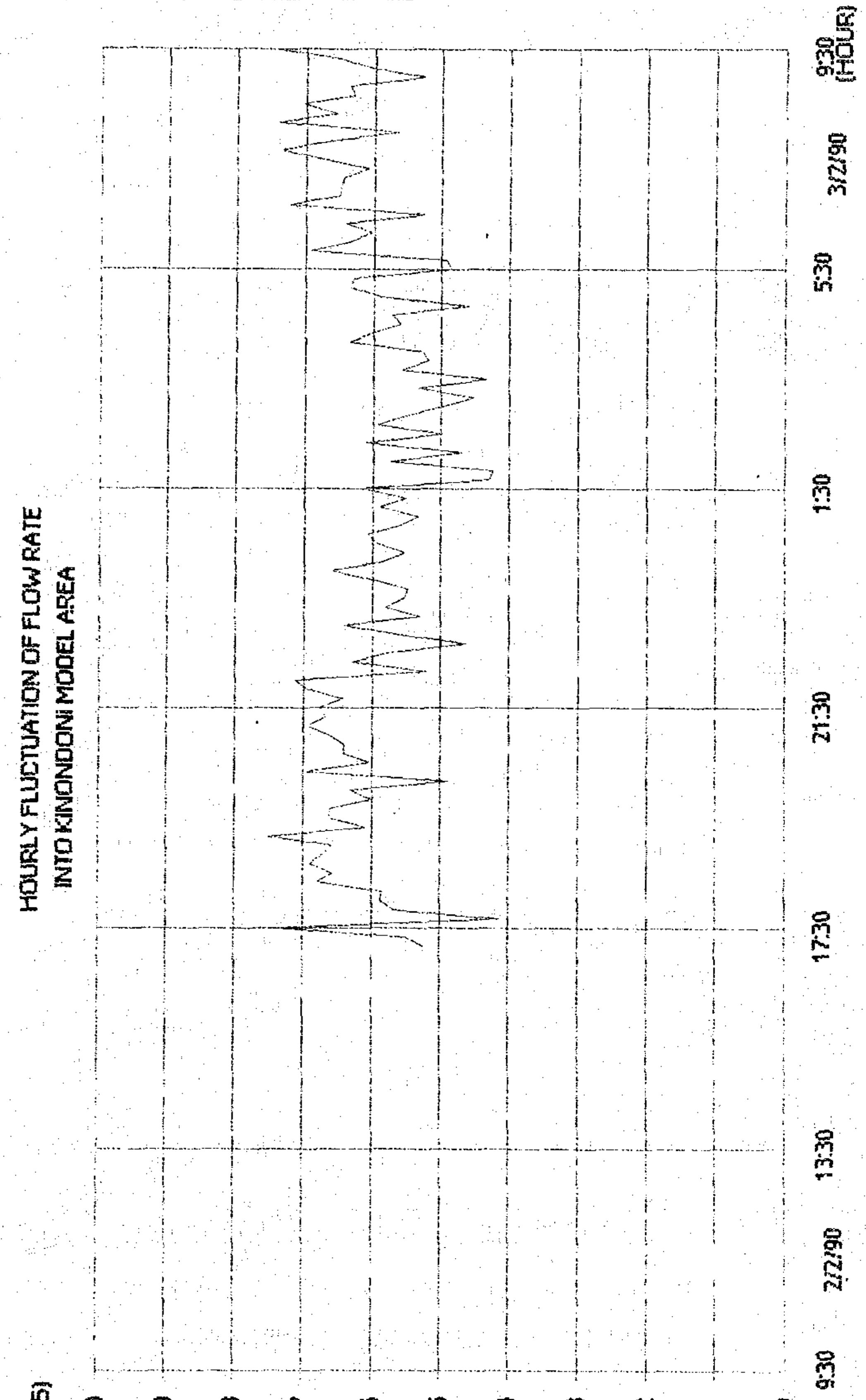
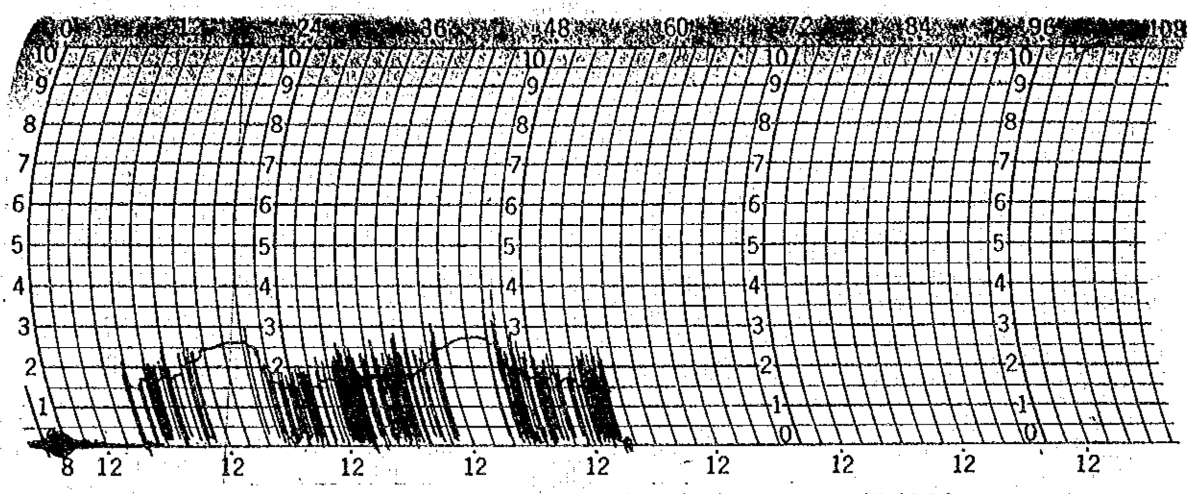
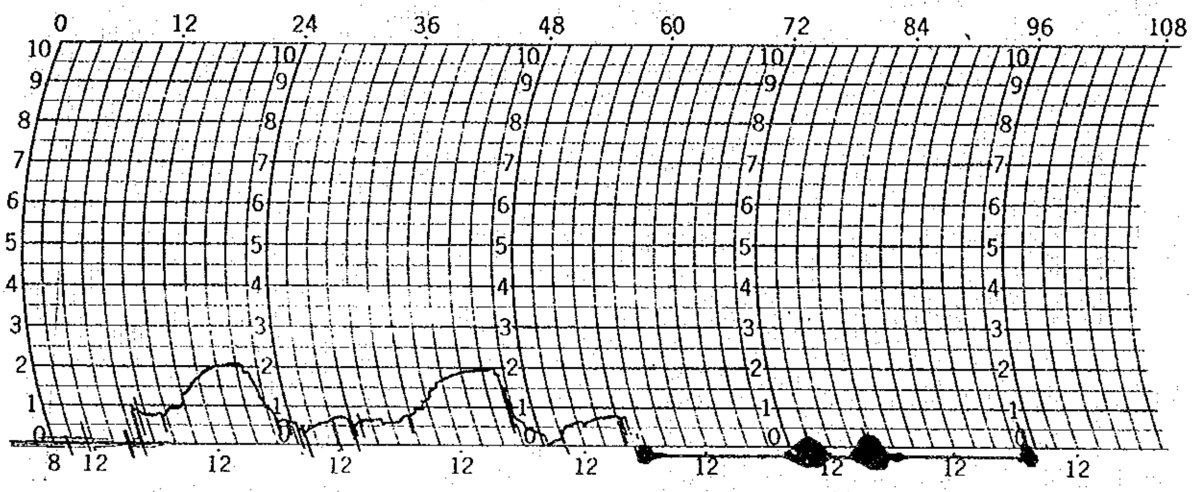


FIG. C.4.12 | INFLOW INTO KINONDONI AREA

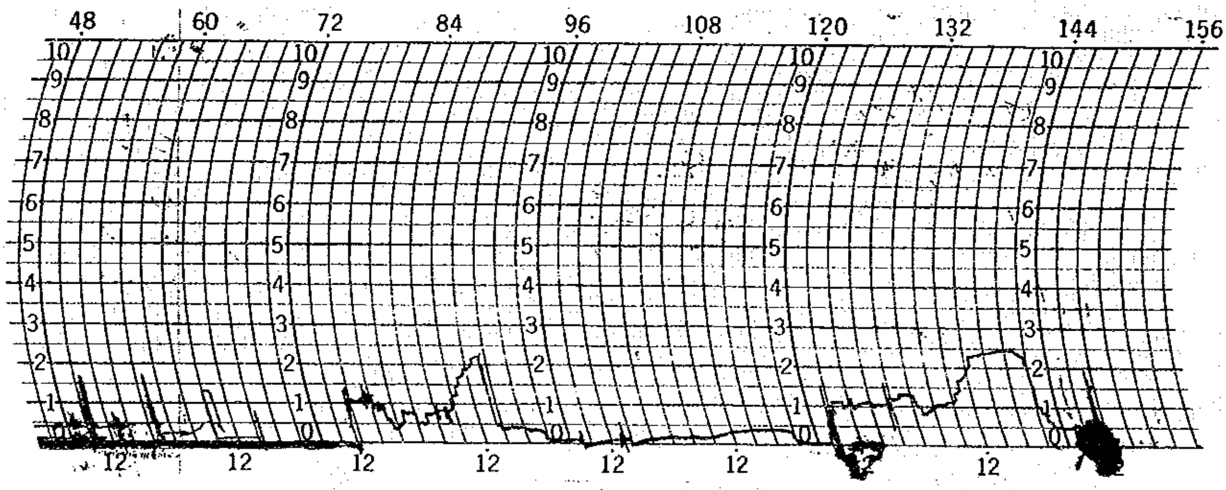
THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY



KARIAKOO MODEL AREA (31/1/90 to 1/2/90)



KINONDONI MODEL AREA (2/2/90 to 4/2/90)



MAGOMENI MODEL AREA (7/2/90 to 10/2/90)

FIGURE C.4.13 WATER PRESSURE IN 3 MODEL AREAS.

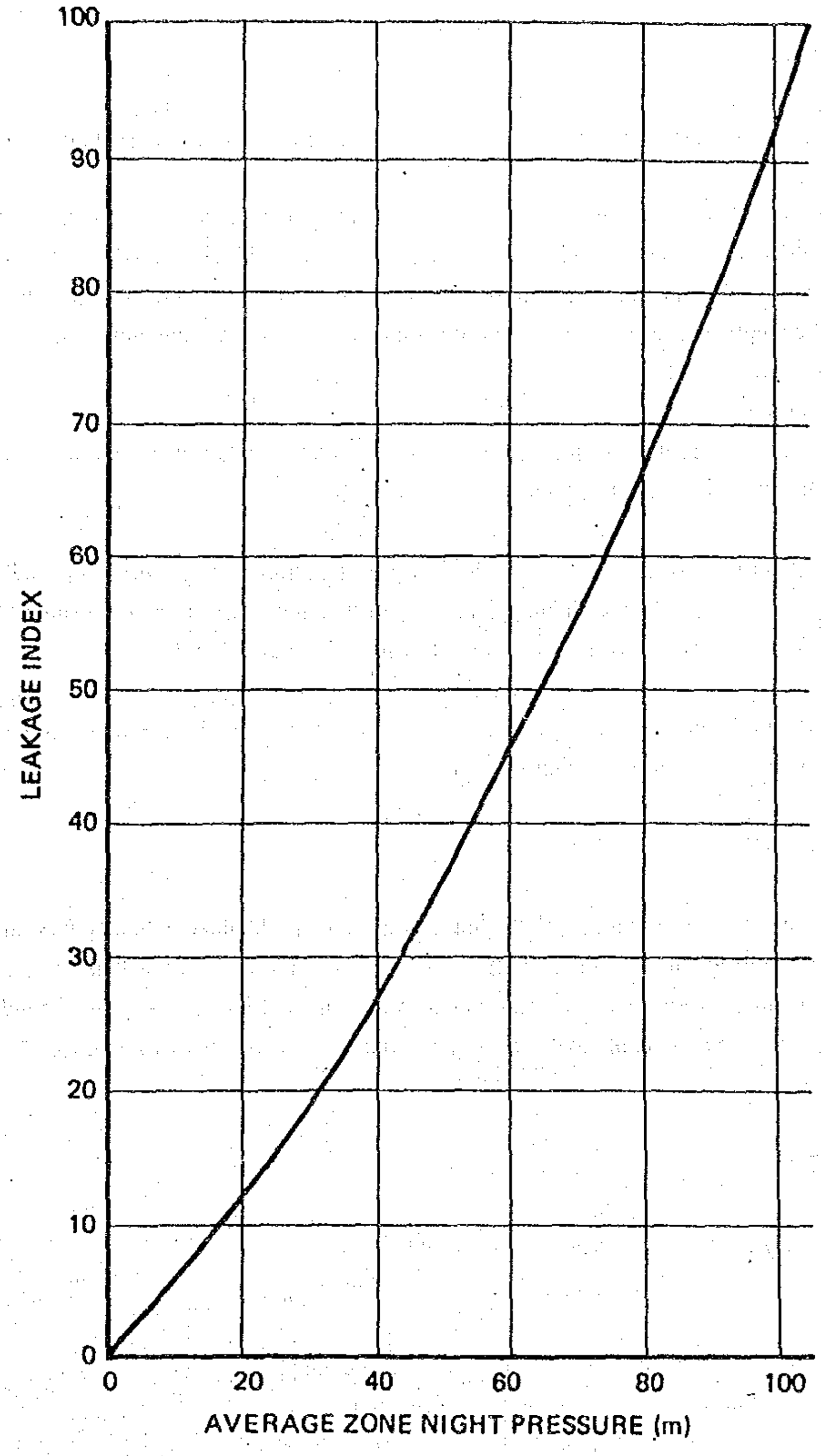


FIG. C.4.14 RELATIONSHIP BETWEEN LEAKAGE AND PRESSURE

THE STUDY ON REHABILITATION OF DAR ES SALAAM WATER SUPPLY